basic information on selected Trenchless Technologies (TT)

Bogdan Przybyła, dr inż.,
Faculty of Civil Engineering, Department of Mechanics of Structures and Urban Engineering.

in the information from prof. M. Kawa – Microtuneling, Pipe Jacking and Direct Pipe methods listed

polish literature:
collective work edited by A. Kuliczkowski, ***Trenchless Technologies in Environmental Engineering***, Seidel - Przywecki Publishing House, 2010; 2019 (new, improved version)

basic informations about most common methods --- important monograph on the Polish literature market

other authors: Madryas C., Kolonko A., Zwierzchowska A. …

the most important and reliable source of knowledge about TT on polish market is the journal ***"Inżynieria Bezwykopowa"*** published by the *Inżynieria* publishing house, https://inzynieria.com/

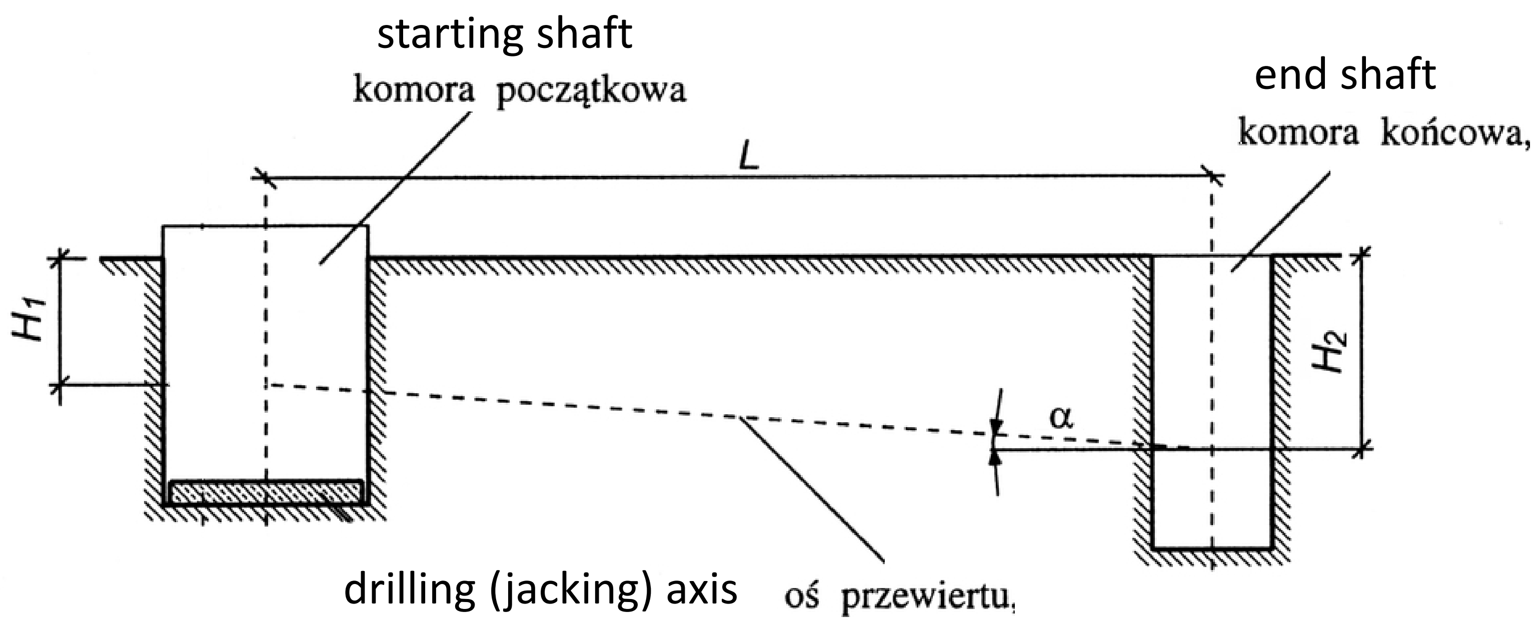
after logging in to the portal Inżynieria.com, the materials are available for free,

also (but less) „Nowoczesne Budownictwo Inżynieryjne” jurnal

famous foreign authors eg.: Najafi M., Sterling R., Stein D., Kramer S. R. …

TRENCHLESS TECHNOLOGIES
(**NO-DIG** as popular shortcut) (def. as solution for instalation of new elements)

understood as construction (realisation) techniques of underground line structures (pipelines, canals, conduits, tunnels) <u>without excavations along their route, except for the necessary</u>, resulting from the requirements (specificity) of a given technique.



horizontal or inclined, straight or curved

small construction site, on the side of starting shaft and if needed on end-shaft,

depending on method used, also without shaft – but with small ground-excavations , (also without when passing under road-enbankment)

shaft dimensions depend on the technique adopted for indyvidual solution

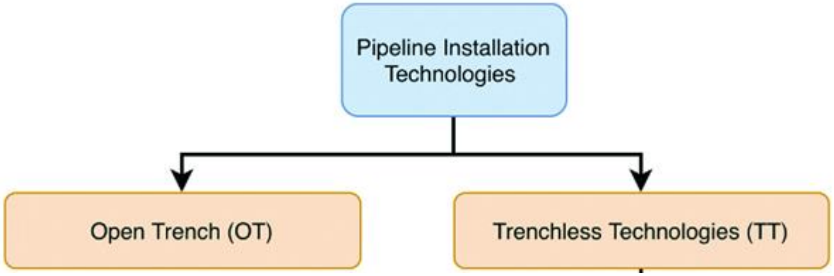
Trenchless Technologies as some kind of activities in pipelines industry, in the field of urban civil engineering.

Two separate areas for TT :

New installation
(understood as constraction of new pipelines)

and

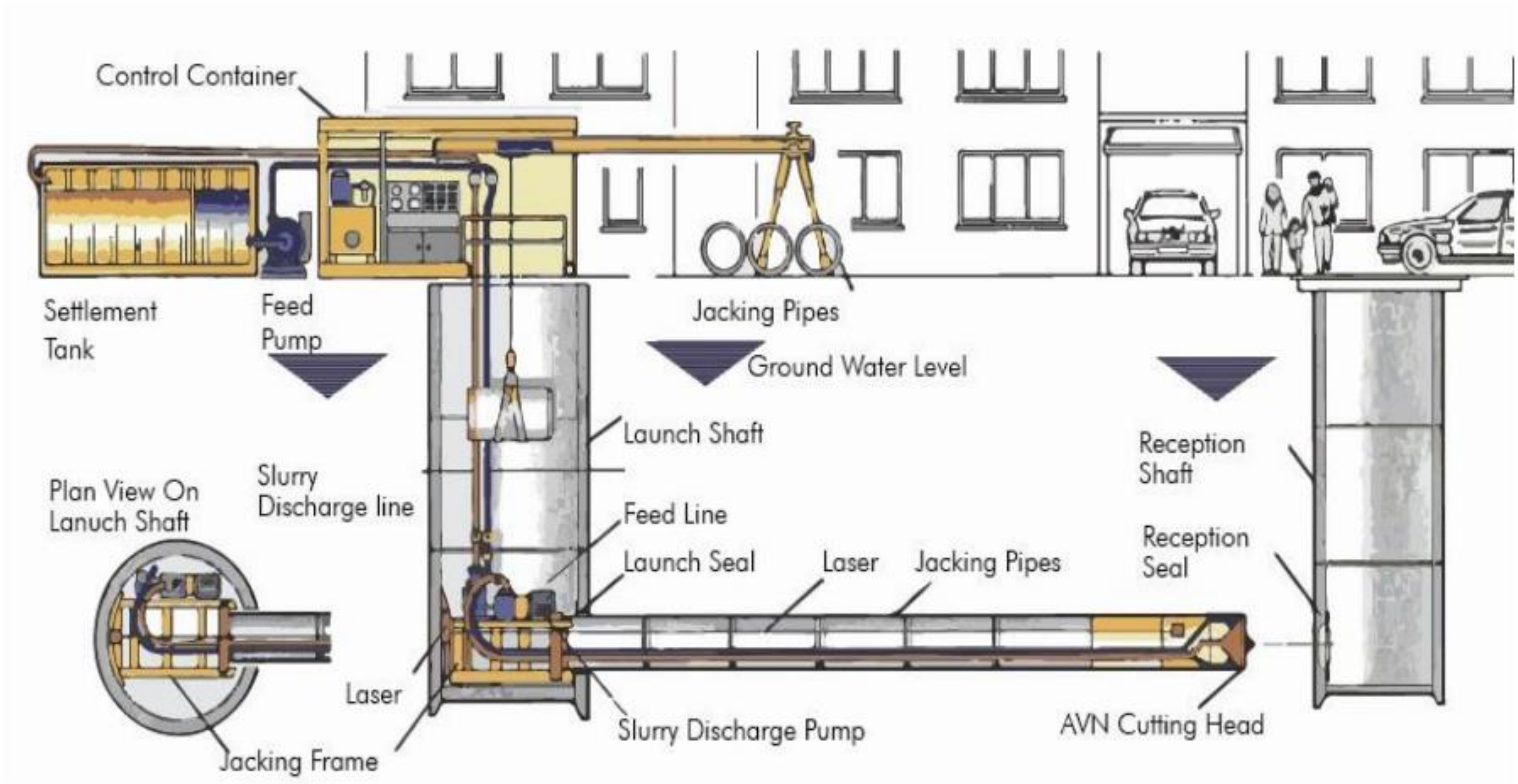
Technical rehabilitation
(as removal of damages in exising pipelines)



in general the two big subset of techniques
commonly used shortcuts – OT (Open Trench) contrary to TT

replace, repair, renovation are notions for classifying independent subsets of specific rehabilitation techniques (methods) *eg. using of pipeline repairing robots, CIPP technikes as a small part of a large set of solutions*
technical rehabilitation as overiding term

No-dig methods - often used, not always noticed …

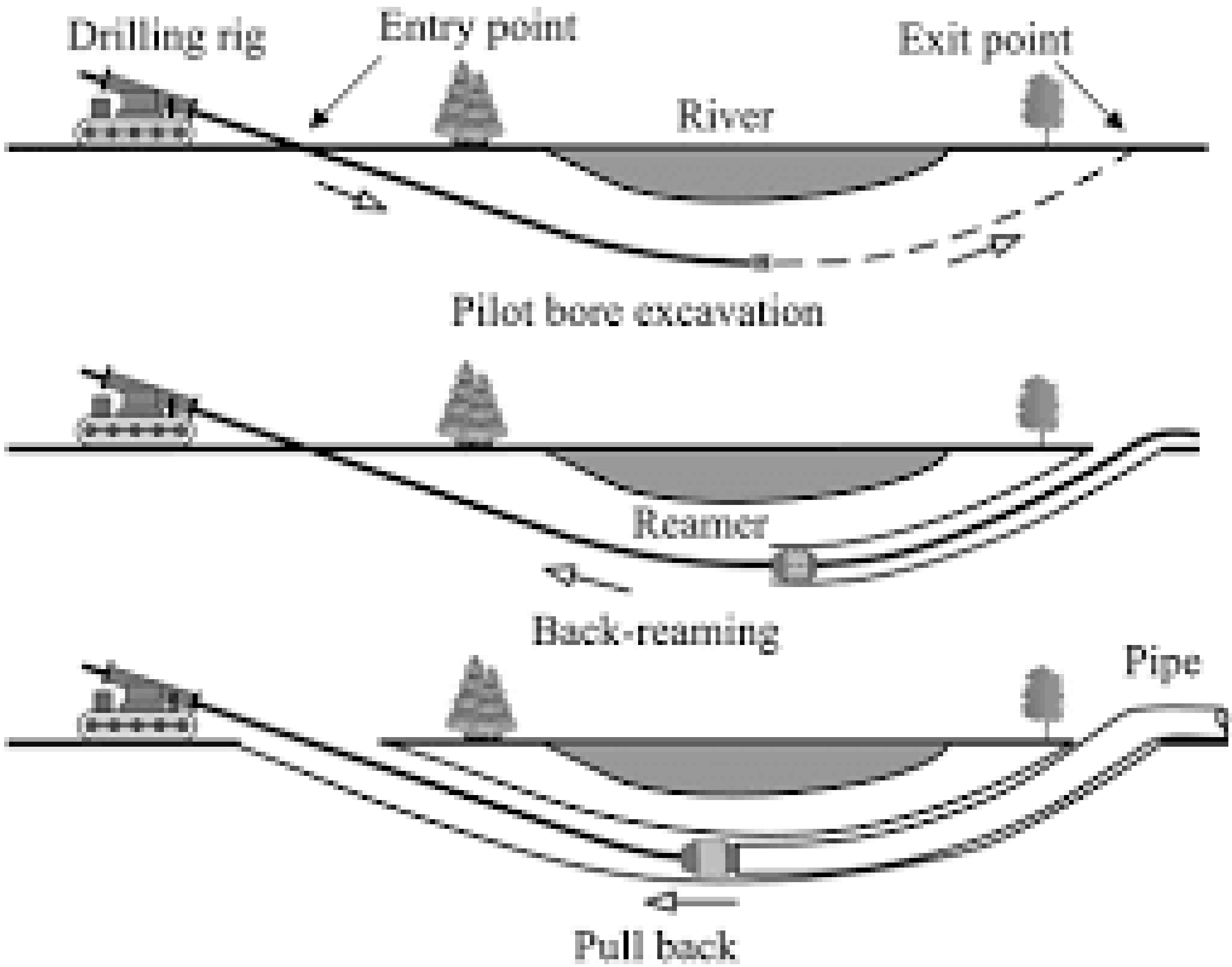


idea:
pushing short pipes into the ground behind the ground excavating machine

11.2025, Wrocław

idea:

pulling the pipe into the ground space where a suitable hole has been previously drilled



Step 2 - gradual widening (drilling) of the hole to the dimensions of the pipe pulled there finally

„rod pusher with directional control”

(DitchWitch, lata 60 XX w.) The development came with the improvement of the "walk over" (radiometric) control system.

small sets for small task - the work is even more hidden and carried out from a manhole

popular classification of ISTT (International Society for Trenchless Technology)

- Impact Moling,
- Impact Ramming,

dynamic pushing of pipes with use of impact

- Pipe Jacking,

Pilot-Tube Microtunneling

- Boring and Guided Boring,
- Microtunnelling,

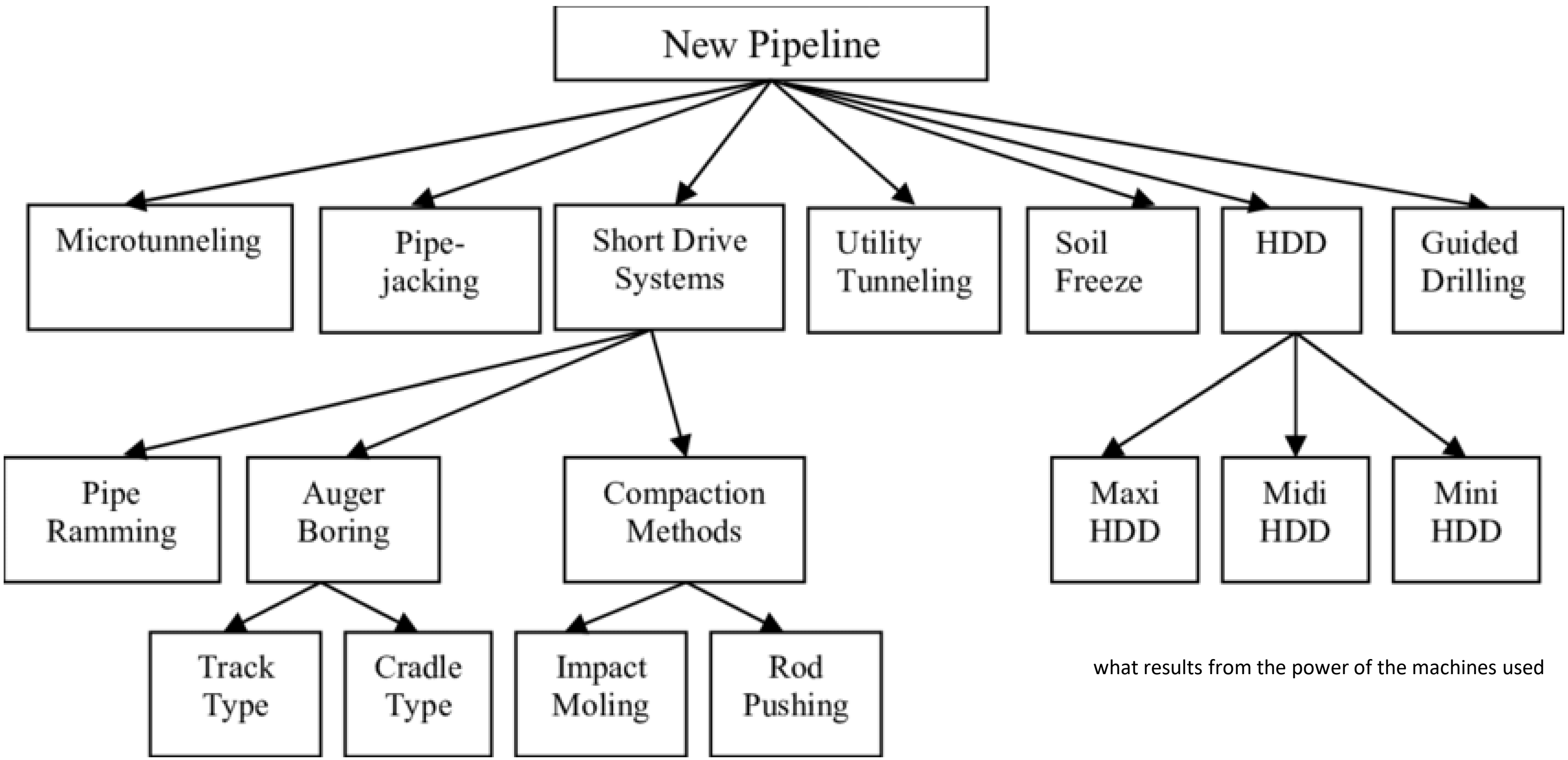
static pushing into the ground space

- Horizontal Directional Drilling,
  - rod pusher with directional control
  - Direct Pipe

pulling of pipes etc.
through the ground space

during time still new arriving technologies (often based on the old) – Direct Pipe, Axis, Front Steer, Überbohr (ABB - method) …

