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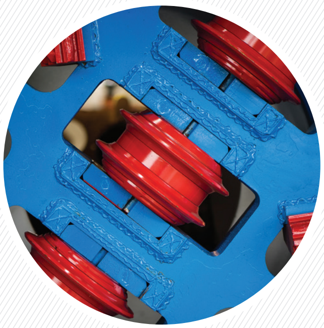
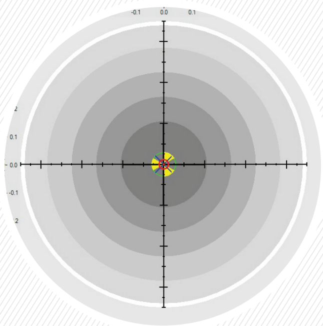


MICROTUNNELING

Method of Operation



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MICROTUNNELING SYSTEM OVERVIEW

Slurry microtunneling is a trenchless underground construction method employed to accurately install pipelines under existing utilities, highways, railroads, levees, waterways, in sensitive wetlands, unstable ground conditions, and contaminated soils. Microtunnel Boring Machines (MTBMs) install pipelines from shaft-to-shaft or can be retrieved from a body of water.

Microtunneling is desirable for its ability to reduce project risk, constrain the construction zone within easements and right of ways, minimize ground surface settlement, and is applicable to a wide range of geological and changing ground conditions with extreme accuracy.

Microtunneling systems are remotely-controlled and comprise several pieces of machinery or subsystems that function together. They are managed by an operator who monitors and controls pipe jacking operations from a console inside a container on the surface, alongside the launch shaft (see Figure 1). Personnel entry in the tunnel is not required for routine operation of a microtunneling system.

MTBMs are accurately controlled by exerting continued support at the face of the bore by balancing thrust pressure and slurry with groundwater and earth pressures. This support at the face differentiates it from other open-face pipe jacking and tunneling methods.

Figure 1. Microtunneling systems are remotely controlled from a control console inside the control container on the surface.

MICROTUNNEL BORING MACHINES (MTBMS)

Akkerman MTBMs are manufactured in base sizes of 30-114-inches OD, and are available in center drive models for smaller base diameter machines, and face-access, peripheral drive models for the largest diameters. Center drive MTBMs contain a single motor that drives a planetary gear box, coupled to a drive shaft in the center of the MTBM (see Figure 2). Face-access, periphery drive MTBMs have interior motors on the periphery of the gear ring with pinions on a slewing bearing (see Figure 3).

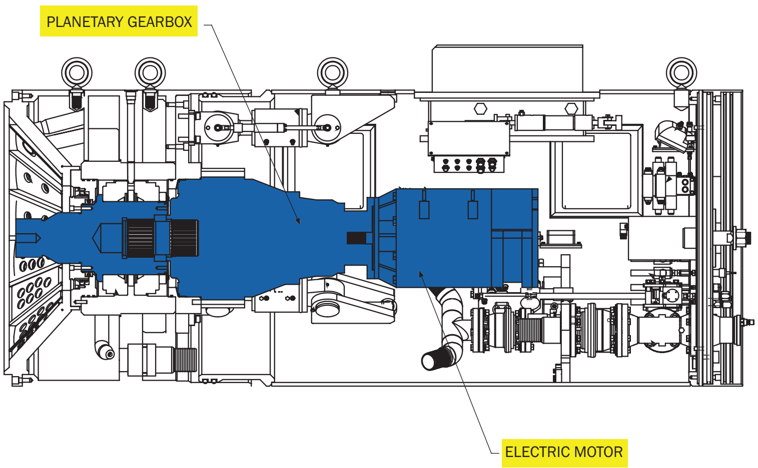


Figure 2. Center drive MTBM contains a single motor that drives a planetary gearbox coupled to a drive shaft.

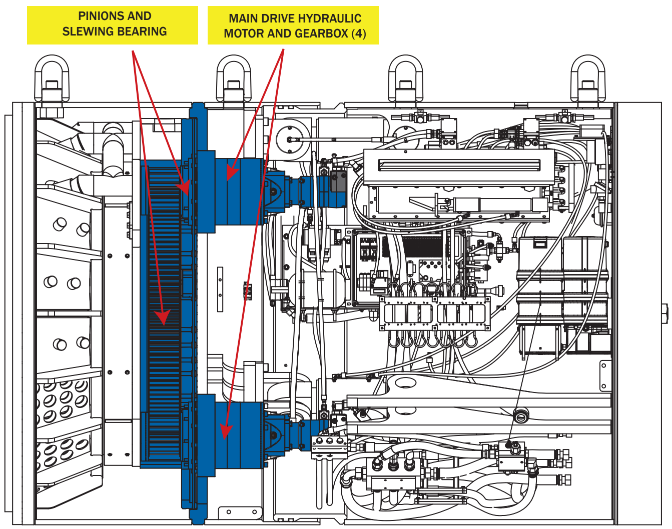


Figure 3. Face access periphery drive MTBMs contain four interior motors on the periphery of the gear ring with pinions on a slewing bearing (some components removed for visibility).

Face-access, periphery drive MTBMs feature higher power and torque for the larger diameter pipe installations, and an access door at the cutter head with back loaded tooling mounts (see Figure 4) to replace worn tooling on extended drives. These MTBMs come with an on-board electric over hydraulic power pack for cutter head drive in low, medium, and high torque for accurate control in changeable geology.