Different trenchless techniques that are used in the installation of new pipeline – by Mohamed Hegab



what results from the power of the machines used

with pushing the soil to the sides and compacting it
(other than in mehods with ground excavation)

example for classification (Internet)

the classificatins are more or less precise and accurate;

more official classification of TT is presented in:

EN 12889:2000
Trenchless construction and testing of drains and sewers

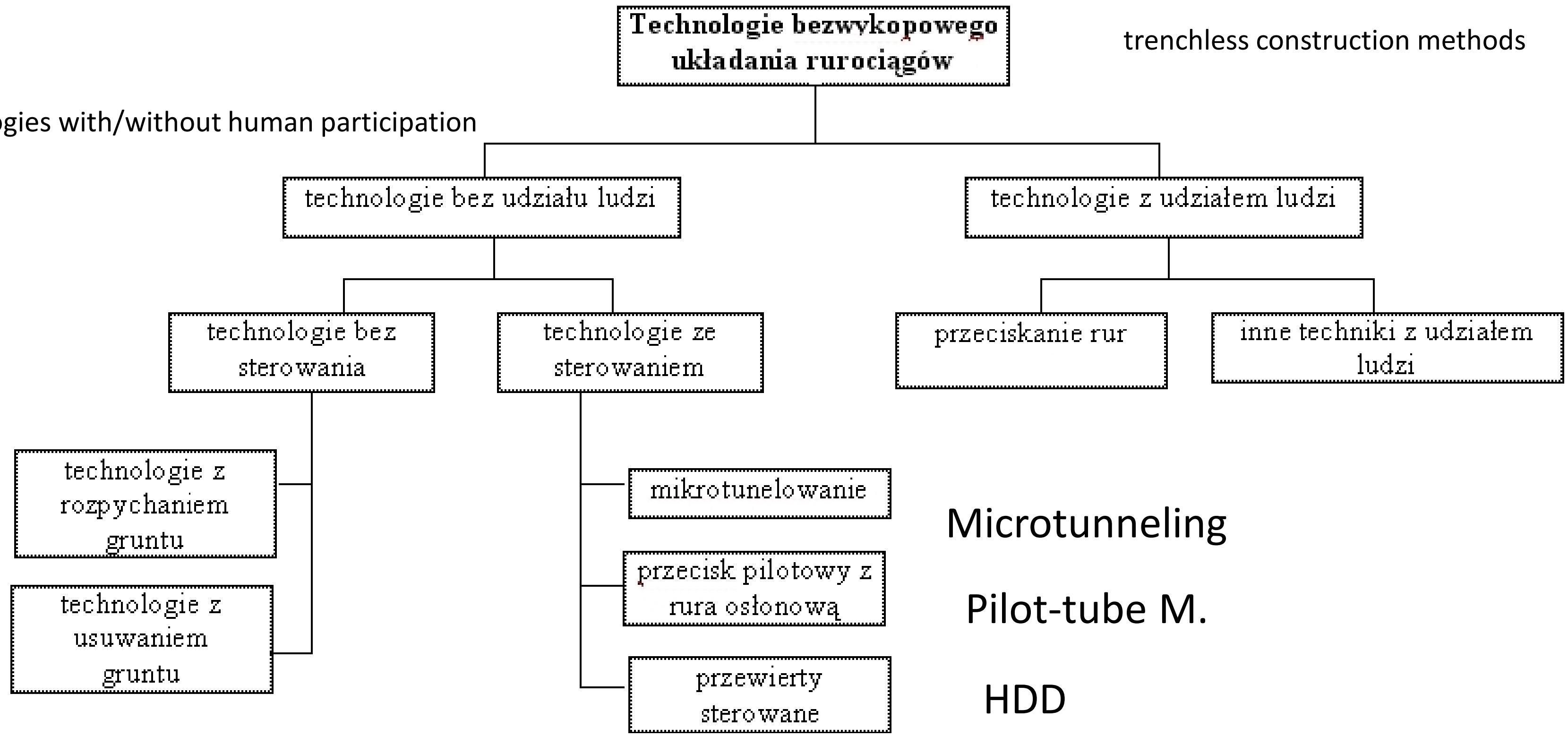
PN-EN 12889:2003 – polish version
Bezwykopowa budowa i badanie przewodów kanalizacyjnych

newest: PN-EN 12889:2023-04 – English version

this means that only the title page has been translated

PN-EN 12889: 2003

technologies with/without human participation



cases with employees who appear in the system (underground) only in exceptional
(maybe critical) situations or work there constantly

technologies with/without control and steering possibilities during construction process

technologies with pushing the soil to the sides
(without removing it to the ground surface)

technologies with/without human participation

cases with employees who appear in the system (underground) only in exceptional (maybe critical) situations
or they work there constantly

closed and open face of MTBM

backhoe excavator and its operator steering process of ground excavation

Advantages of trenchless techniques (as a result of no excavation):

- unnecessary technical measures for securing excavation slopes, exept shafts
- unnecessary lowering of the groundwater level, exept around shafts
- reduced risk of damage to existing buildings,
- no damage to road surfaces,
- reducing damage to vegetation,
- reducing exhaust emissions and noise,
- no restrictions on access to facilities, services, offices, etc.,
- usually shorter construction (realisation) times,
- fewer employees involved,
- no need to close communication routes under which works are carried out

of course, it depends on the correctness of the task implementation

(things don't always work out)

… to be underlined

- the ability to perform tasks which would be technically very difficult to implement using other technologies

this is (with other words ..)

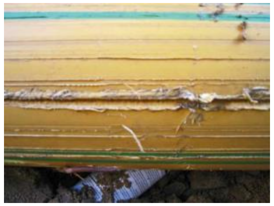
Trenchless techniques used in conditions where there are no alternative solutions or there is a significant technological or legal barrier.

(eg. crossing vast terrain obstacles, solutions in conditions of underground space with dense infrastructure, crossing of protected areas, a nature reserve etc.)

if we have advantages, there are also disadvantages

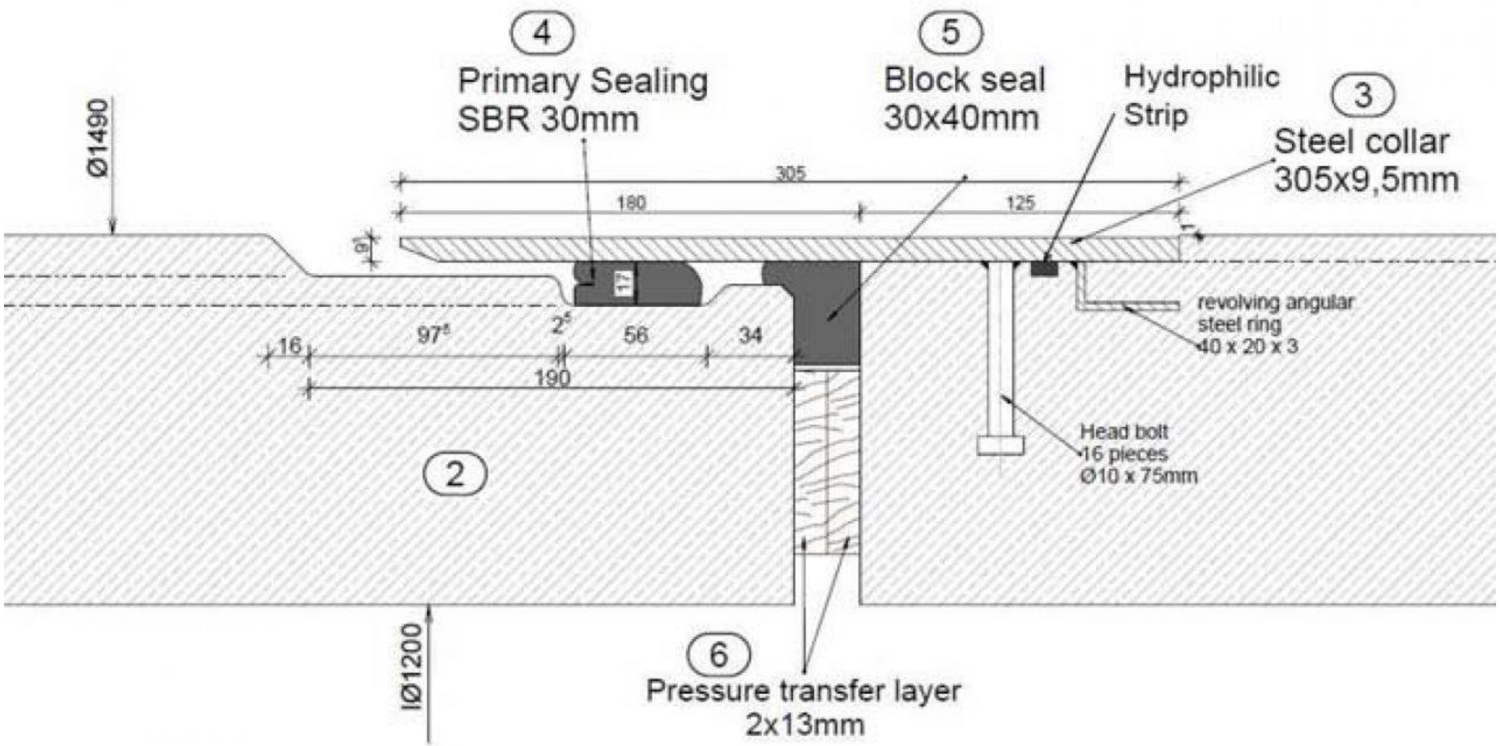
disadventages of TT

- the need to use highly specialized, expensive equipment,
- when building new lines, it is necessary to use usually pipes with appropriate properties (not these for lying in OT)
- potentially lower accuracy when laying pipelines comparing to OT,
- significant consequences of the occurrence of unexpected events during laying of pipes (resulting mostly from bad ground conditions and lack of its proper identification) – what is cousing high costs of continuation of works,
- the big importance of appropriate planning / design process for achieving success and completing the works as planned



what makes jacking pipe?
no protruding parts on the outer surface (to awoid bigger friction), guide ring mostly of steel, sometimes greater pipe wall thickness, additional reainforcement in concrete pipes

connection detail



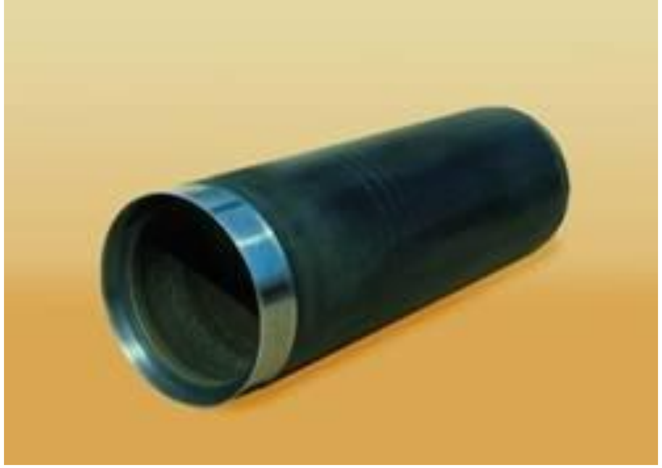
wood, mostly wood-based material,
hoses with hydraulic fluid for pressure measurement as special solution

jacking pipes

steel guide rings

transfer-ring of wood-based material

GRP (polyester or epoxid resine pipe with glassfibre reinforcement), stoneware



here with v-shaped kinet

concrete (reinforced), polymer concrete, fused basalt

no protruding parts on the outer surface, guide ring of steel, transfer-ring, For methods involving pipes being pulled into the ground (HDD-method), welded steel pipes and butt-welded polyethylene pipes are primarily used.

Less commonly, ductile iron pipes (for water supply systems) are used, with special socket connections capable of transferring tensile forces.

For short sections (up to approximately 100 m), short pipe modulus are also used.

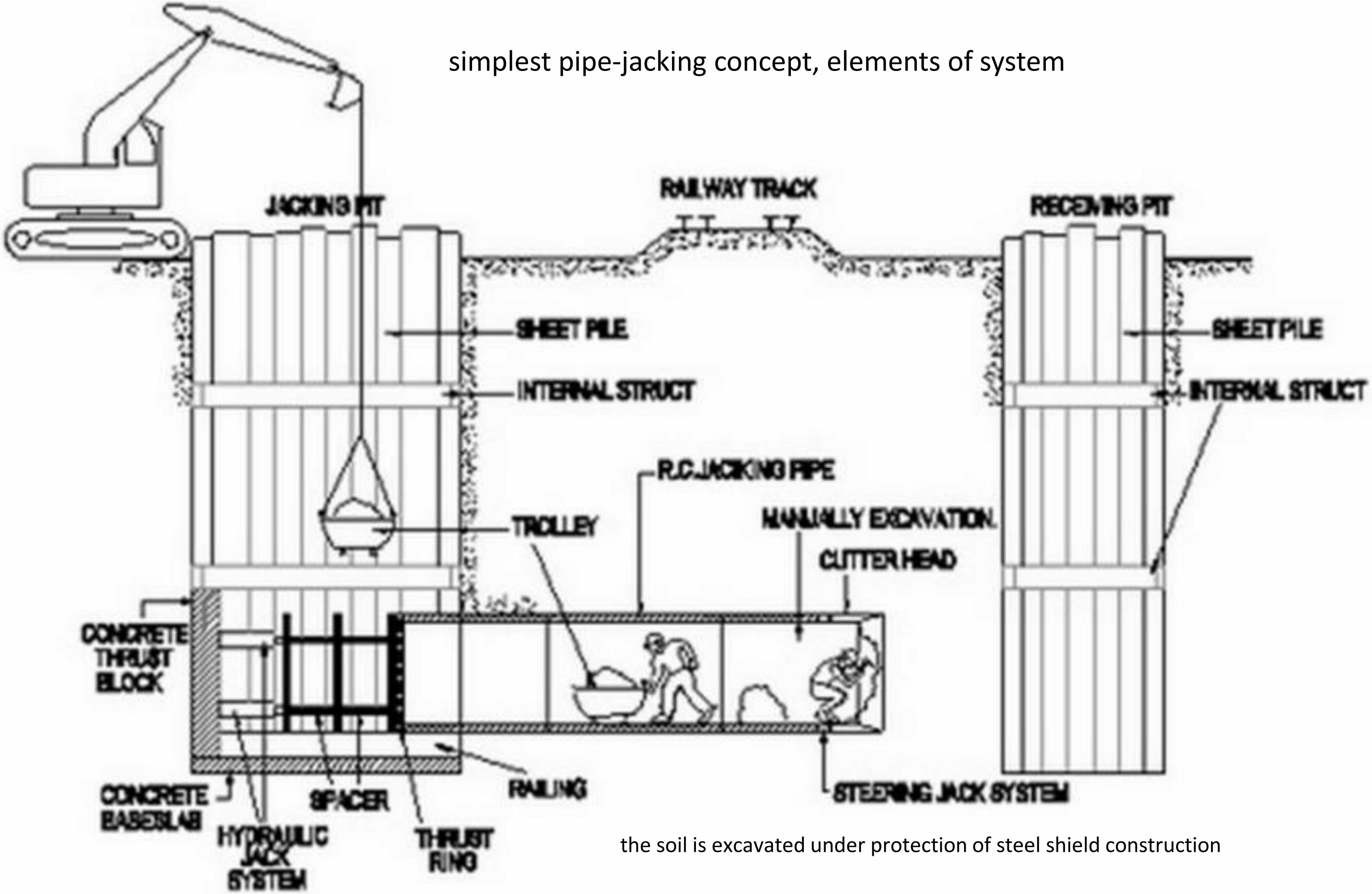
Pipe Jacking,
Boring and Guided Boring,
Microtunnelling

considered to be similar techniques, differing in the instrumentation solutions used - mainly in connection with ground transport/excavation.