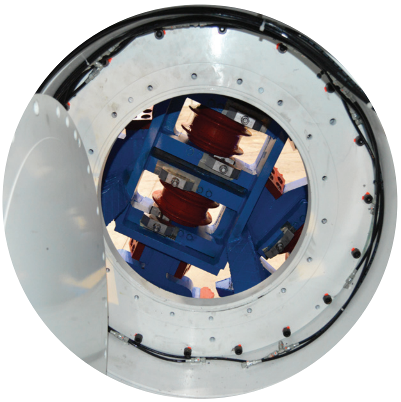


Figure 4. Photo of the periphery drive MTBM access door with back loaded tooling mounts.

All Akkerman MTBMs feature high pressure jetting nozzles (see Figure 5) that speed up the breakdown of the cuttings and cleans the crushing cone to prevent clogging in the slurry intake manifold. The articulated steering joint extends and retracts with three-point steering control. Hydraulically activated dirt wings on the outside of the MTBM minimize MTBM torque roll. Akkerman MTBMs include a live one or two-way audio and camera systems for system monitoring for maintenance and target viewing.

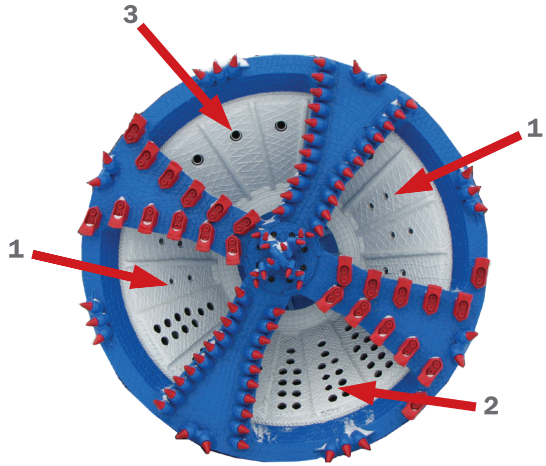


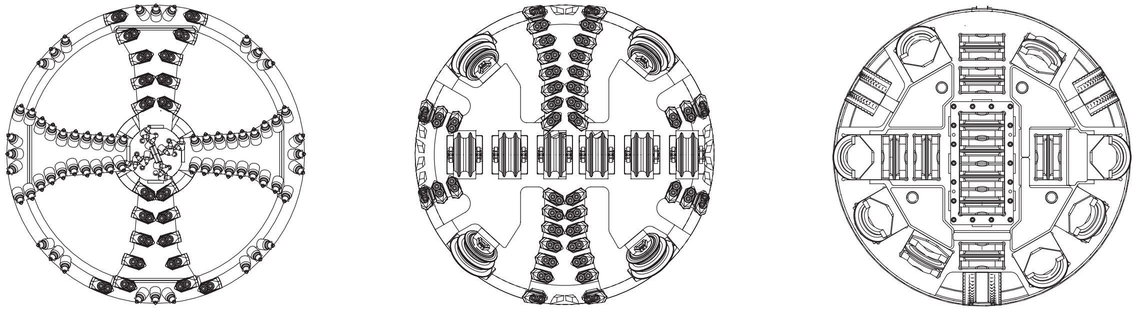
Figure 5. MTBM crushing cone 1) high pressure jetting nozzles, 2) slurry inlets, and 3) slurry cutting nozzles.

MTBM cutter heads are configured as follows (see Figure 6):

- Soft ground - carbide tipped bullet and chisel teeth
- Mixed ground – a mixture of carbide tipped bullet, chisel teeth and disc cutters
- Rock - disc cutters
- Project specific cutter head – includes a combination of all the above tooling

Cutter head outer gauge cutters overcut typically up to one inch in radius larger than the pipe OD to reduce friction on the pipe string as it is jacked through the ground.

Cutter heads can be equipped with increase kits for adaptability. Cutter head and crushing cones are hard-faced to withstand wear.



SOFT GROUND CUTTER HEAD

For soft, wet, easily displaceable ground
Bullet Bit Tooling

MIXED GROUND CUTTER HEAD

For varying, soft to high compressive strength geology
Disc Cutters and Bullet Bit Tooling

ROCK CUTTER HEAD

For high compressive strength geology
Disc Cutters and Bucket Scrappers

Figure 6: Standard Microtunneling Boring Machine cutter head configurations.

CONTROL CONTAINERS

The control container features a climate-controlled operator's area and a separate power distribution area. Operators monitor and adjust all facets of the microtunneling operation from a multiple monitor display console including MTBM's pitch, yaw, rotation, torque, jetting, jacking thrust advance rate, ground pressure against the face, slurry flow and pressures, the MTBM's anticipated position at the cutter head face, and air and drive motor temperatures all using proprietary software (see Figure 7). The system logs over 100 data points for customized reporting to track and graph alignment deviation, face pressure and torque changes. An on-site generator or 480 vac 3 pti line power supplies electricity for the control container.

The remote hydraulic power pack is situated alongside the control container on the project site to supply hydraulic distribution to the jacking frame, auxiliary functions and intermediate jacking stations/propulsion cans if relevant.

Figure 7. Microtunneling control console screen displaying functions of the MTBM using the Akkerman proprietary software.

SOIL DIGESTION AND SLURRY CIRCULATION

The MTBM excavates spoil at the face of the bore while simultaneous pipe segments are installed in the launch shaft and thrust forward by the hydraulic cylinders on the jacking frame. The MTBM's rotating cutter head is steerable, and bi-directional for precise ground excavation.