<u>Pipe Jacking</u> sometimes is used as an overarching concept where Microtunneling is only a specific solution related to the adoption of a special machine for soil excavating and removing.

alternatively we can treat them in order of their level of complexity and the time at which they were developed, with Pipe – Jacking as most simply and oldest method. Mirotunneling as most advanced method - all are used successfully today …

simplest pipe-jacking concept, elements of system



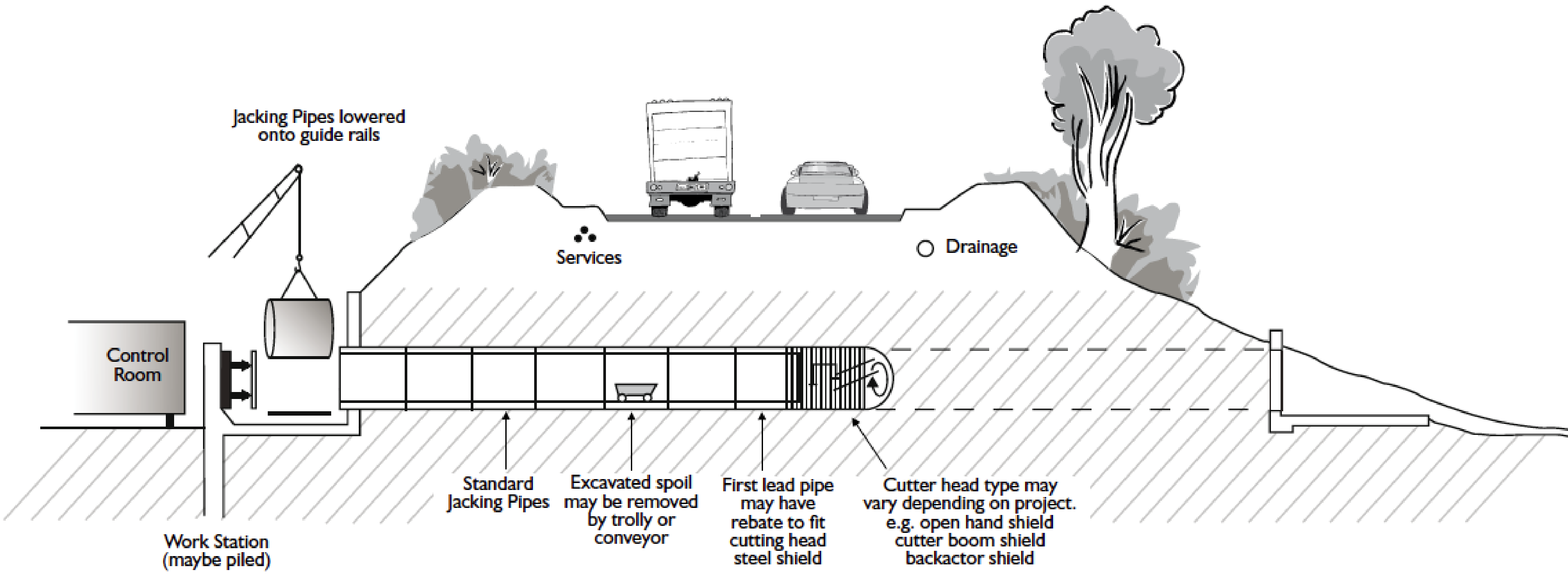
the soil is excavated under protection of steel shield construction

jacking systam based on (connected with) thrust block

hydraulic cyliners go forwards and then backwards

Manshield Pipe Jacking

the excavator or crane is used to raise excavated groud and to lower the pipes to the bottom of the trench, finally, connection or inspection manholes will be set up in shafts



initially used for crossing road and rail embankments, in Poland popular just in 70th years of XX century, most often for laying steel casing pipes

for small cross-sections of the pipes, the soil was transported to starting shaft with use of a screw conveyor (auger)

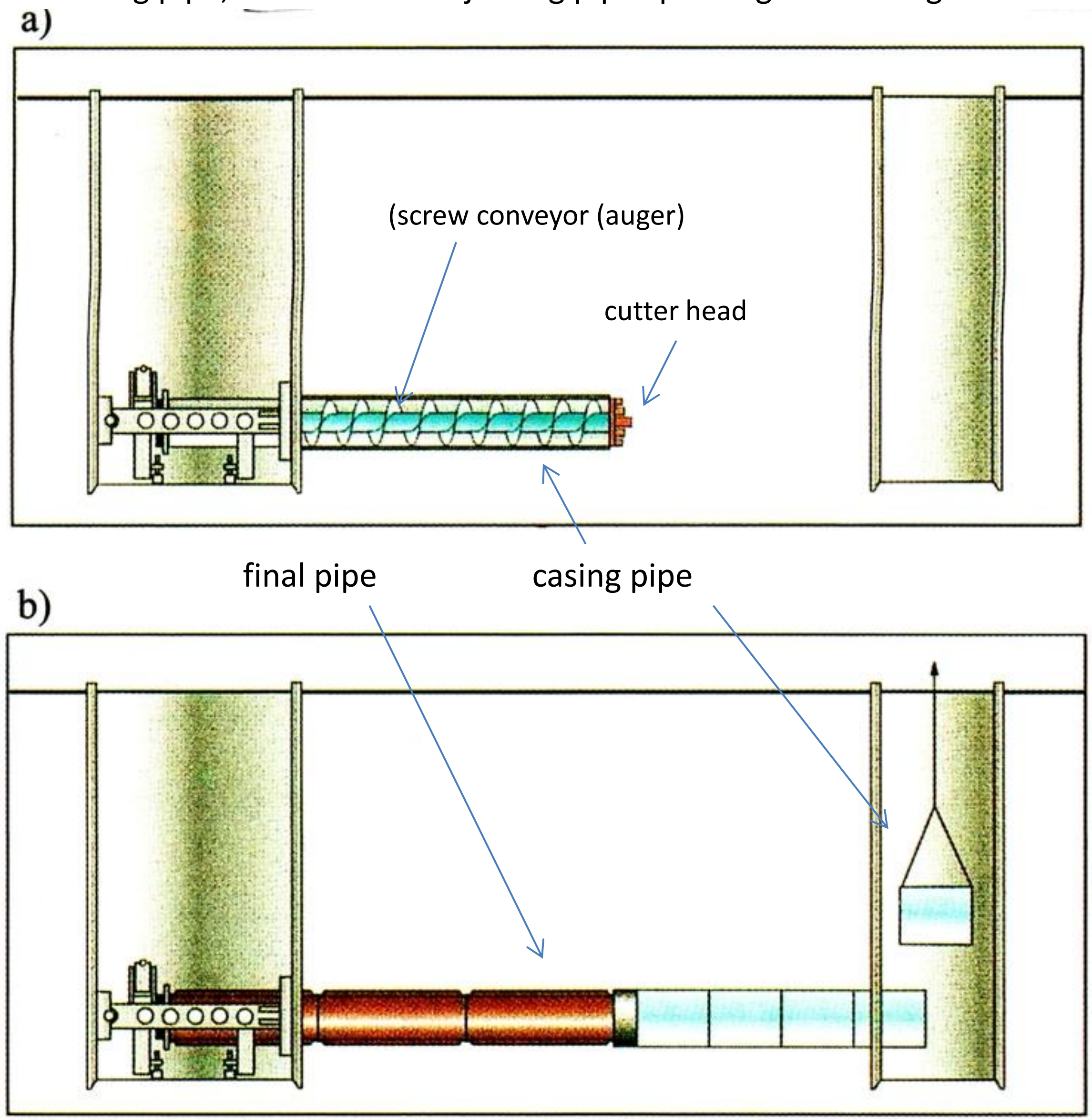
technologies with/without human participation circular shield with bracings for the mining front and backhoe excavator

small height of the ground above the pipe - safe can be high of one and a half or two pipe diameters
- in the situation of the road surface in use

Pilot tube bohring metod when crossing the railway line

Maszyna WP 80/100 firmy Wamet podczas wykonywania przewiertu żerdzią ϕ114 mm

two stages for **Auger Boring** methods:
first – steel casing pipe, second – finnal jacking pipes pushing with casing removal



first step
(stage)

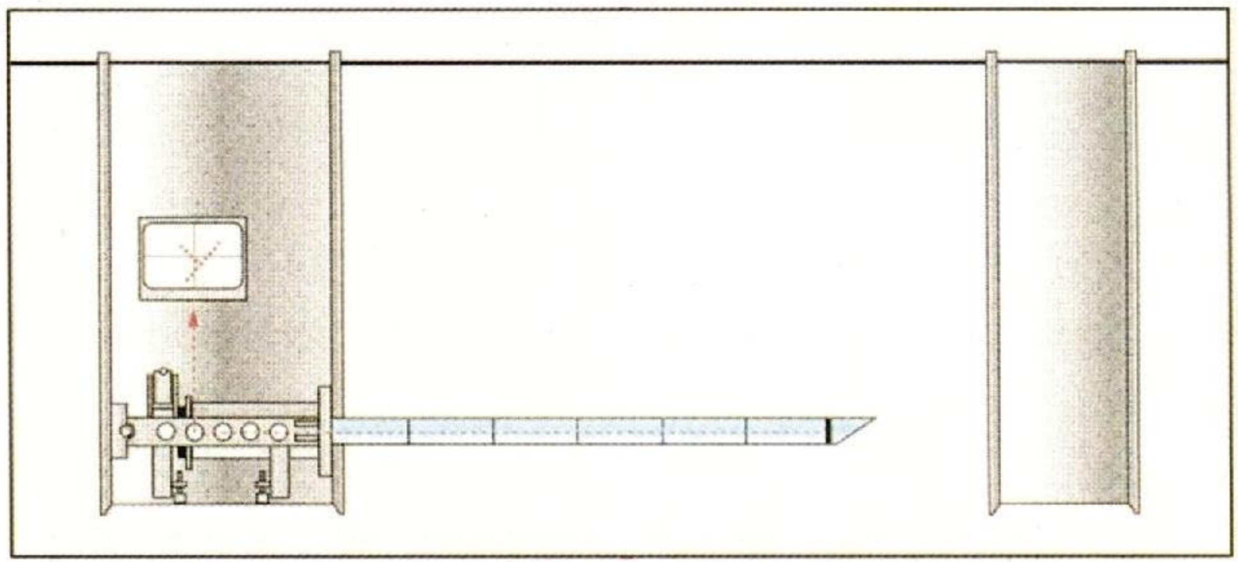
second step
(stage)

a set of steel casing pipes with the appropriate elements (parts) of the auger conveyor

Guided Boring Method (pilot tube method) for bigger accuracy

Auger boring metthod developed further with the application of pilot rods of small diameters pushed at first step into the ground for improvement of accuracy of realisation

Step I – pilot drilling (pilot rods and pilot head)



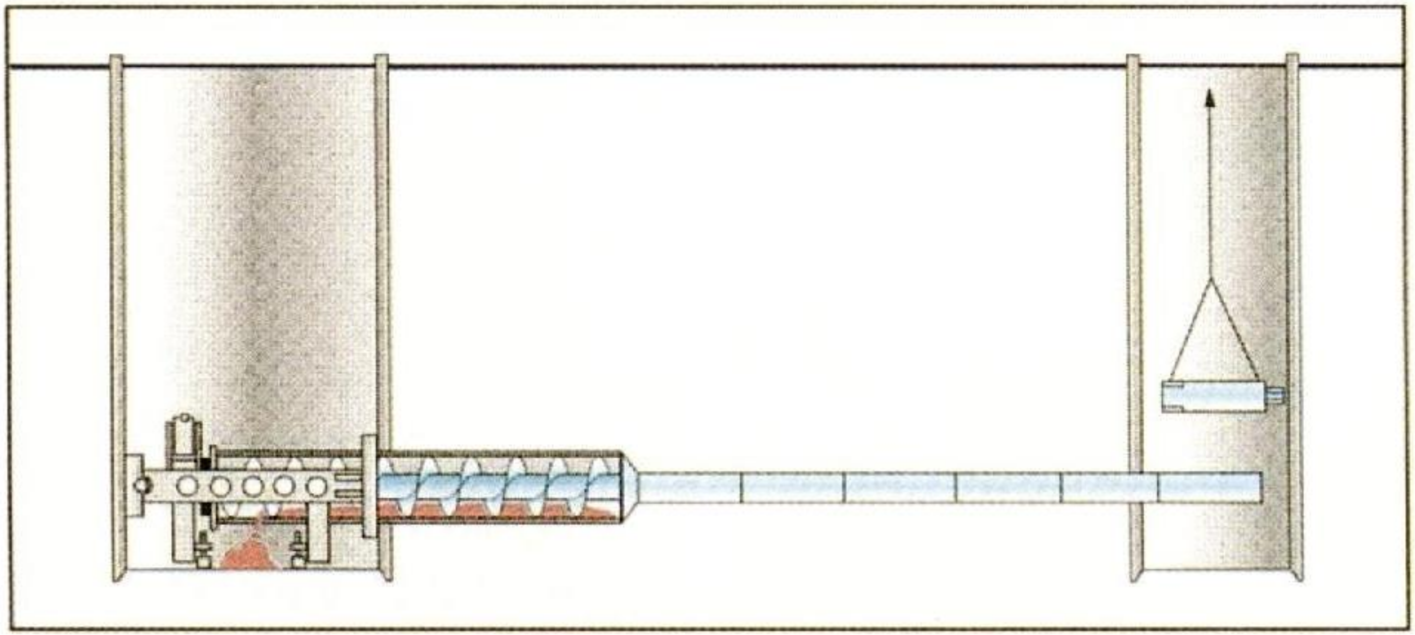
controlled process of pushing the pilot rod into the ground, ground in not transported to the starting shaft, only pushed to the sides in ground area

(na podstawie materiałów reklamowych firmy Bohrtec)

drill rods for pilot drilling

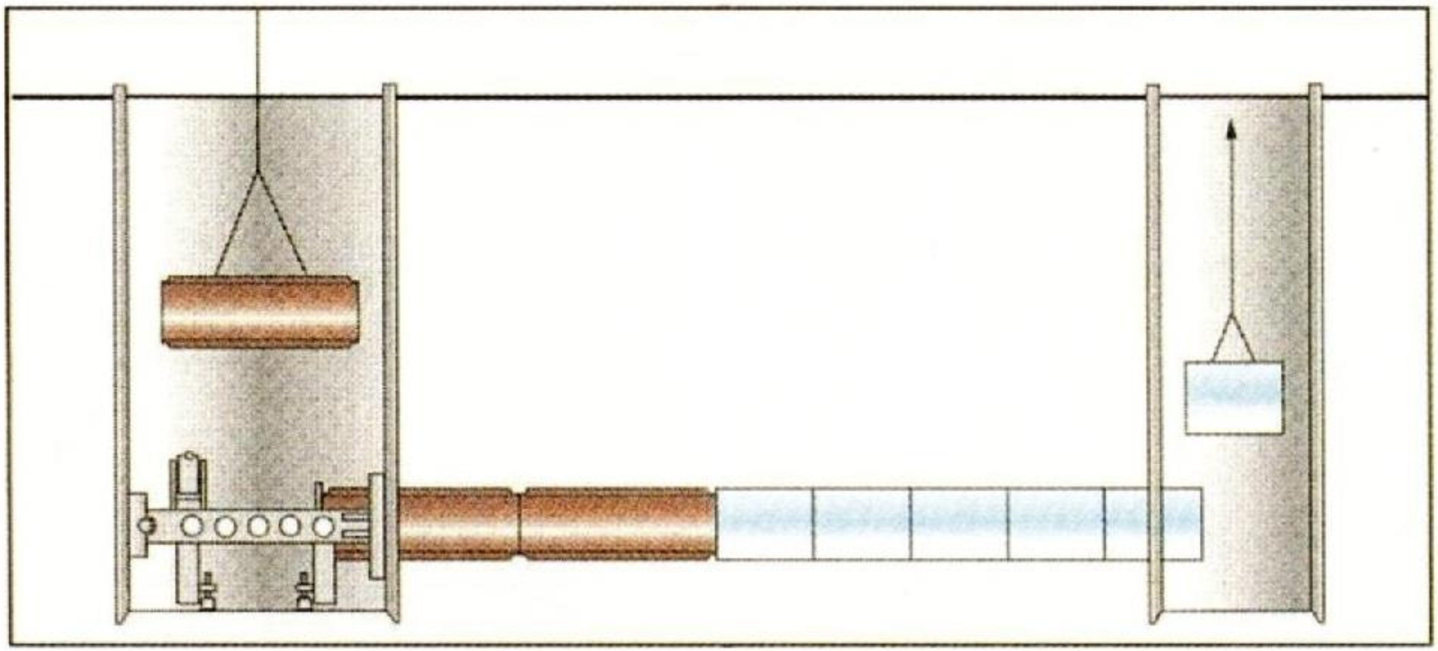
Zwierzchowska A., Technologie bezwykopowej budowy sieci gazowych, wodociągowych i kanalizacyjnych, Wydawnictwo Politechniki Świętokrzyskiej, 2006.

Step II - reaming of the borehole with simultaneous jacking of casing pipes, pilot rods removed at end shaft

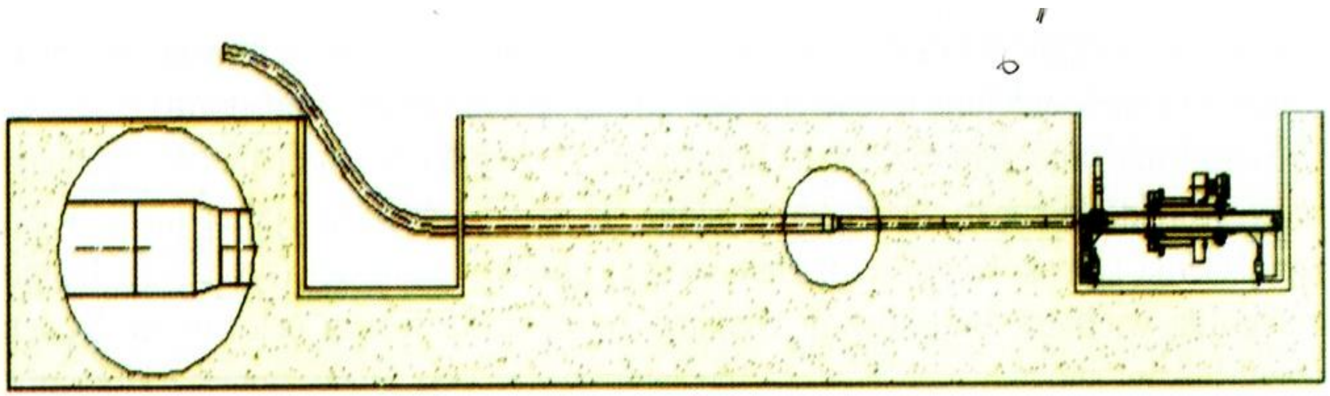


(na podstawie materiałów reklamowych firmy Bohrtec)

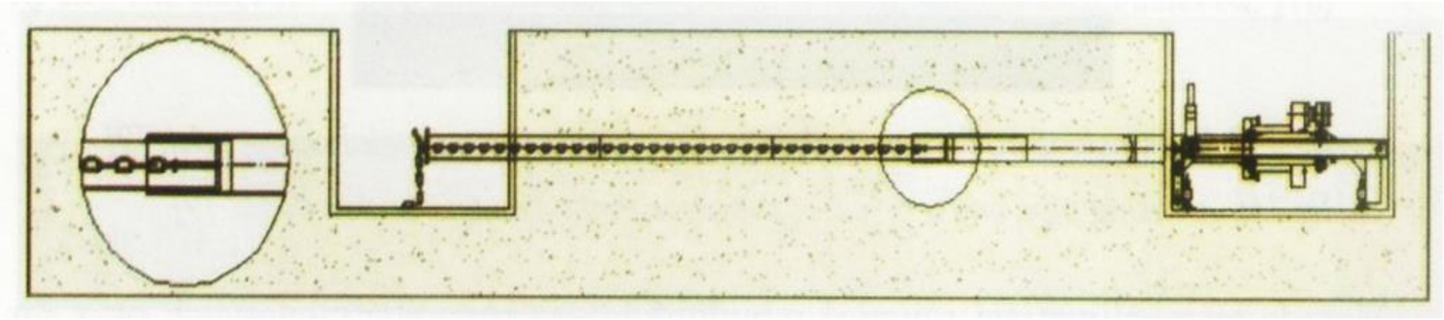
Step III – hydraulic jacking of final pipes