The forward advancement of the pipeline combined with the rotating action of the cutter head excavates the soil and forces the cuttings into the cutter head's crushing cone and pulverizes them into smaller particles for transport through the slurry lines. MTBMs are capable of crushing cobbles up to 28% of its outside diameter.

Slurry is formed by mixing the ground-up cuttings with water by injecting water or a water with a bentonite clay mix in the MTBM's crushing cone. Inside the crusher cone, cobbles breakdown, are mixed with slurry and pass through the slurry inlet holes for transport into the slurry return lines (see Figure 7).

Feed, return and booster pumps keep the slurry traveling to a slurry separation tank, slurry tank or settlement pond where it is separated and re-circulated back to the cutter head in a closed system (see Figure 8). The slurry balance system is deployed immediately at launch to prevent material from entering the MTBM's inner chamber.

Operators carefully monitor the face pressure by simultaneously assessing a combination of spoil, groundwater volume, and slurry feed and return flow rates using sensors, flow meters and pit valves in the closed loop slurry system. Balancing the input and output of the slurry by volume and pressure is vital for effective and accurate advancement and to avoid overloading the cutter head or removing too much soil thereby causing settlement.

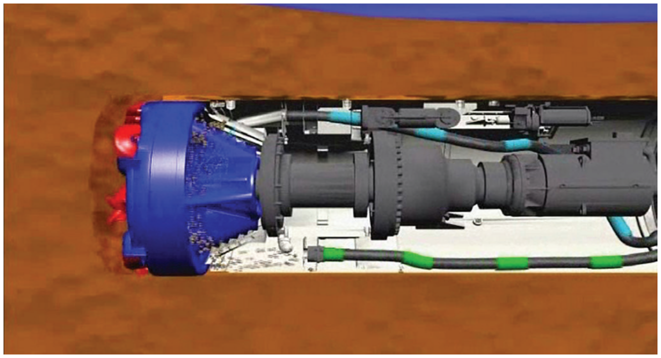


Figure 7. Cuttings are pulverized into smaller particles in the crushing cone then forced for transport through the slurry lines.

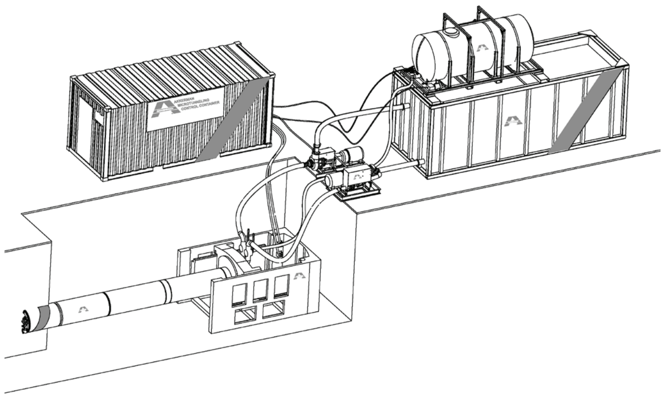


Figure 8. Slurry travels to a separation tank and is re-circulated back to the cutter head in a closed system.

PREPARING THE SHAFTS

A contractor must design and construct the jacking and if applicable, receiving shafts. It is important that the jacking frame tonnage and jacking pipe loads are properly calculated during the design.

A concrete reaction wall is poured at the rear of the jacking shaft to disperse jacking loads (see Figure 9). The jacking force is bore by the jacking frame against the reaction wall, shaft wall and ground outside of the shaft.

In order to stabilize the soil around the shaft, ground improvement and/or dewatering takes place.

The MTBM is typically launched through a shaft seal on the launch shaft wall which acts as a gasket around the pipe to prevent subsidence from entering the launch shaft (see Figure 10).

The reception shaft or exit shaft is often prepared with a retrieval shaft seal mounted on the shaft wall at the anticipated MTBM emergence location.

After it emerges, all slurry, ventilation, microtunneling utility and electrical lines are removed from the reception shaft.

If the project design requires an MTBM wet retrieval, the back of the MTBM is equipped with a bulkhead to create a water tight seal between the body of water and the tunnel and shaft. Crews will enter the tunnel from the launch shaft end, disconnect and remove the microtunneling utility lines from the reception shaft. After it's disconnected from the tunnel, the MTBM is advanced forward into the body of water for retrieval by divers (see Figure 11).

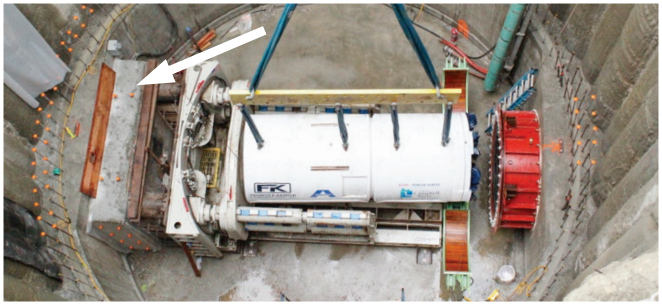


Figure 9. Concrete reaction wall is poured at the rear of the jacking shaft to disperse jacking loads.

Figure 10. The MTBM is typically launched through a shaft seal to prevent subsidence from entering the launch shaft.

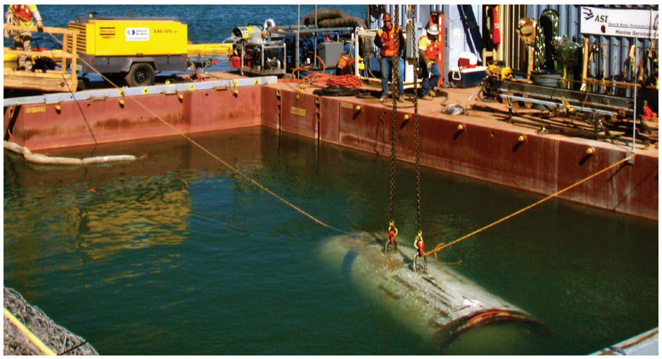


Figure 11. MTBM emerging from a wet retrieval after the bulkhead seals off the tunnel.

JACKING FRAMES

The jacking frame is sized to accommodate the MBTM, pipe diameter and the specific needs of the project according to ground conditions and shaft length.

The jacking frame is positioned in front of the reaction wall on line and grade (see Figure 12). During setup, a stationary set of cables is routed from the bulkhead connection on the control container to the jacking frame in the launch shaft.

The jacking frame contains horizontally-mounted hydraulic cylinders that advance the MTBM forward with up to 1,200 tons of thrust. Keyed notches on the cylinders lock into place to ensure smooth and continuous advancement.

To advance the MTBM and pipe string and add new pipe segments, the jacking frame exerts uniform hydraulic jacking force onto a thrust ring which moves the MTBM and then previously installed pipe along the path of the alignment. The force of the jacking frame reacts against the concrete thrust block and the ground outside of the shaft. Between the installation of each pipe joint, MTBM rotation and slurry flow is paused, the jacking frame's hydraulic cylinders are retracted with a winch, a new pipe joint is lowered onto the jacking frame, microtunneling utility lines are added and connected to the existing lines, and mining is resumed (see Figure 13).

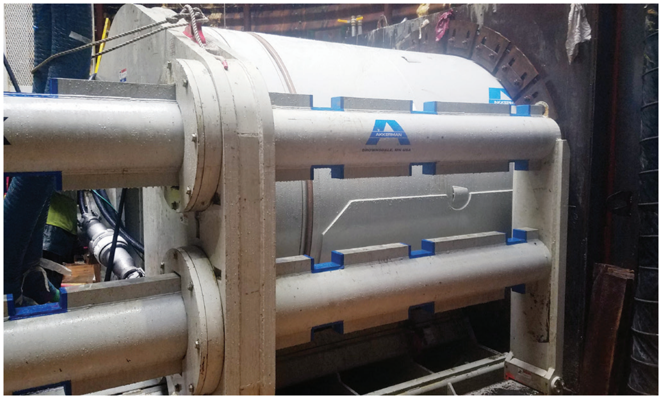


Figure 12. The jacking frame is positioned in the base of the launch shaft on line and grade and its hydraulic cylinders advance the MTBM and pipe.

Figure 13. As pipe segments are lowered into the launch shaft, microtunneling utility lines are lowered inside the pipe and are connected to the existing lines.

PUMPS

Slurry is circulated through the microtunneling lines with feed, return and booster pumps that are regulated through the control container's variable frequency drives.

The slurry feed pump is located on the surface near the slurry tanks, settlement ponds or separation plant. The slurry feed pump pushes the slurry water to the MTBM for slurry injection in the crushing chamber.

The slurry return pump is placed in the bottom of the MTBM launch shaft to assist with the flow of the soil-laden slurry back up to the surface for separation, then is re-circulated through the system.

A slurry booster pump is often placed within the MTBM to aid in transporting the heavy, soil-laden slurry from the MTBM to the launch shaft.

A high-pressure jetting pump provides high velocity jetting through the microtunneling utility lines to the MTBM cutter face to break down clay and silty soil, clean the crushing chamber and assist with spoil intake and flow.