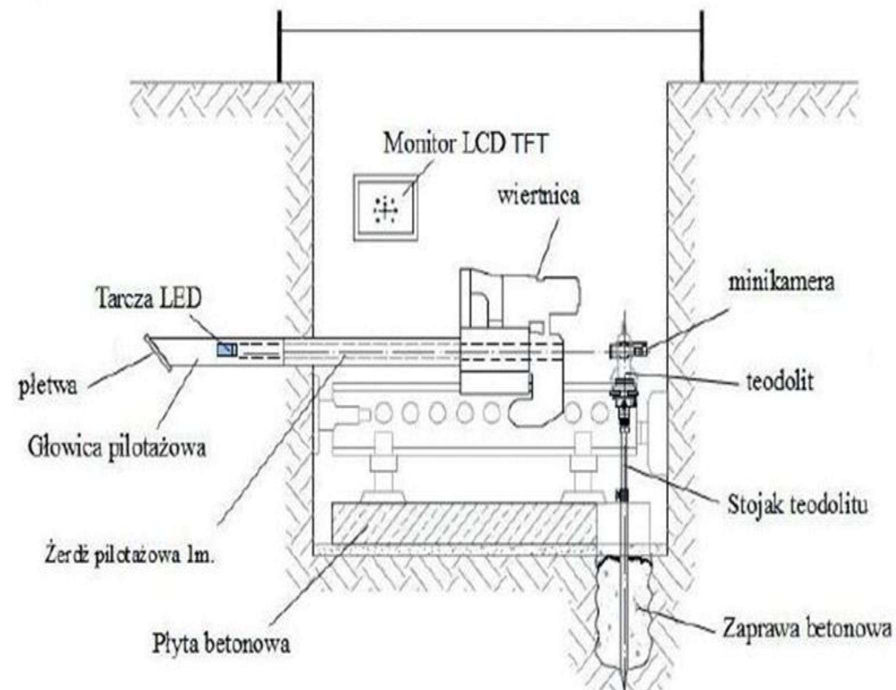


(na podstawie materiałów reklamowych firmy Bohrtec)



PE pipe or short modulus of PP, PVC pulled when reversing pilot rods

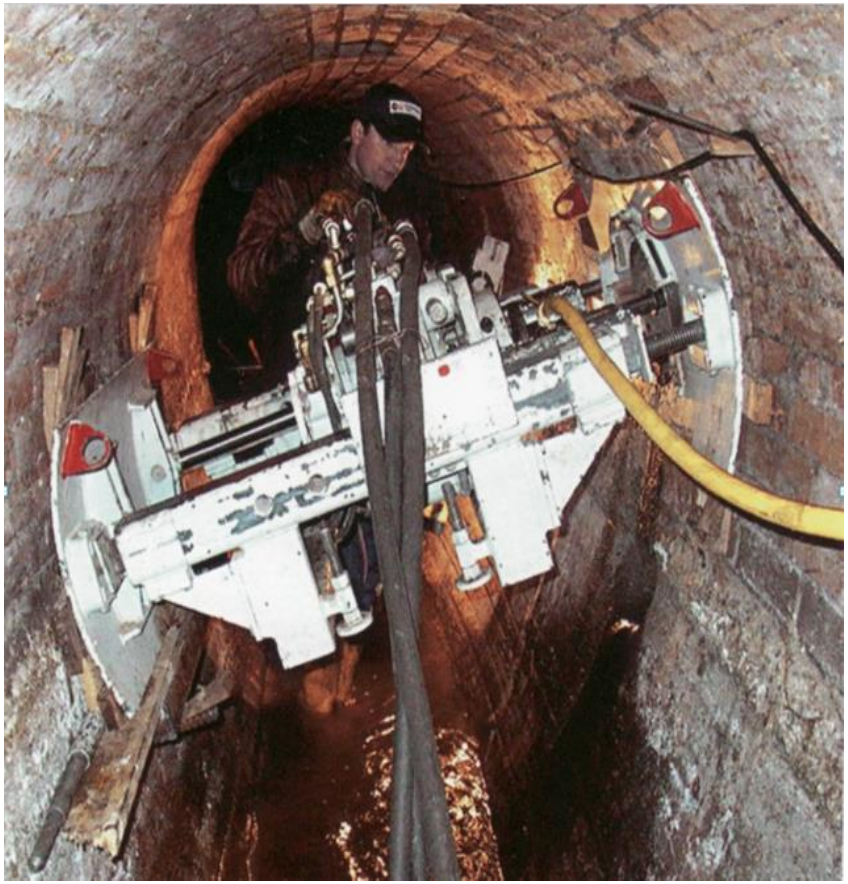




materiały informacyjne firmy Jumarpol Gliwice *accuracy !*

Wybrane parametry techniczne	Przecisk hydrauliczny niesterowany	Przecisk hydrauliczny z wierceniem pilotowym
Maksymalne długości wbudowywanych jednorazowo rurociągów, m	60	80
Zakres średnic wbudowywanych rurociągów, mm	100 – 1500	100 – 600
Rodzaj gruntu, w którym możliwa jest budowa daną metodą	1 – 6	1 – 6
Możliwość wykonania rurociągu w gruncie nawodnionym, maksymalna wysokość zwierciadła wody gruntowej, m	tak 3	tak 3
Materiał wbudowywanych rur	wszystkie przeciskowe	wszystkie przeciskowe oraz PVC i PE
Możliwe odchylenie spadku oraz odchylenie osi przewodu w planie od przewidzianego w dokumentacji	1-2% długości wbudowywanego odcinka rurociągu	±20 mm w pionie ±25 mm w poziomie

Zwierzchowska A., Technologie bezwykopowej budowy sieci gazowych, wodociągowych i kanalizacyjnych, Wydawnictwo Politechniki Świętokrzyskiej, 2006.



boring of the route directly from manholes and collectors

materiały informacyjne firm DTA Tracto Technic i Bohrtec

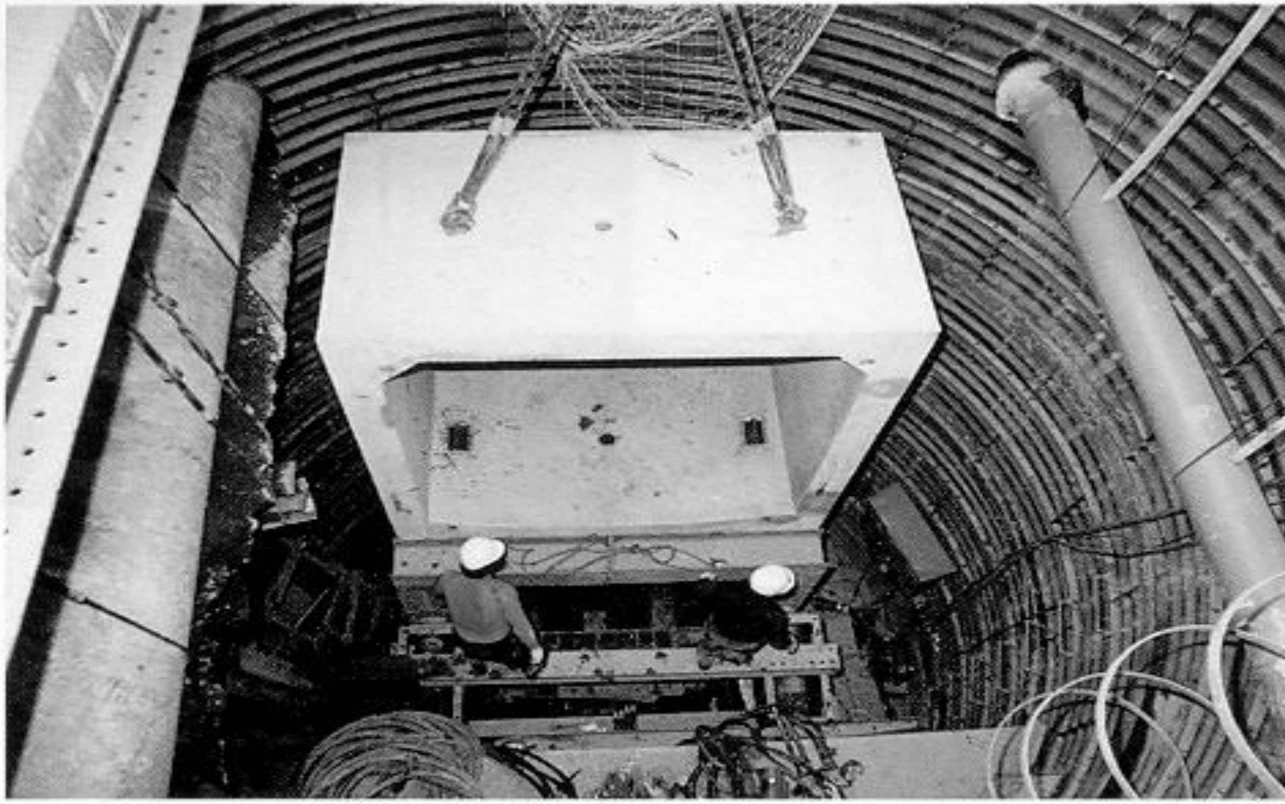
Pipe jacking of concrete elements with bigger dimentions

(3) Shaft top

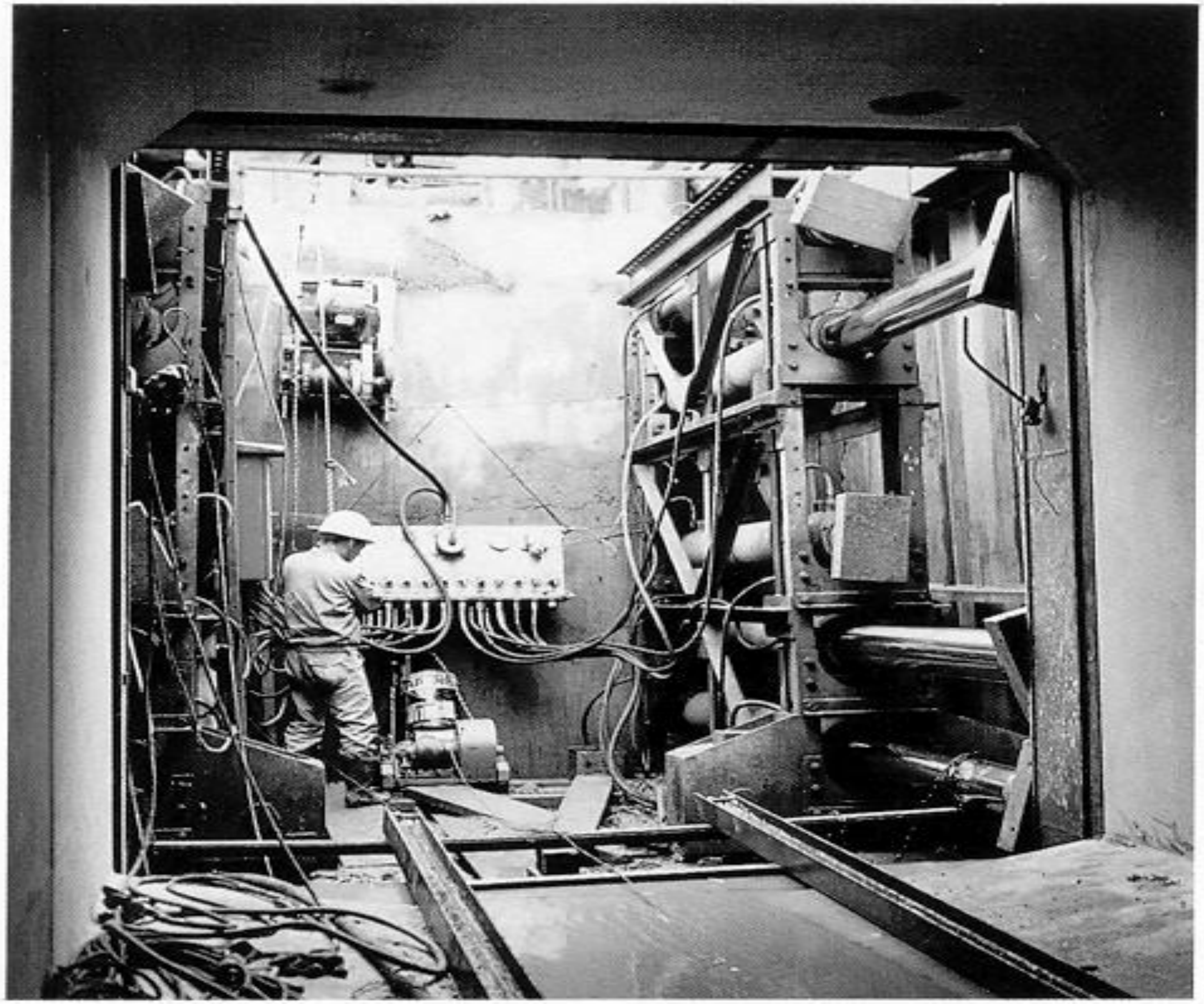
rectangular elements
pushed into the ground

project performed in Japan (Madryas at all), one of historic examples

(4) Lifting down of product



Jacking source hydraulic unit



Discharge of soil by belt conveyor

(2) Discharge of soil

(1) Excavation of front section

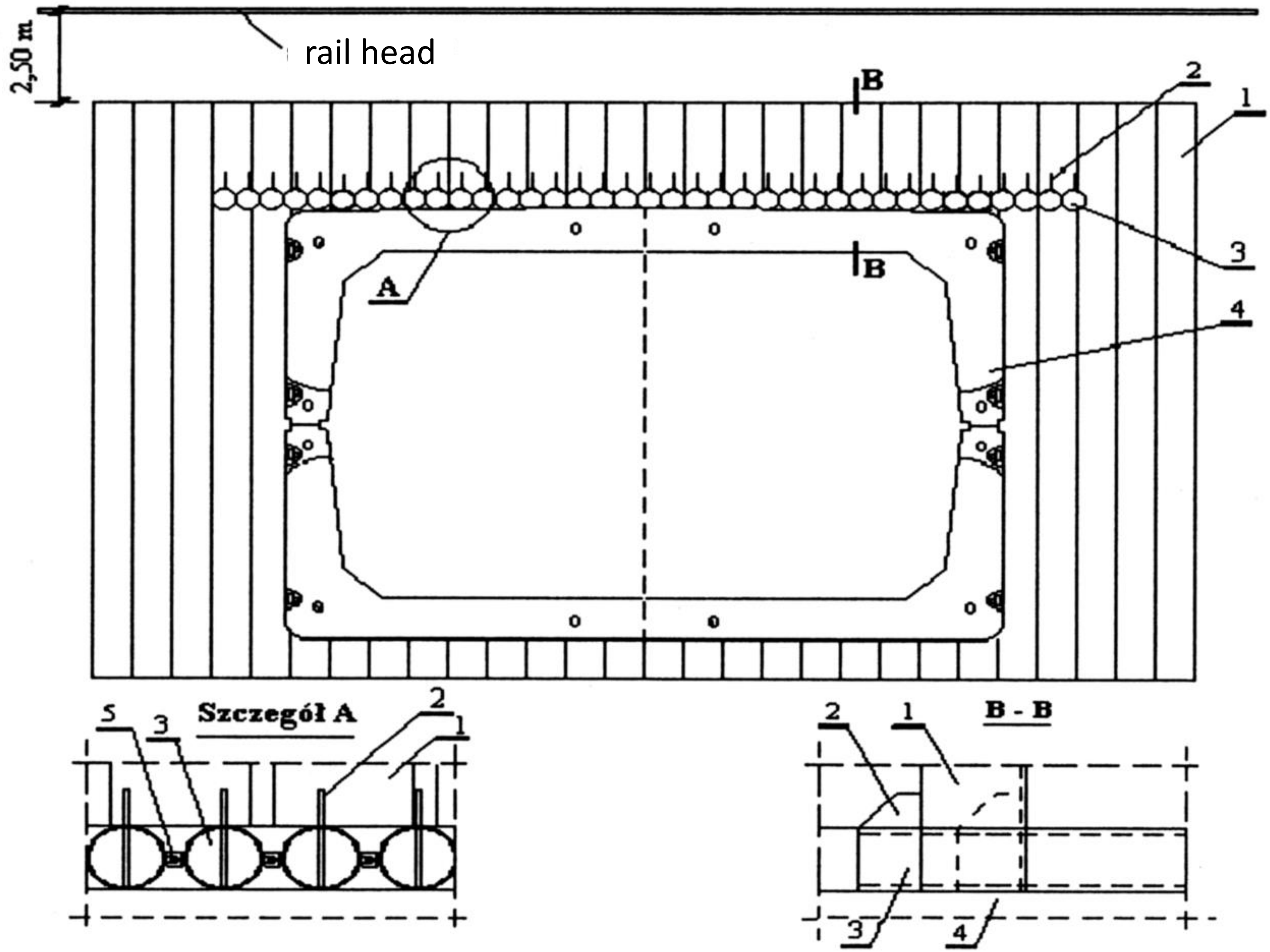
steel shield in ground – not visible (protection against ground collapsing)

road tunnels in Piotrków Trybunalski along the W-Z route (1997-99):
width 8.00 m, height 5.00 m, length 26.00 m.
(two twin tunnels with an adjacent tunnel for pedestrians 2.55 x 4.50)

Jacking of 1.20 m long prefabricated elements, assembled from two parts, jacking unit with a total force of 4000 kN,
bentonite suspension pressed through injection holes in the segments,jacking carried out under the cover of an artificial ceiling made of steel pipes fi 273/8, approx. 2.70 m, under the active railway line.

The engineering company "KKIM" S.A.

similar realisations in Łodź and Nowy Sącz two elements of concrete put together and inserted into the ground under the cover of the initial casing, made of steel pipes (pipe-roofing methods)



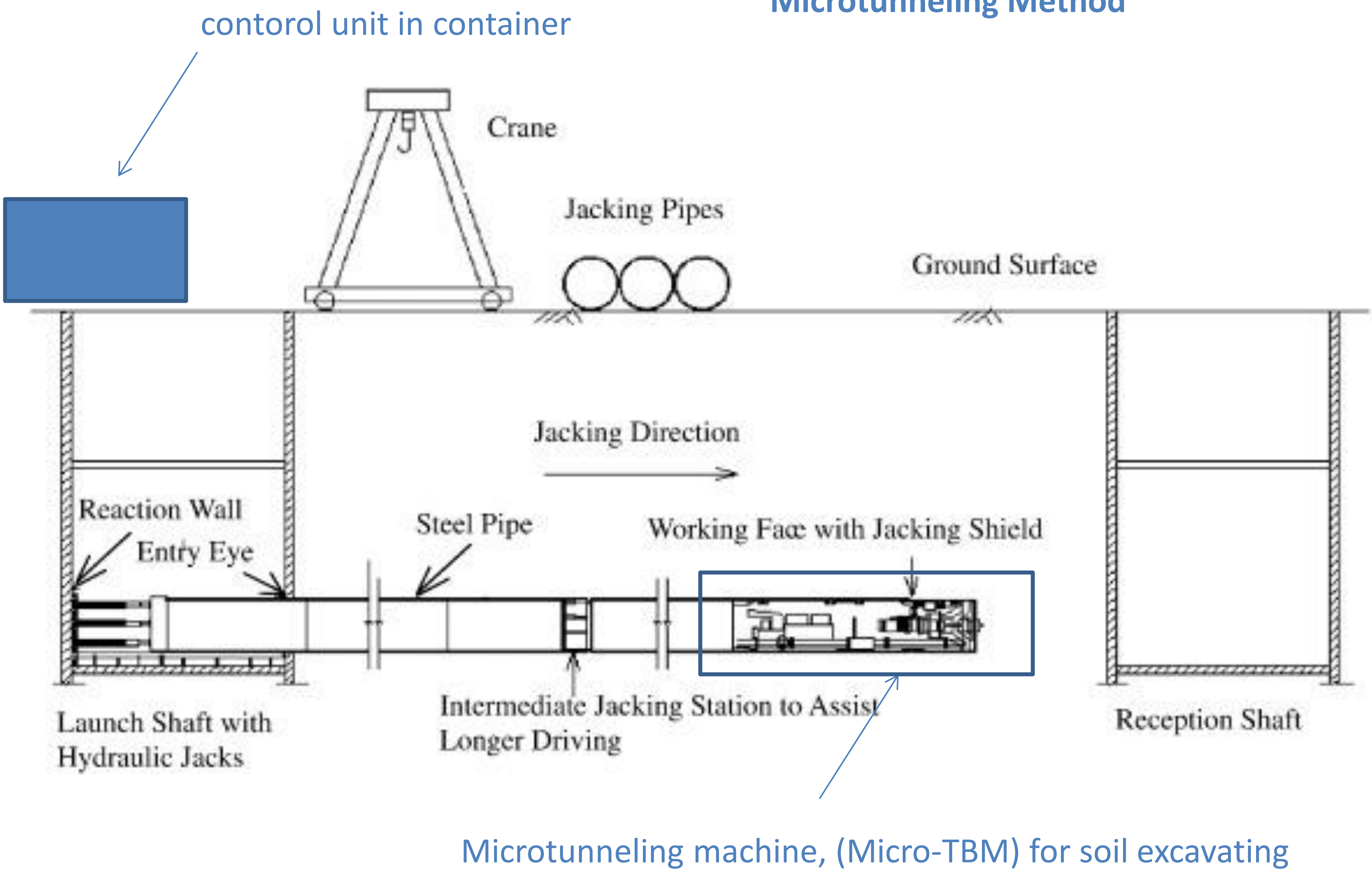
Construction of an underground passage using the hydraulic jacking method at al.Powstańców in Warsaw; monolithic reinforced concrete structure relised at the construction site, XXI century …

- DN3600 under an active railway line, L=31m, Jacking along the route of the old culvert leading the watercourse, with the necessity of its demolition

completed work GRP (resine pipe with glassfibre reinforcement

underpass for pedestrians and cyclists, Parczew, 2019

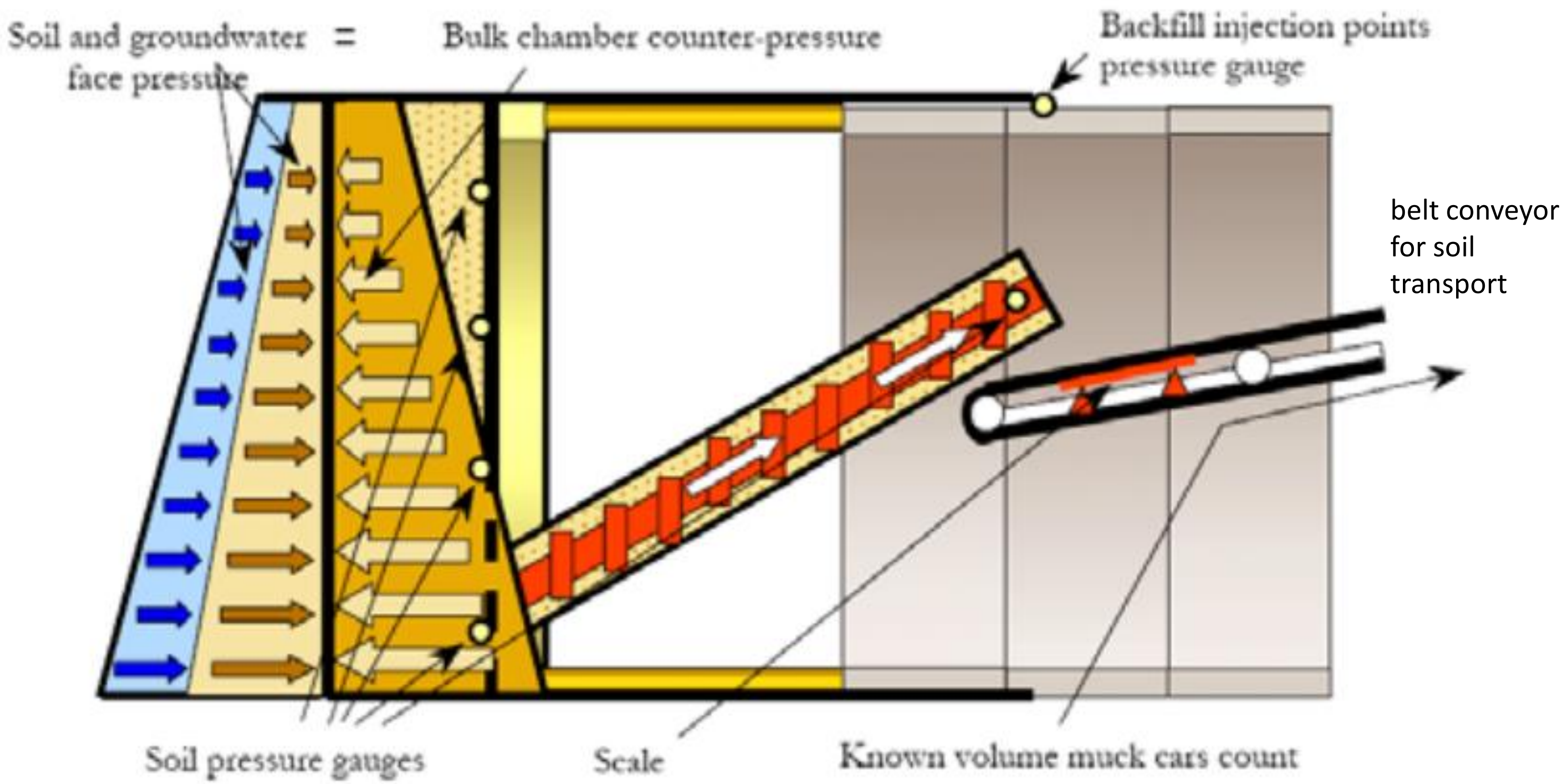
Microtunneling Method



Two types of MTBMachines: slurry shield and EPB shield

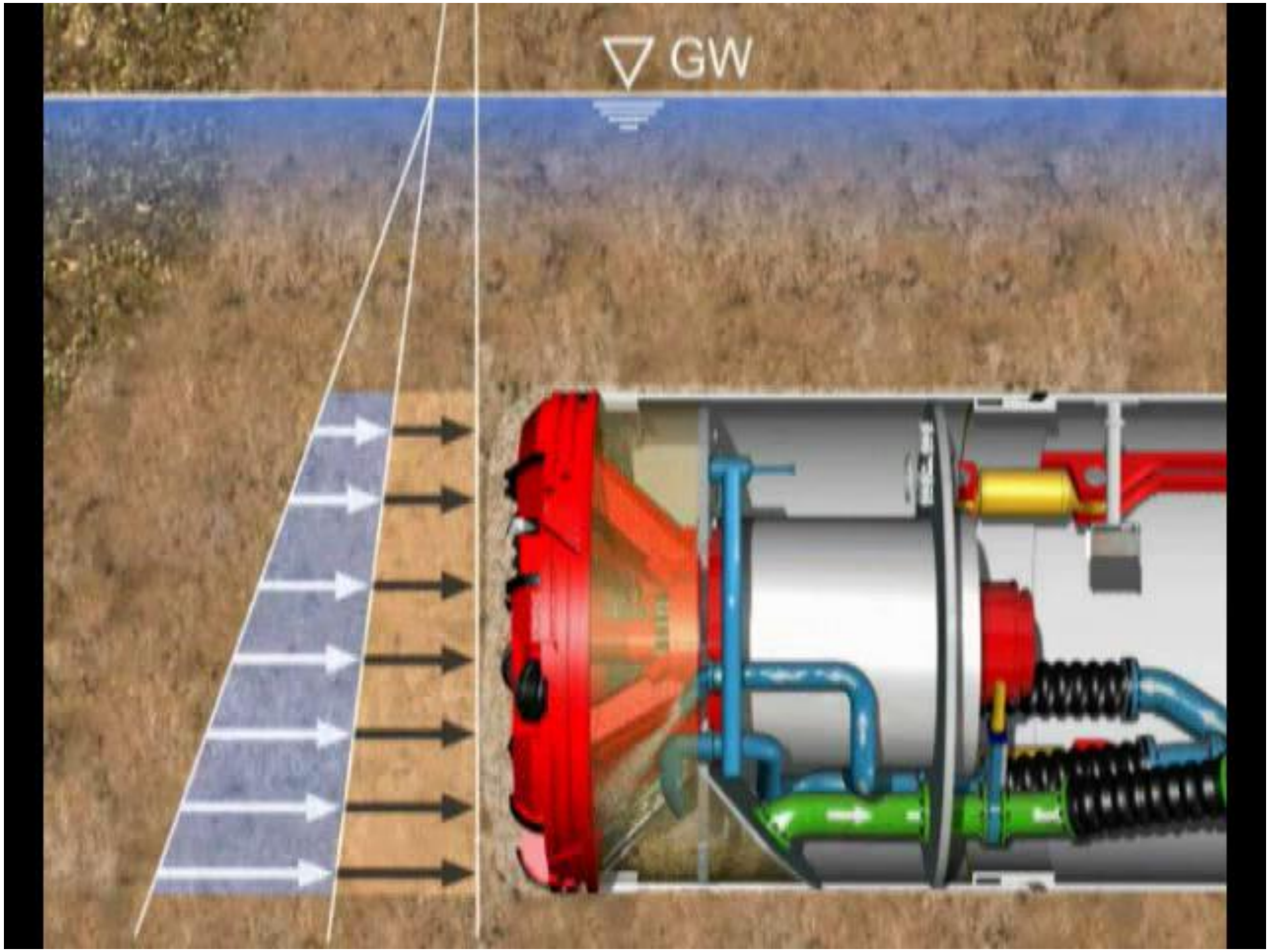
Earth Pressure Balance Microtunneling Machine
(used in homogeneous cohesive soils – clays and loams)

chamber with excavated and shredded soil

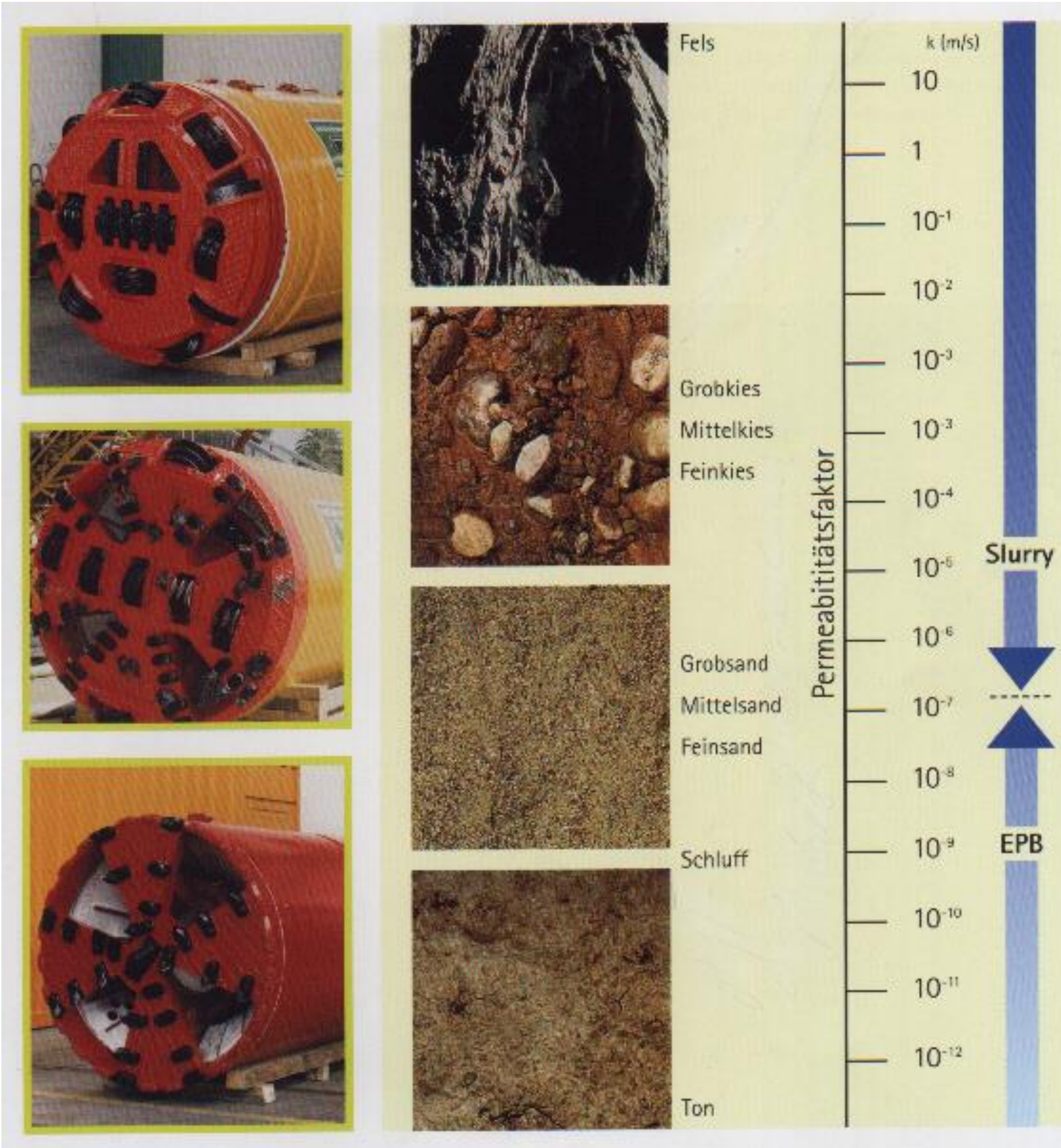


slurry shield as (rather) universal – for various ground conditions
with use of bentonite suspention for transport of excavated soil

stabilization of groundwater pressure with the use of an airbag at slurry shields



movies !



hard rock

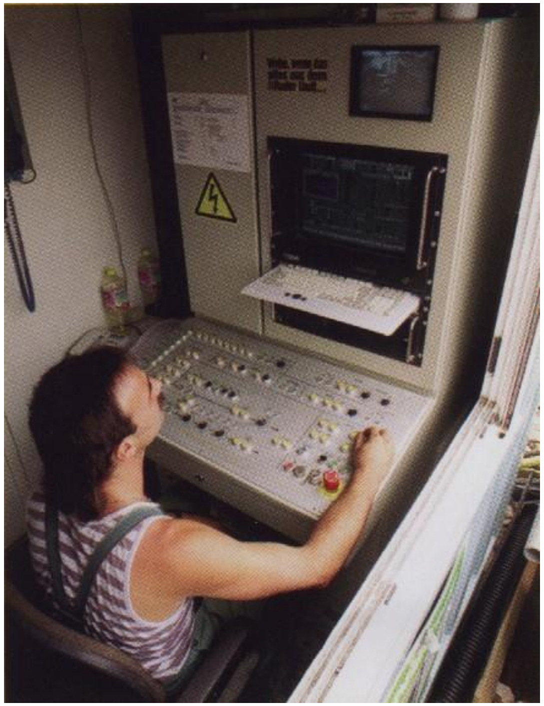
ground excavating disc adapted to different ground conditions with holes of various diameters and different cutting tools

sandy soil

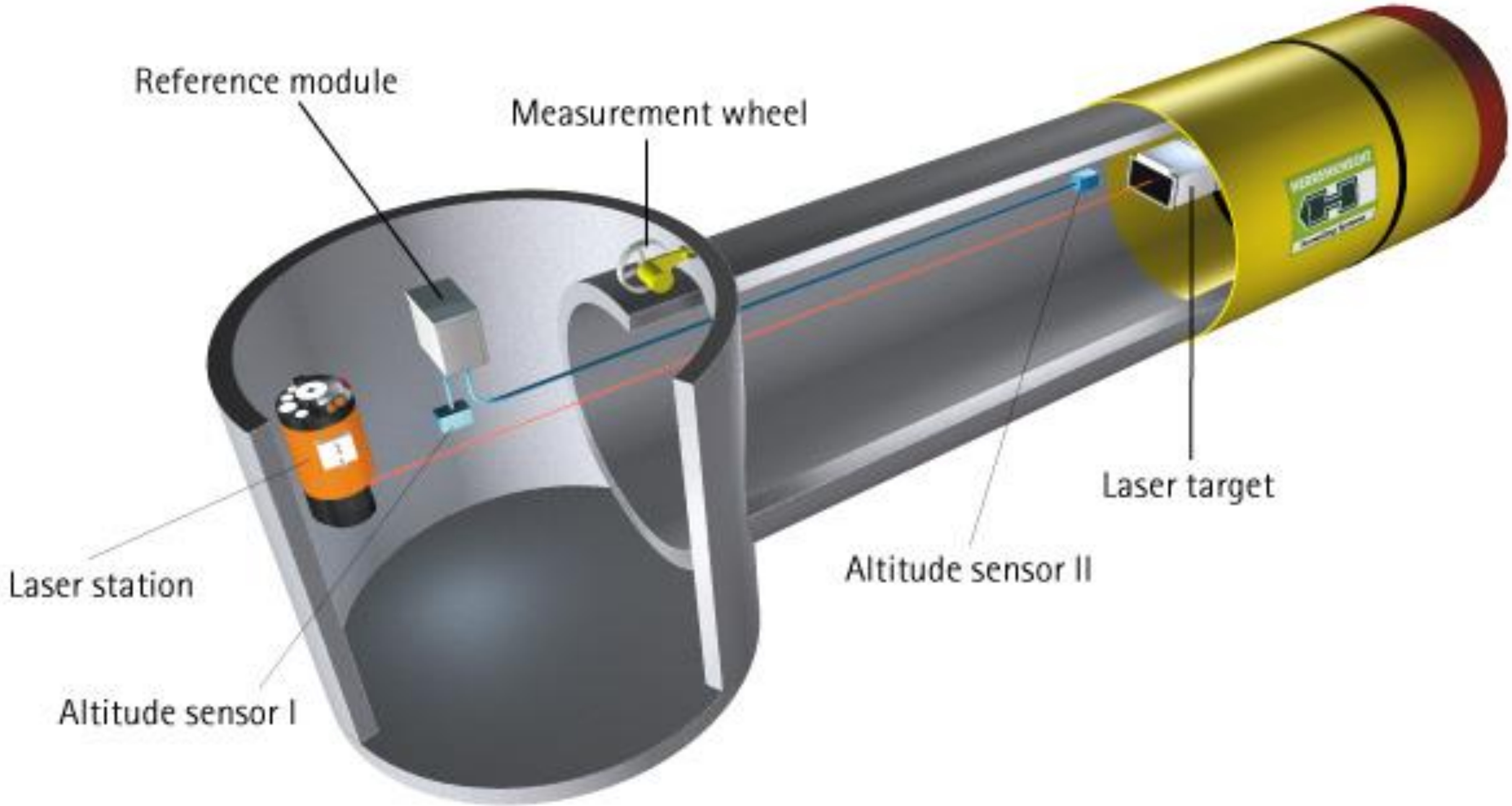
clay as application limit

control system for shield machine

console of first unit used in Poland – 1997, microtunelling in Toruń



ELS system with laser and hydrostatic leveling (HWL).