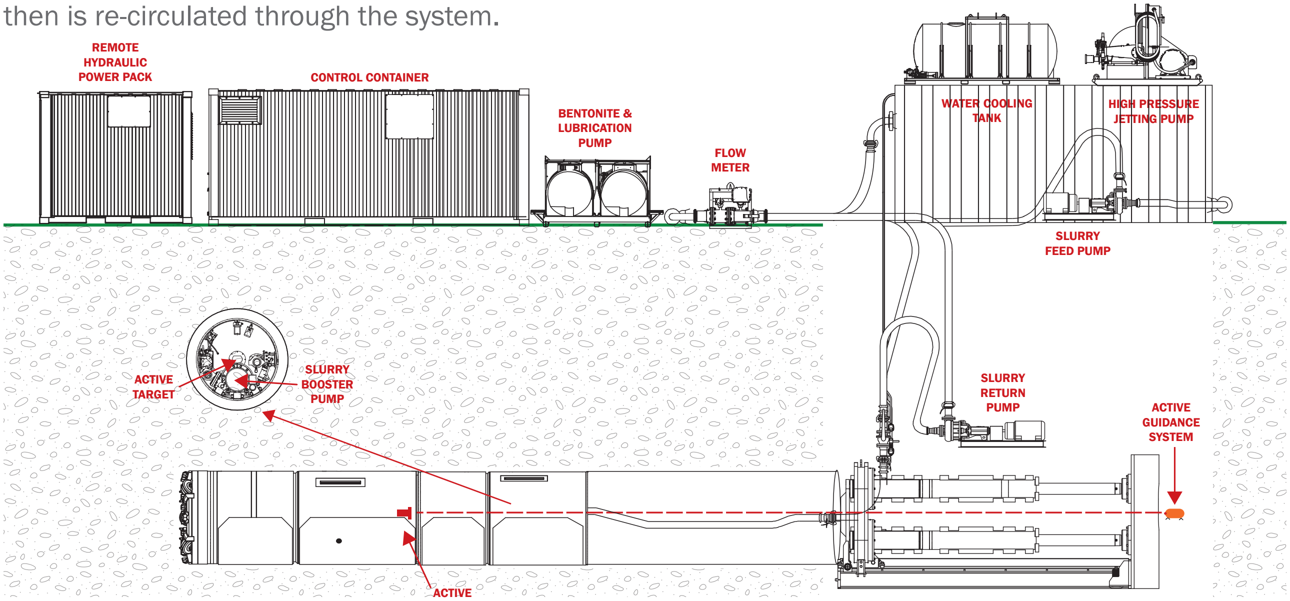


Figure 13. The jacking frame is positioned in the base of the launch shaft on line and grade and its hydraulic cylinders advance the MTBM and pipe.

WATER COOLING TANK

The water-cooling tank, positioned alongside the launch shaft, provides cool water which travels through utility lines to keep the MTBM's drive motor and in some applications, the booster pump motor cool, and flush seals for optimal operation (see Figure 13, previous page). This cool water flow also assists to cool the tunnel air temperature which helps with the guidance system's laser clarity.

ANCILLARY EQUIPMENT

For specific project conditions, the following ancillary equipment is sometimes used on a microtunneling project, although the list is not exhaustive:

- Sealed Intermediate Jacking Stations – distribute thrust load to facilitate longer drives
- Propulsion or Jacking and Lubrication Cans – Used to exert even jacking force on the MTBM face for smooth advancement, typically used on projects presenting varying ground conditions, contains larger valves that feed the MTBM's lubrication ports for bentonite injection around the pipe annulus (see Figure 14)
- Pipe Clamp – to contend with buoyant forces when installing a MTBM within a body of water, the pipe clamp holds the previously installed pipe in place while the next pipe joint is being installed (see Figure 15)
- Automatic Bentonite Injection System – Remotely-controlled, delivers lubricant directly to the annulus of the pipe at predetermined pressures and intervals to reduce jacking forces (see Figure 16)
- Compressed Airlock Package – a decompression chamber that allows manned entry to the MTBM face on projects located under groundwater, by adjusting and regulating the atmospheric pressures for safe entry to access the cutter face for tooling changes

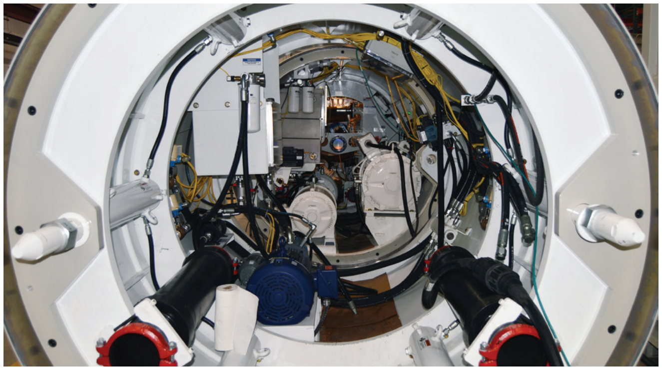


Figure 14. Propulsion or Jacking and Lubrication Cans exert even jacking force for smooth advancement and house lubrication feed valves for the MTBM.

Figure 15. A pipe clamp is used when microtunneling within a body of water to hold the previous pipe segment in place and contend with buoyant forces.

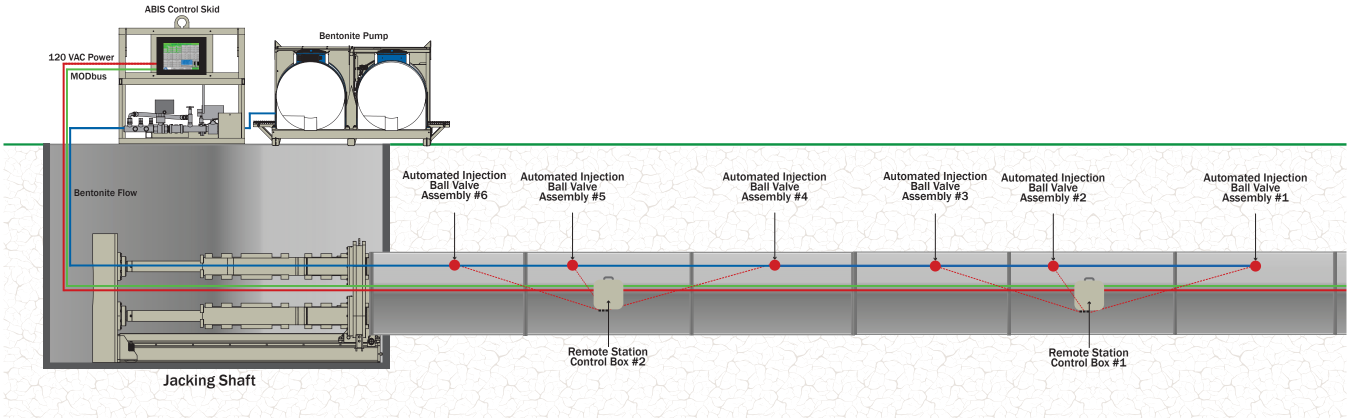


Figure 16: The ABIS system is used to automatically deliver bentonite at specific intervals from a touch screen monitor.