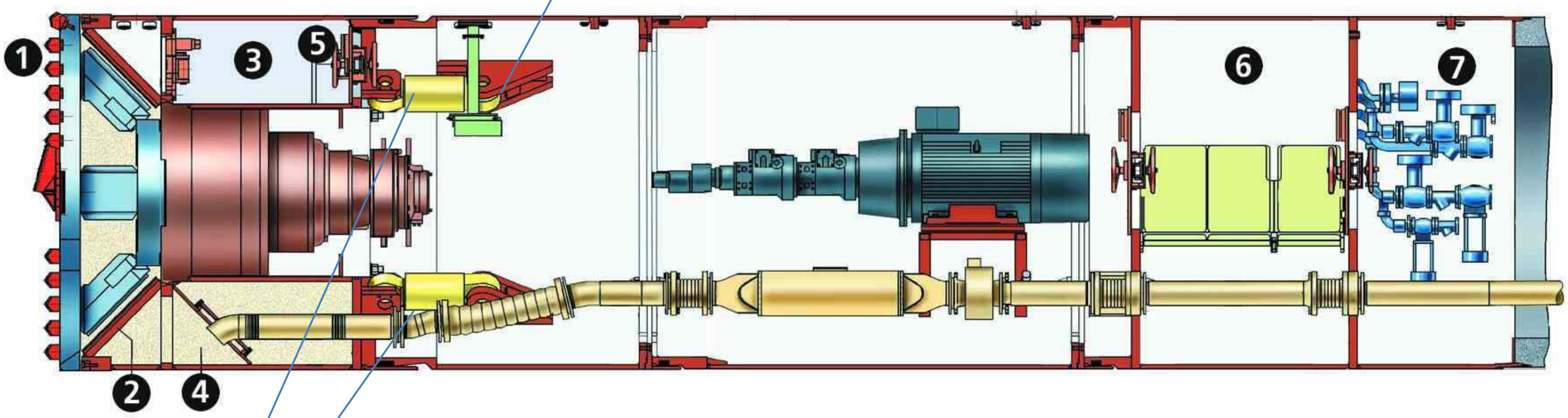


The laser beam allows to control the position of the drill head on an ongoing basis
It is possible to control the head -variations of 1.5-2 degrees per meter are obtained

dzięki uprzejmości firmy Herrenknecht

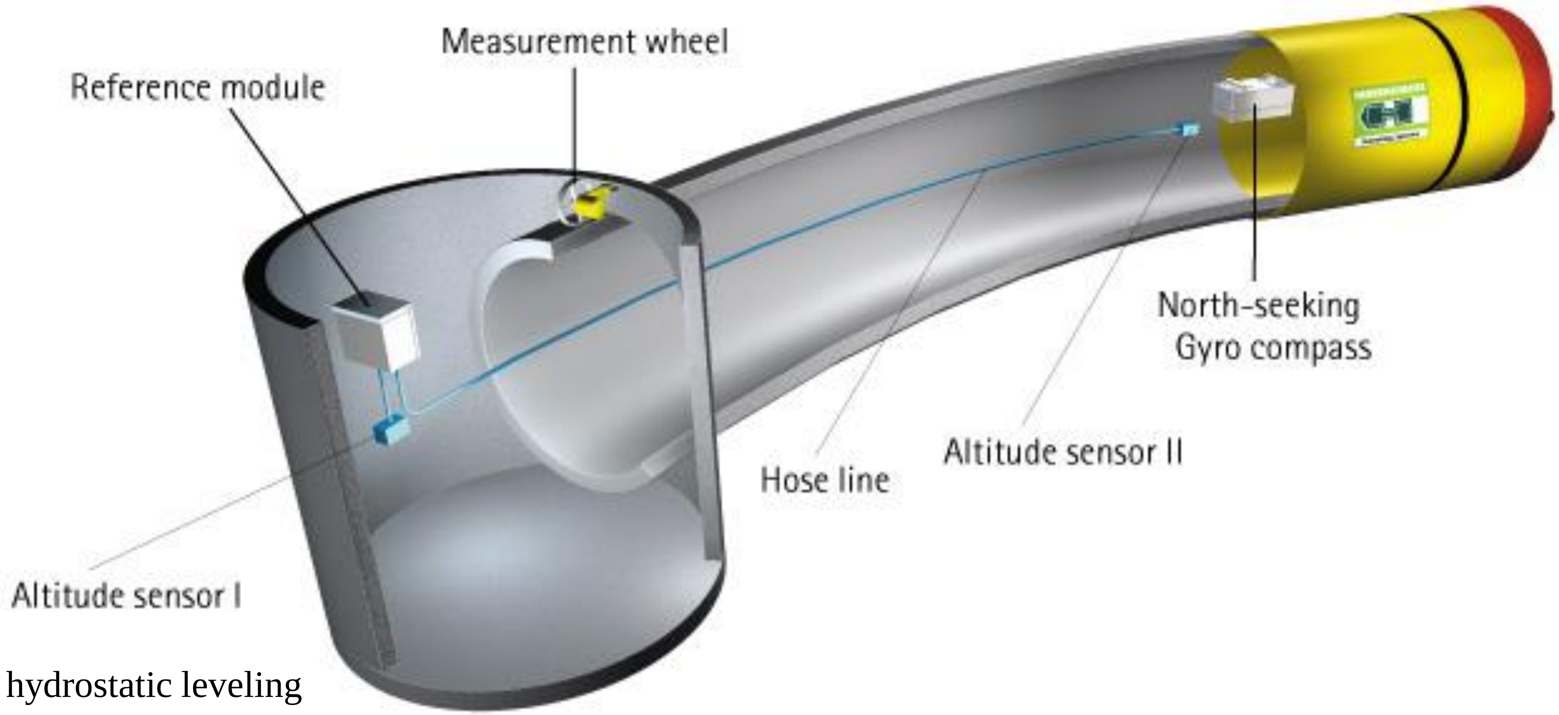
cross-section through a slurry shield

target (active or passive screen) on which falls laser beam



hydraulic cylinders for correcting the machine position - also for the implementation of curved jacking (min. 100 m with a special solution for pipe connections and control, usually with a radius of 350 m and more)

GNS-P curved route of pipeline

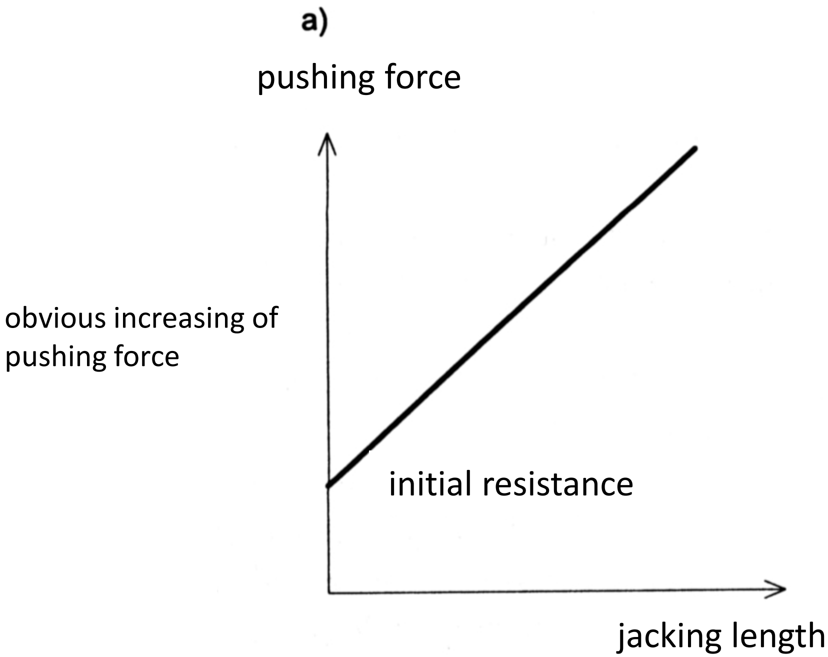


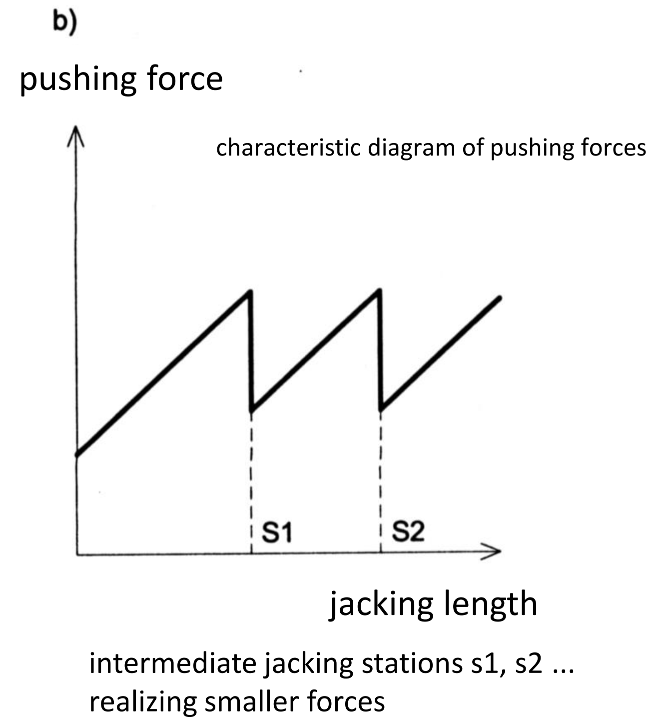
for hydrostatic leveling

- Without use of laser.
- Gyro compass guidance in the horizontal plane
- Pipe diameters DN > 800 mm.

dzięki uprzejmości firmy Herrenknecht

diagram pushing force – jacking length





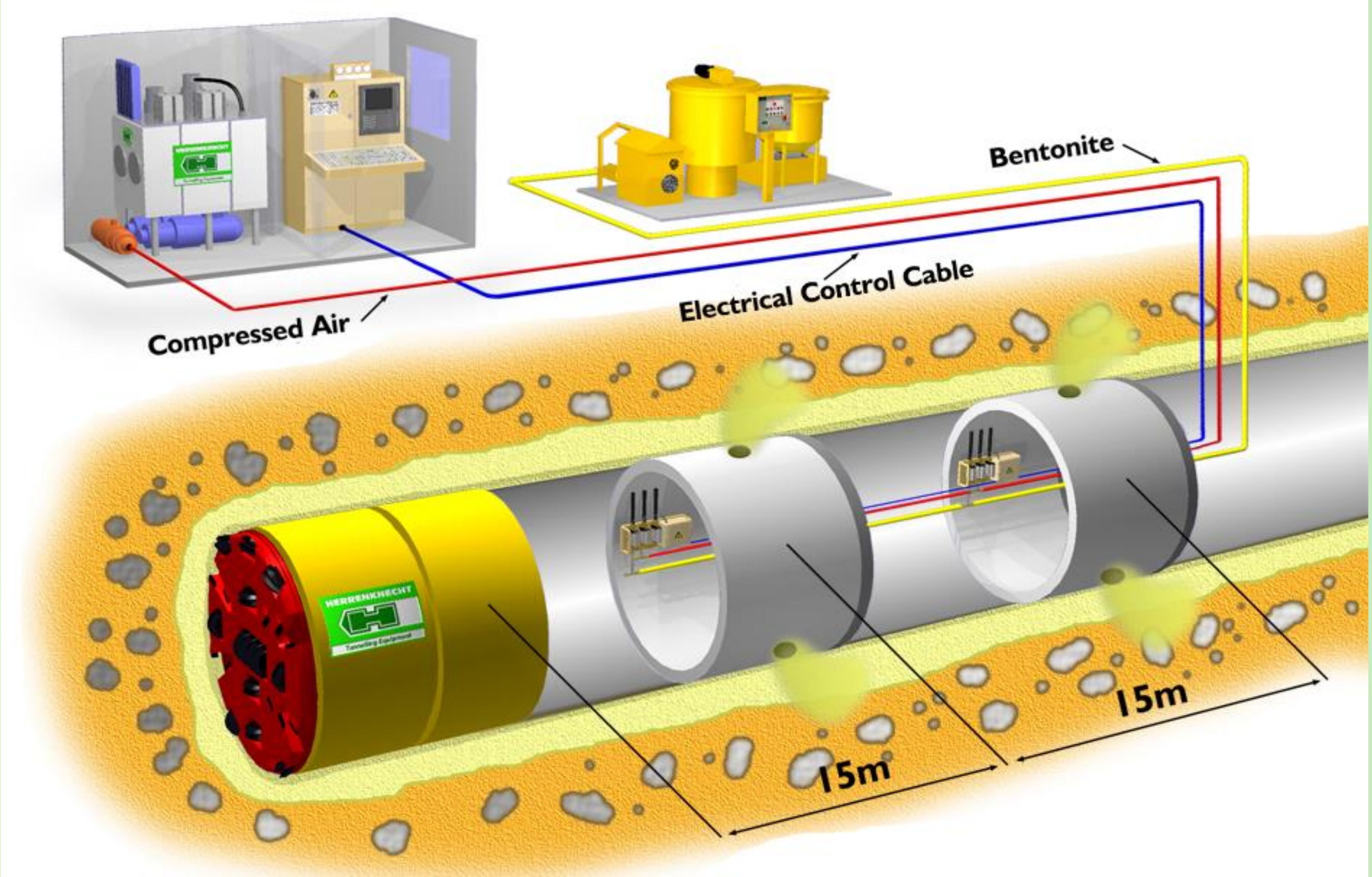
to make pushing force smaller (assumming certain length):

1. to reduce the friction resistance between the moving tunnel and the soil around the pipe, the overcut or annular space around the jacking pipe can be filled with bentonite or polymer suspension. This lubricant is pumped through hoses and injection ports in the tunnel via watertight openings through the pipe wall and into the annular space.