MICROTUNNELING GUIDANCE SYSTEM

Design criteria Installation accuracy is maintained using active laser guidance systems. Navigation control is one of the key elements for successful microtunneling.

The shaft station reference laser is positioned on line and grade behind the jacking frame and protected from disturbance. The laser from the shaft station is projected down the tunnel onto the MTBM's target.

The Akkerman standard active guidance system includes an active target and the MTBM contains three inclinometers that read and transmit data to the operator at the control console (see Figure 17). Two inclinometers located in the target and the rear of the MTBM track roll and incline and a third in the front of the MTBM assesses incline. Sensors in

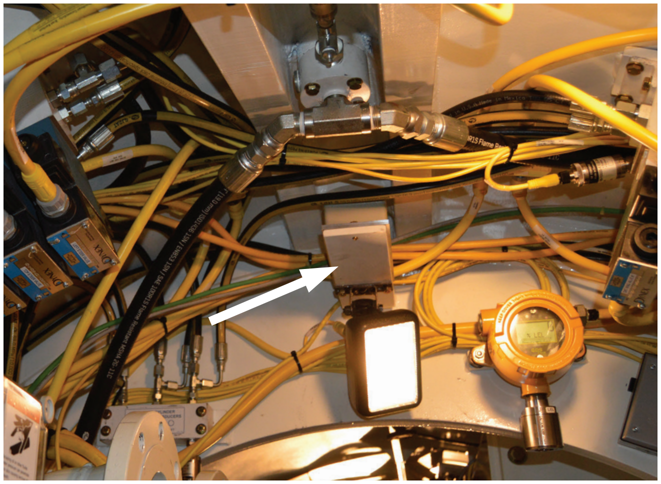


Figure 17. Front MTBM inclinometer; one of three.

the target relay this data to the operator's control console.

An active laser target is mounted in the back center of the MTBM (see Figure 18). The pipe laser beam in the jacking shaft is directed up the tunnel at the design's line and grade and projects onto the back of the MTBM's active laser target. The laser beam's position is calculated and numerically displayed on the operator's control console.

The guidance system reports the MTBM's pitch, yaw, and X and Y coordinates to the control console for operator assessment. These coordinates plus steering position and inclinometer data inform the operator of the MTBM's location at 10-feet ahead (see Figure 19).

The guidance system software reads the location of the most intense light. Active laser guidance systems are subject to tunnel refraction and diffraction which presents a diminished laser at extended lengths and cannot be configured for curved alignments because of interruptions in the line of sight. At greater distances the laser's intensity becomes more dispersed and tunnel temperature variations can cause laser curvature. Where project conditions permit, tunnel ventilation can be used to reduce laser distortion. For these reasons, active laser navigation systems are recommended for use on straight microtunnels up to 700-feet.

Figure 18. The MTBM active target is mounted in the back center of the MTBM.

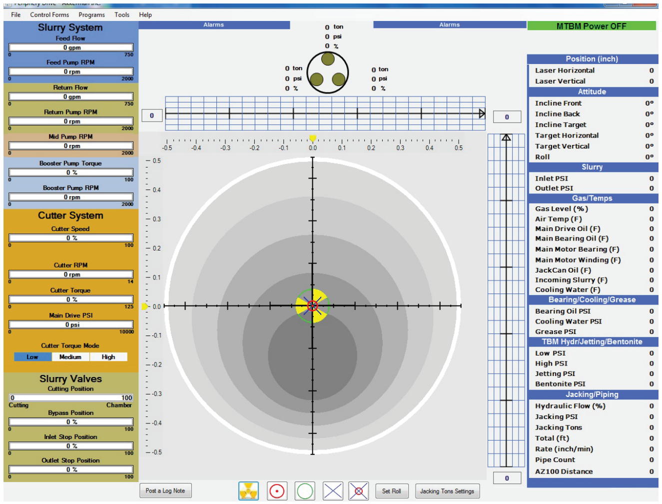


Figure 19. Active target data numerically displaced on the operator's control console screen.

AZ100 TOTAL GUIDANCE SYSTEM

Exclusive to Akkerman, the AZ100 Total Guidance System (TGS) is an azimuth based tunneling navigation system with self-leveling station units that is used for extended and curved tunneling, pipe jacking and microtunneling applications. It comprises individual, self leveling, station units that maintain a location measurement connection throughout the alignment without continuous manual surveying. The system interfaces with the standard Akkerman MTBM target but can be configured with any manufacturer's target.

The most significant point of differentiation between the AZ100 TGS and other tunneling navigation systems is that an initial survey to ascertain tunnel starting and end points is the only survey that is required; therefore, downtime is pointedly reduced for uninterrupted mining.

The system comprises a jacking shaft station and several pipe stations that look to stationary measurement prisms to provide reference points for guidance system location and azimuth.

After an initial underground survey has been conducted, reference prisms are installed on the launch shaft wall to determine bearing. Next the shaft station and prism are placed on a self-leveling tribrach according to the design axis behind the thrust wall (see Figure 20). The first pipe station is added at 300-linear feet (see Figure 21, 22) and additional pipe stations are added as required along the alignment to maintain a line of sight among stations. On average, a 1,000-3,500-linear feet range of distance can be achieved and is dependent upon prism size, tunnel diameter and atmospherics.

The AZ100 TGS has proven to be most economical on straight and curved critical alignments exceeding 700-feet, for any 48-inch ID or larger microtunneling project or 72-inch minimum pipe jacking or tunneling operation. After a contractor's initial investment, the pipe and station units can be modified for a large variety of project designs.

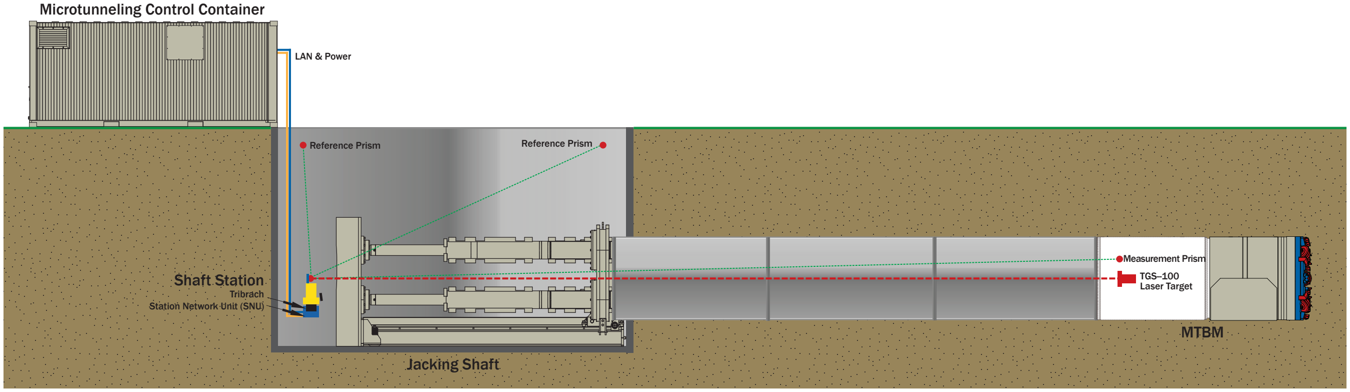


Figure 20: The AZ100 TGS shaft station is positioned behind the thrust block in a microtunneling operation.

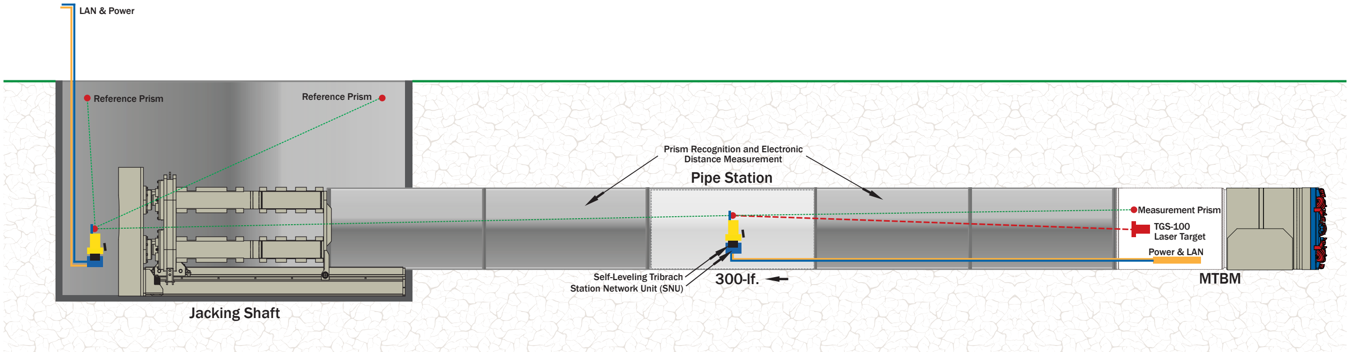
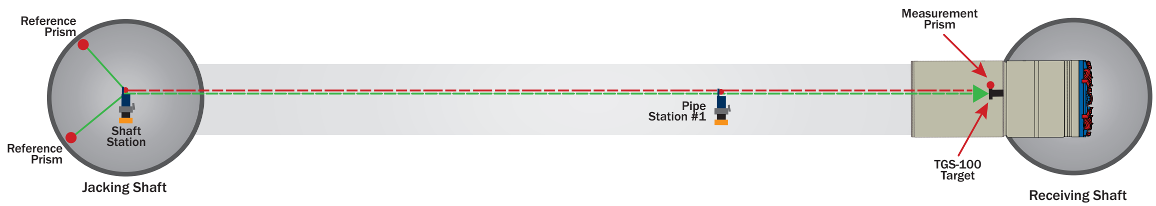


Figure 21: The AZ100 TGS pipe stations are added throughout the tunnel to maintain a line of sight between all stations.