2. control of the direction (straightness) and continuity of the jacking as important principle for minimalizing of the pressing force

3. the solution for longer distances is the use of intermediate jacking stations

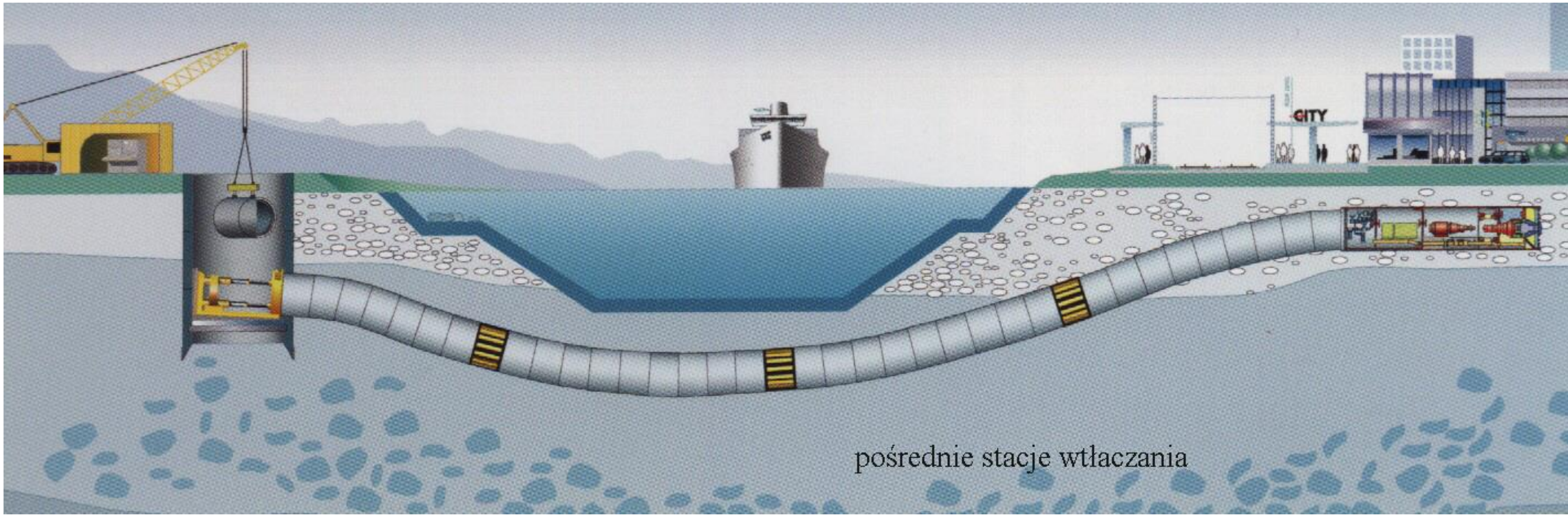
Automatic Lubrication System



lubrication at distance 3-5 pipes – ca. 9-15 m

air mixed with suspension is pressing it into annular gap

dzięki uprzejmości firmy Herrenknecht



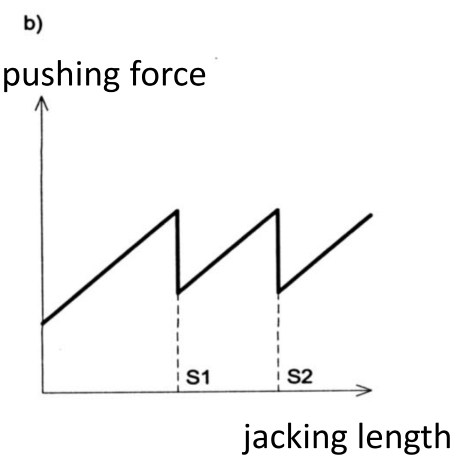
intermediate jacking stations

are activated one after the other, each pushing its own section (lenght) of pipeline

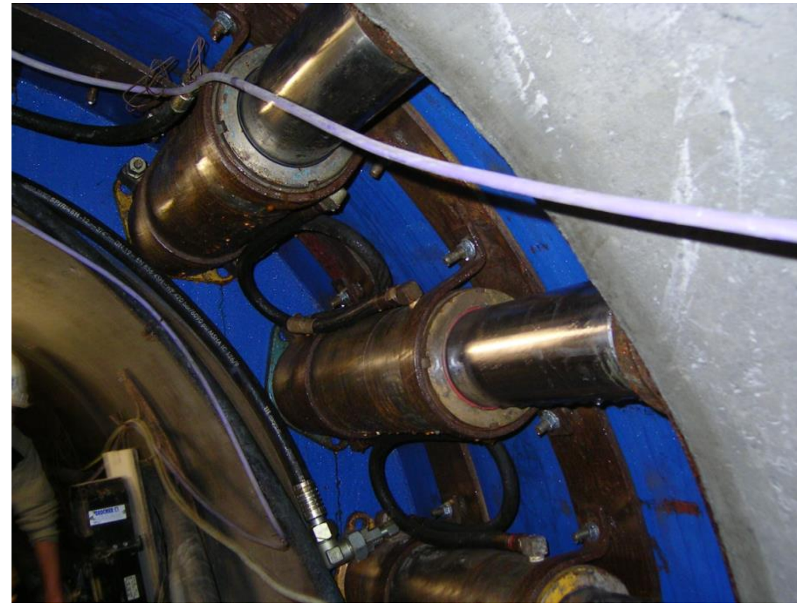
used in pipelines of length > **~ 130 m**

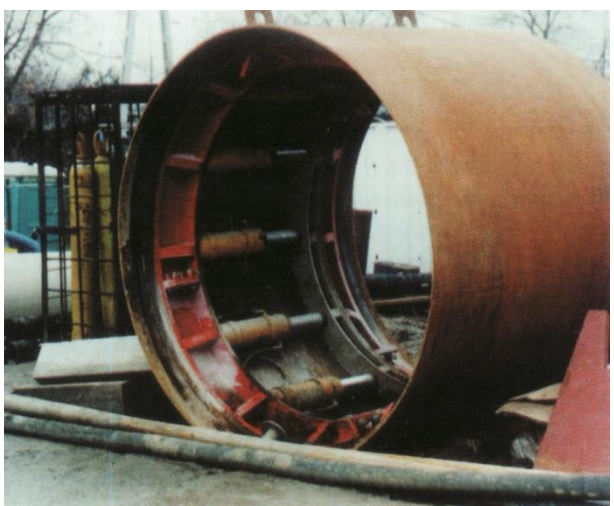
diameters > **800 mm**

stations placed in distances ca. **100 m**



generation of a certain jacking force by each intermediate station





steel pipe covering intermediate jacking station

the pipe behind the jacking station has a special design so that it fits in the steel casing and to be moved under it without losing tightness

The largest microtunnel in Poland:
Forwarding collector to the "Czajka" sewage treatment plant in Warsaw, 2011, DN 3000, record length of a single section of 930 m, (Collector Burakowski-BIS).

design issues to be solved when the use of pipe-jacking and microtunneling

Design calculations for the implementation of pipelines realised in pipe-jacking (microtunnelling) technology

designs of the starting and end- shafts

Calculation of the necessary jacking force

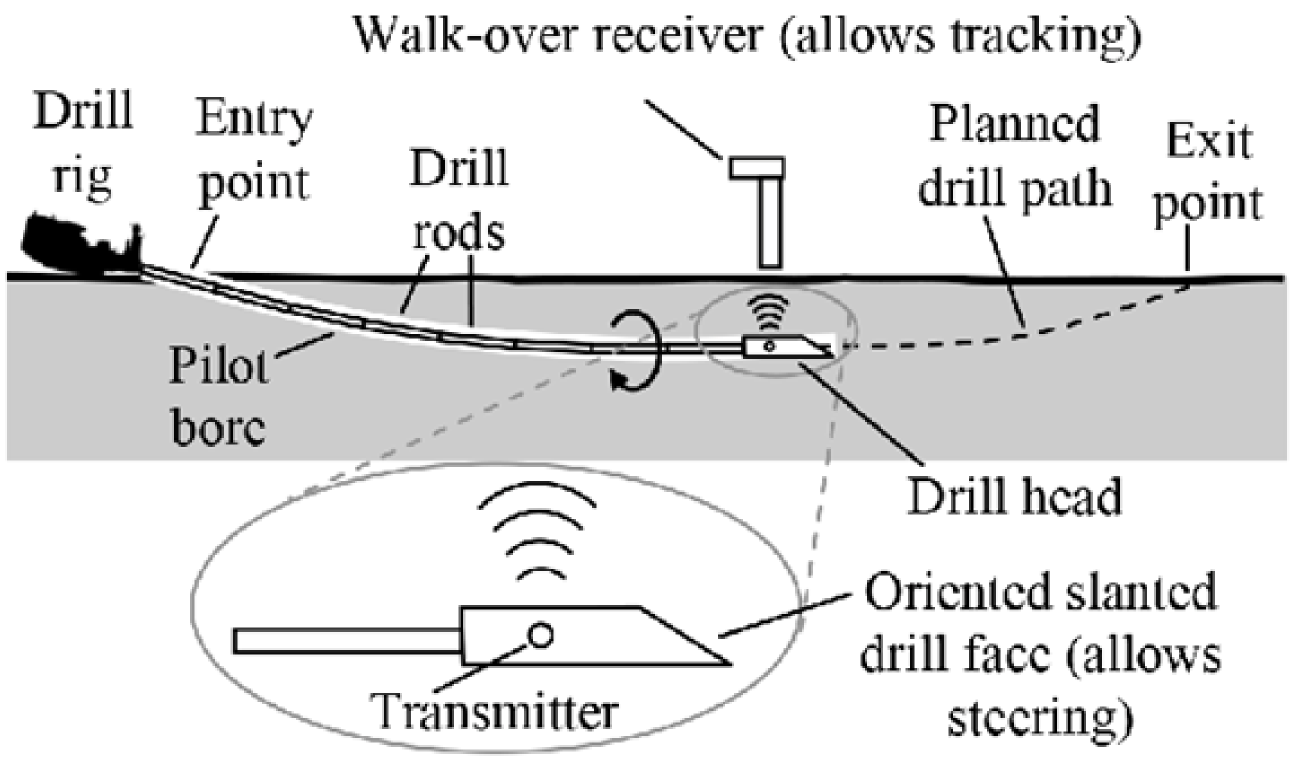
dimensioning of the structure inserted into the ground space (selection and checking the characteristics of pipes)

from this follows the equipment, but also equipment has influence on calculations

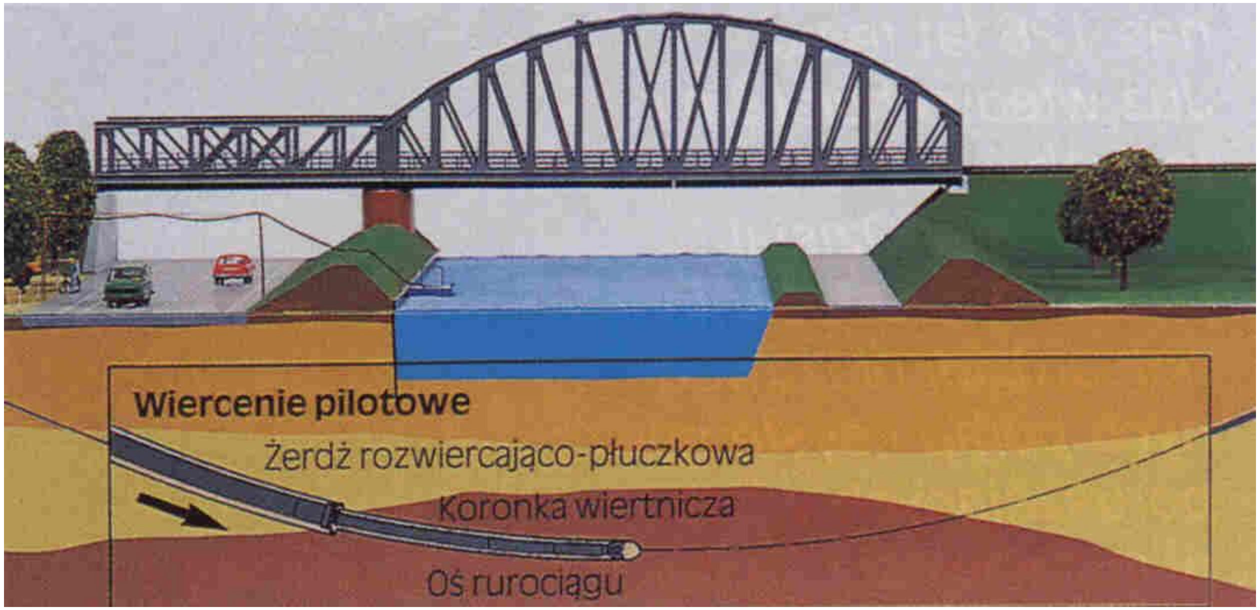
Solution of the set to perform the task (shields, jacking points, lubrication, transport of excavated material, etc.)

has big influence for calculation and designing

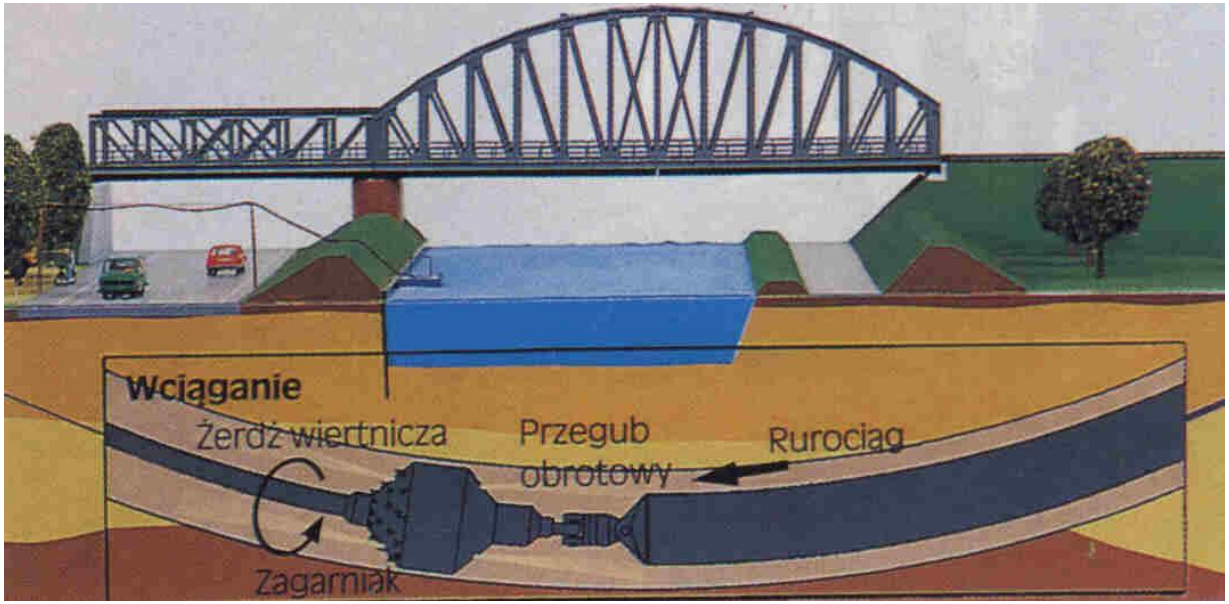
HDD – method – pulling into underground space of pipes with joints transferring tensile forces: welded pipes of steel and PE, ductile cast-iron with special types of socket joints

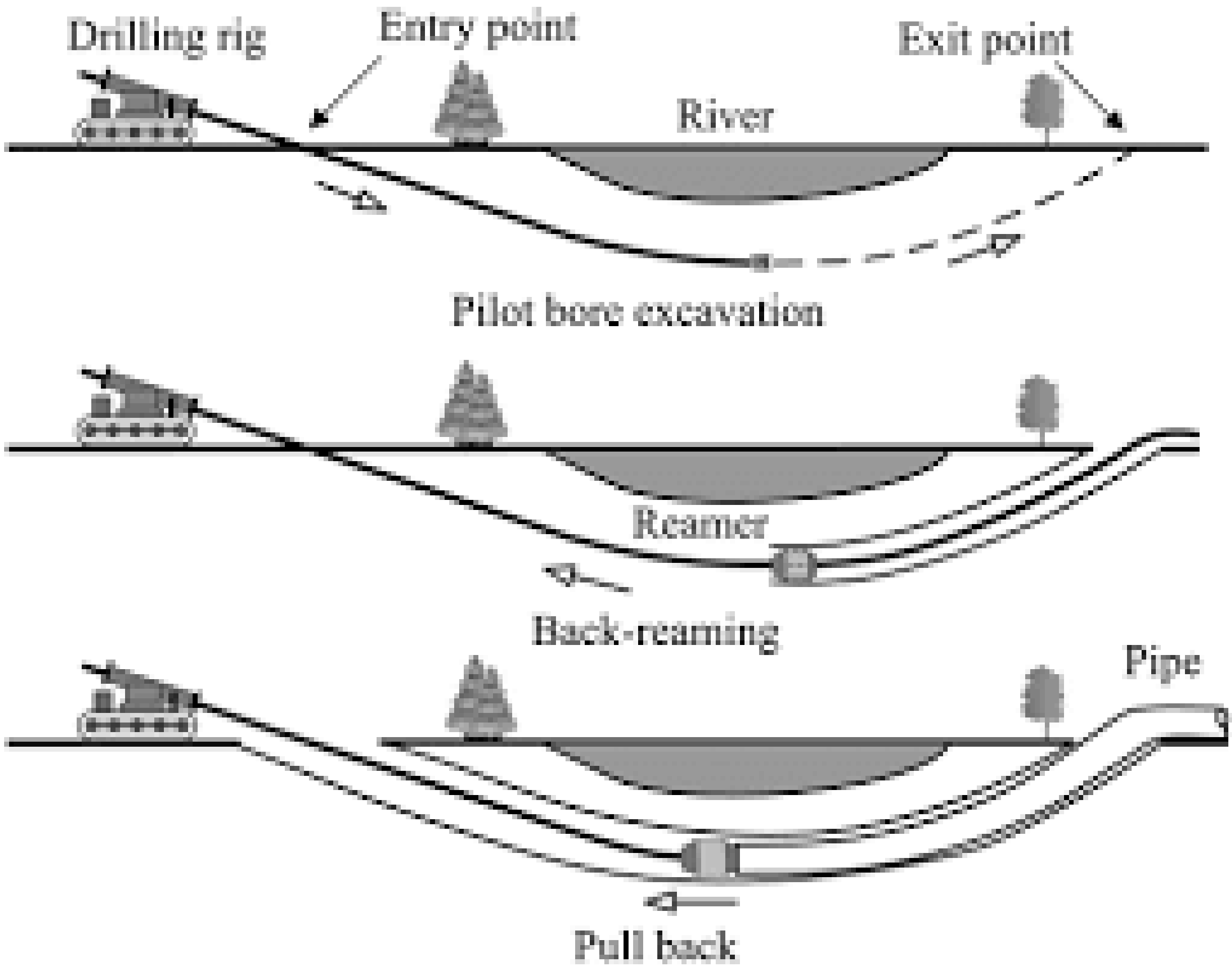


stage I - pilot drilling with a drill rod, for establishing the pipeline route

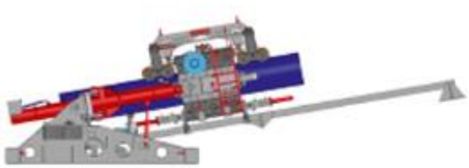


stage II - reaming the hole to the required dimensions and pulling the pipe in



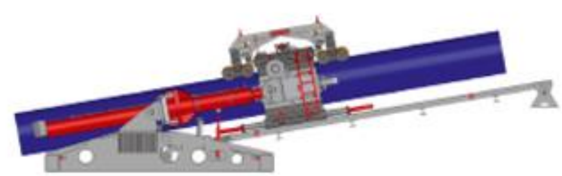


Step 2 - gradual widening (drilling) of the hole to the dimensions of the pipe pulled there finally

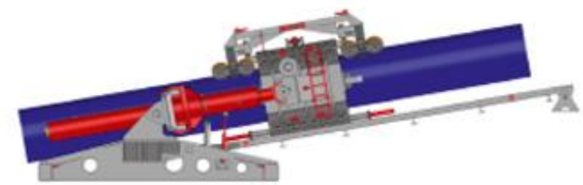


Pipeline diameter: up to 36"
Max. thrust and pull force: 300 t (3,000 kN)