AZ100 TOTAL GUIDANCE SYSTEM >> STRAIGHT TUNNEL



AZ100 TOTAL GUIDANCE SYSTEM >> CURVED TUNNEL

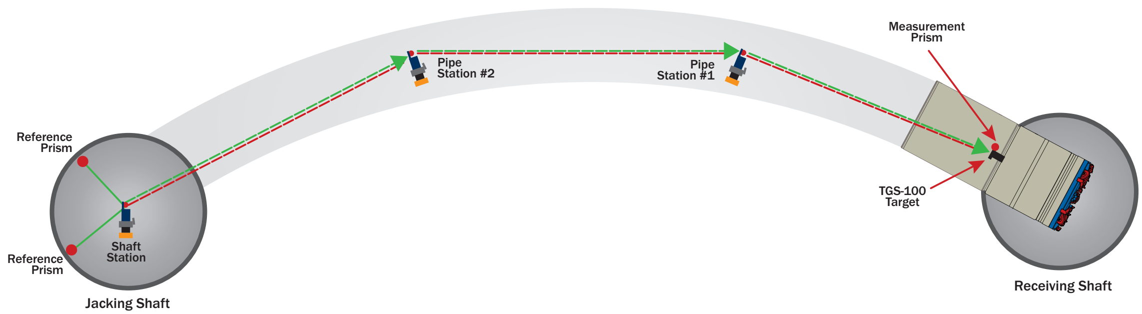
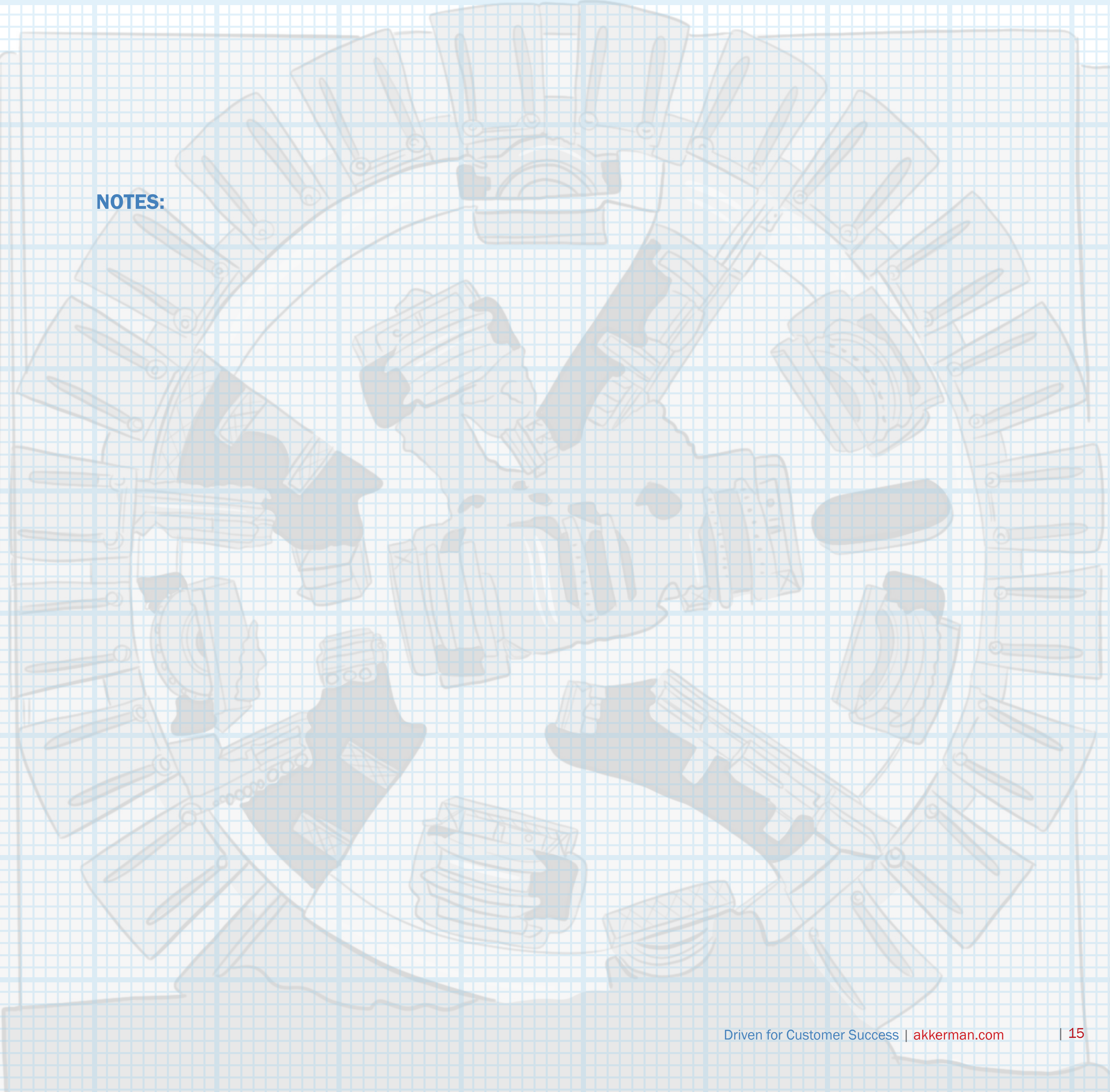


Figure 22: AZ100 TGS station unit set-ups on straight and curved alignments.



NOTES:

AKKERMAN

DRIVEN FOR CUSTOMER SUCCESS

Since 1973, Akkerman has developed, manufactured and supported quality pipe jacking and tunneling solutions that accurately install a variety of underground infrastructure. We are proud to be the only North American manufacturer of our range of equipment and a global competitor.

Symmetry with contractors has been the backbone of our business and a point of distinction above our competition. Before Akkerman the equipment manufacturer there was D. H. Akkerman Construction Company. To satisfy their need to accurately install pipe under crossings, the manufacturing branch of Akkerman was founded over forty five years ago.

Our business operates with the highest level of integrity and Akkerman employees have a personal investment in our customers' success. Our highly skilled sales team has a clear understanding of industry demands. Our in-house engineering department applies the most current standards and continually reviews, reassesses and enhances our equipment offerings.

We are committed to making every effort to position our equipment on your next project. As an added benefit, the purchase of a complete equipment system includes crew training and technical support. Akkerman systems are available for purchase, lease-to-purchase, or rent from our rental fleet. Select equipment will be considered for trade-in. Contact us to pair the best equipment options with your requirements.

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