914 mm



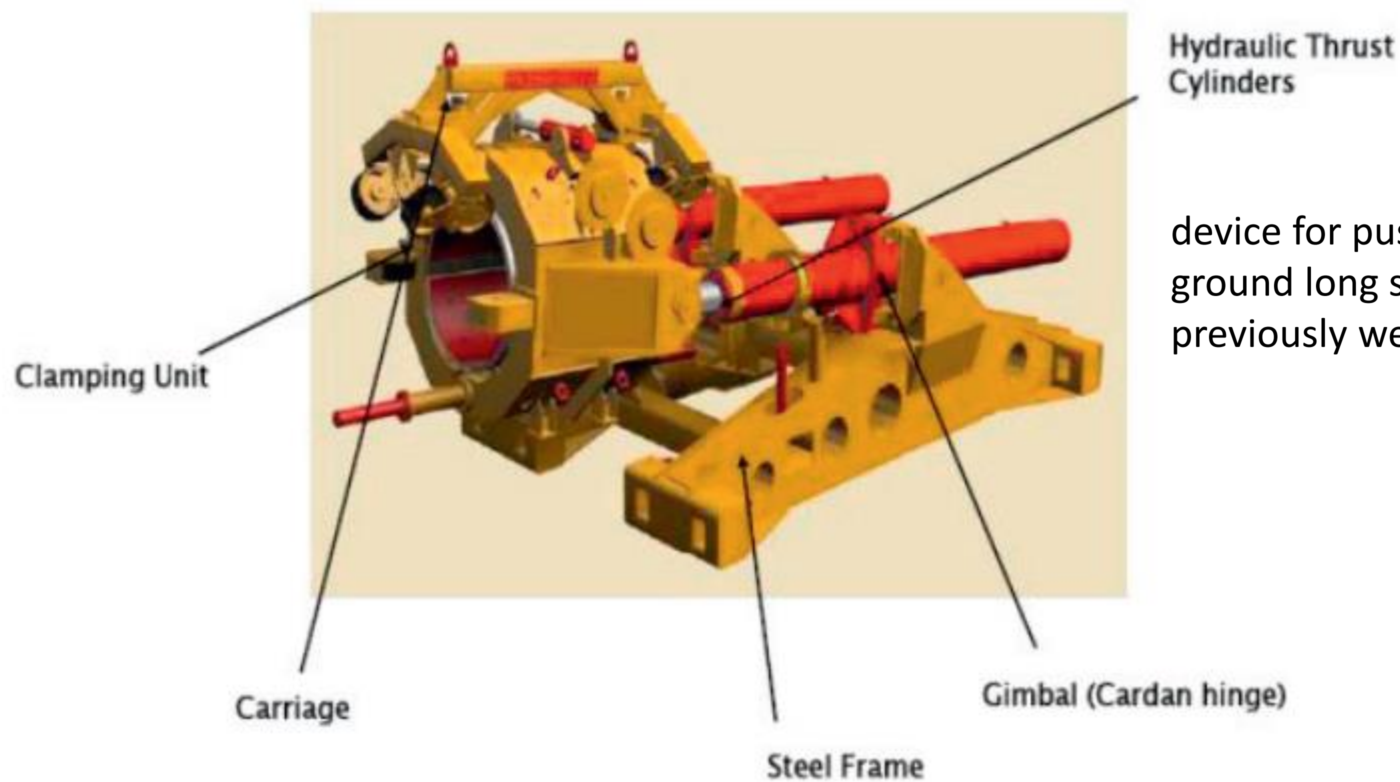
Pipeline diameter: up to 48"
Max. thrust and pull force: 500 t (5,000 kN)



HK750PT:
Pipeline diameter: up to 60"
Max. thrust and pull force: 750 t (7,500 kN)

1524 mm

pipe thruster



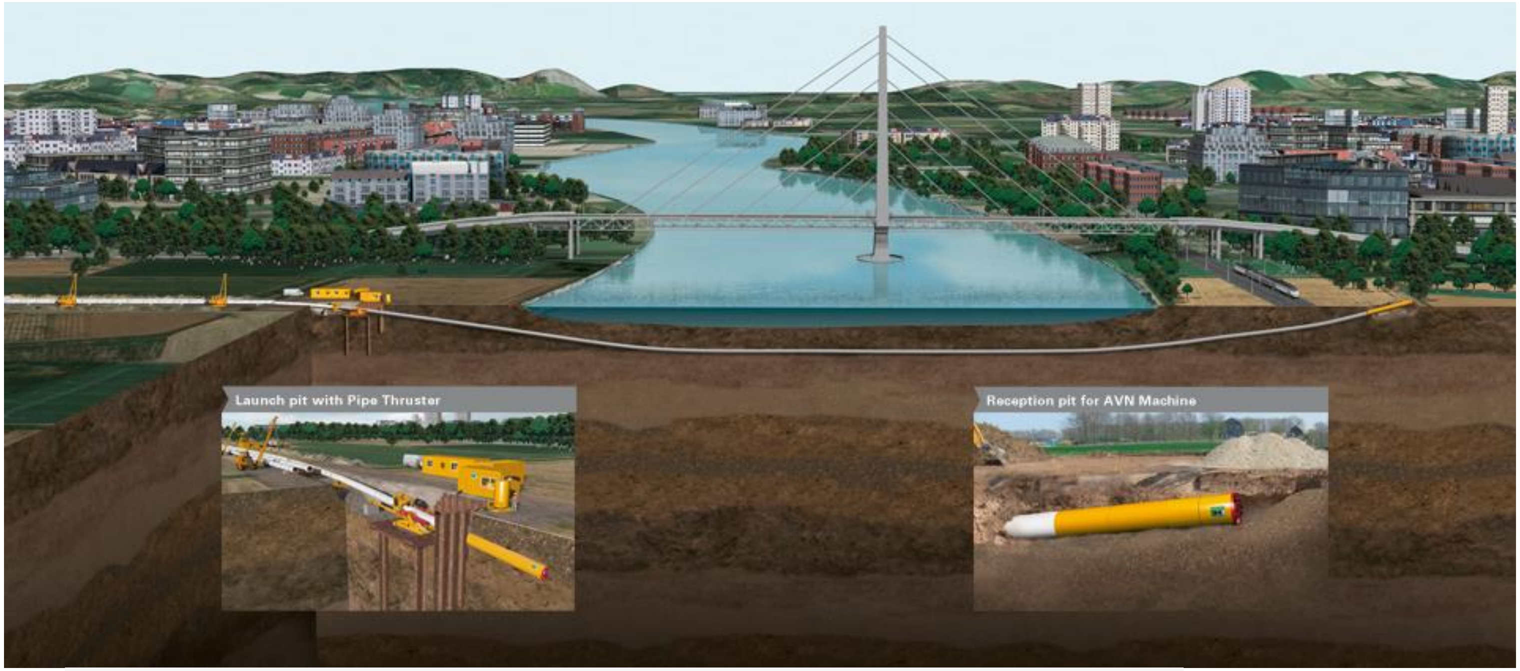
device for pushing into the ground long section of previously welded steel pipes

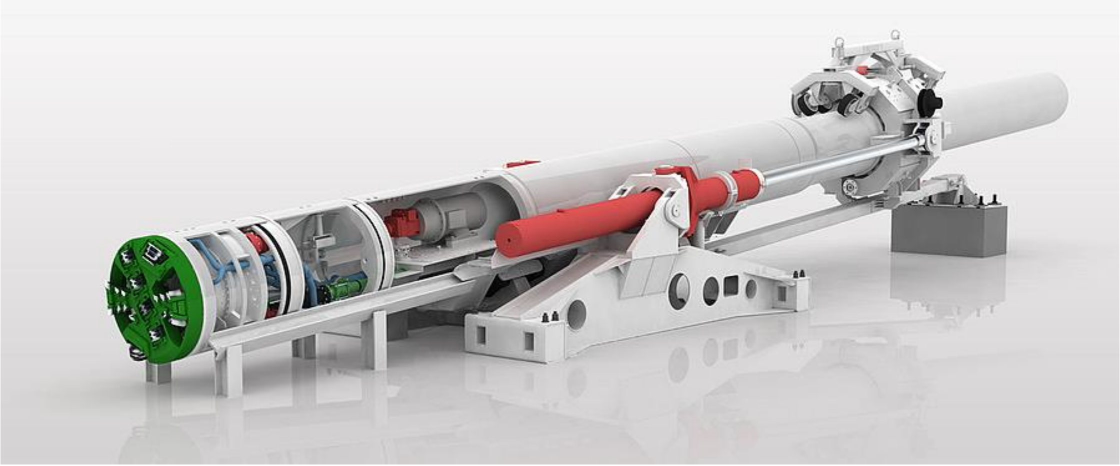
http://www.vshanabdrilling.com/en/equipment/pipe-thruster/pipe-thruster-500t

alternative solution from another manufacturer:
clamping unit in the form of caterpillars

http://www.vshanabdrilling.com/en/equipment/pipe-thruster/pipe-thruster-130t

Direct pipe method - an alternative between microtuneling and HDD using the "pipe thruster" device for crossing vast terrain obstacles





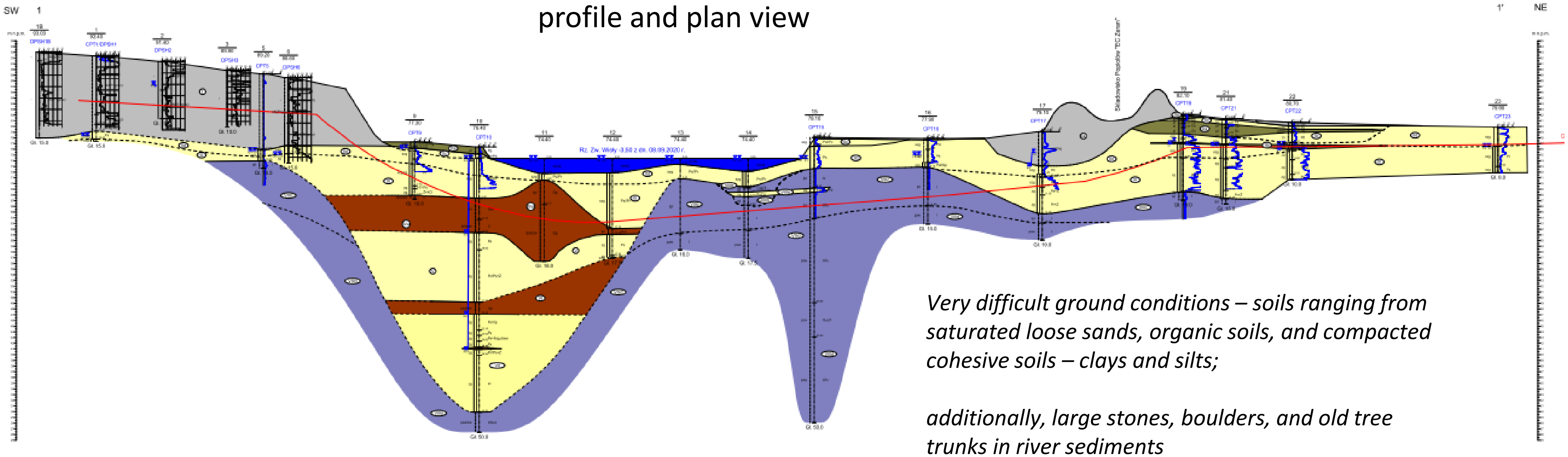
Materiały informacyjne firmy Herrenknecht A.G.

rebuilt microtunnelling machine and Pipe-Thruster

first implementation in Poland
Czeszów – Wierzchowice, gas pipeline, 8.4 MPa, DN 1000, wall thickness 22.2mm, august 2016

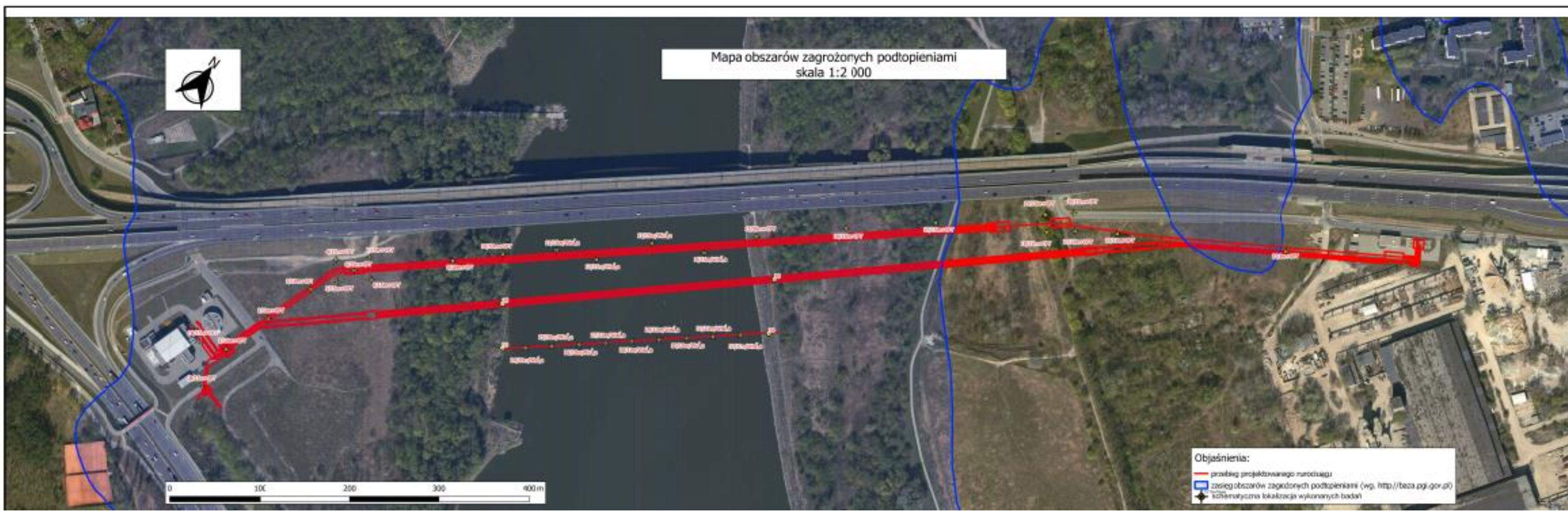
two pipelines for wastewater transported from the left side of the Vistula River to the right and further to the Czajka sewage treatment plant (2020 – 2021)

profile and plan view



Very difficult ground conditions – soils ranging from saturated loose sands, organic soils, and compacted cohesive soils – clays and silts;

additionally, large stones, boulders, and old tree trunks in river sediments



entrence shaft: Zakład Farysa, exit Zakład Świderska

this method made possible to go through various and difficult ground conditions

Important realisation in Warsow

Drilling works on the construction of the first line of the new siphon under the Vistula River began on 2 November 2020 from the starting chamber located at ul. Świderska and completed on December 6, at ul.Farysa. The drilling works lasted 34 days, covered a 792 m long section (until then the longest DP in Poland.

The new steel collector is 1.2 m in diameter, it was laid at a depth of 7 to 8 m under the river bed. The maximum daily drilling progress was 8 11 m, over 1000 m3 of excavated material was excavated. The sewage transmission capacity of the pipeline constructed in this way is comparable with the previously arranged two pipelines on the pontoon bridge. Ultimately, a second, adjacent collector will also be built under the Vistula, and it should be commissioned in June 2021.(za https://inzynieria.com/inzbezwykopowa/wiadomosc/).

The pipeline was divided into 4 sections of 200 m each (entered once each).Pipeline diameter 1,219 mm (steel) + insulation 3LPP 4.2 mm + GRP 5 mm = 1,237.4 mm.

The geological conditions at the site of implementation are very difficult due to the variability - the presence of sands and swelling clays, and the possibility of encountering erratic boulders. At the end of the works, the contractor (PPI CHROBOK, INŻYNIERIA RZESZÓW S.A.) encountered clusters of boulders that were partially excavated by the shield and pushed onto the surface of the site.

Regardless of the route, old tree trunks were encountered, which are very difficult to drill for other trenchless technologies, and with the use of microtunnelling heads, they pose a risk of jamming. The contractors found a very heavy wear of the cutting disk (cutting the soil) - the implementation was a great achievement for contractors and designers.

On May 31, 2021, at the target point on the left bank of Warsaw, the drilling of the second line of the alternative sewage transfer system under the bottom of the Vistula River was completed.

construction site


CHROBOK
INŻYNIERIA
PPI CHROBOK
PPI CHROBOK


PPI CHROBOK
CHROBOK
CHROBOK

heavily worn ground-excavating disc

glacial boulders pushed into the final chamber and partially worn away by the cutting head

obstacles in underground

cut chips of tree trunks lying in river sediments – as an obstacle overcomed by head of microtunneling machine.

The technology was developed and patented by Herrenknecht A.G. - manufacturer of machinery for the construction of communication tunnels and pipelines.

Currently, it allows the laying of steel pipelines with diameters from 762 mm to 1524 mm (from 30 to 60 inches), which is due to the available hardware solutions.

The technology was used for the first time in 2007. In Germany, a steel pipeline with a diameter of 1220 mm was laid in Worms under the Rhine, at a length of 464 m. It was a casing pipe for the water supply, telecommunications and power cables. The tunnel is laid at a very shallow depth of 5 m under the bottom of the river bed and 3 m under the area between flood embankments.

Most of the projects were carried out in the United States and Canada (several dozen), then in Europe.

In Poland 19 drillings were made - mostly for the gas transmission system. (2021)
First implementation in Poland - Wierzchowice gas pipeline, 8.4 MPa, DN 1000, wall thickness 22.2 mm, august 2016.
The longest drilling was the crossing under the Vistula River at a distance of 793 m, with the steel pipeline DN 1200 (12.2020)

A total number of 155 crossings were made worldwide (as of September 2020), the longest of which was 2021 m long ??? How they did it???
(New Zealand, Snells Algies Outfall Pipeline project, outlet pipe for a sewage treatment plant, 1220 mm, July 2020, was the second of the record-breaking implementations carried out by McConnell Dowell).

The Direct Pipe machine AVN1000XC for laying a 48”-pipeline

PIPELINE DIAMETER RANGE*

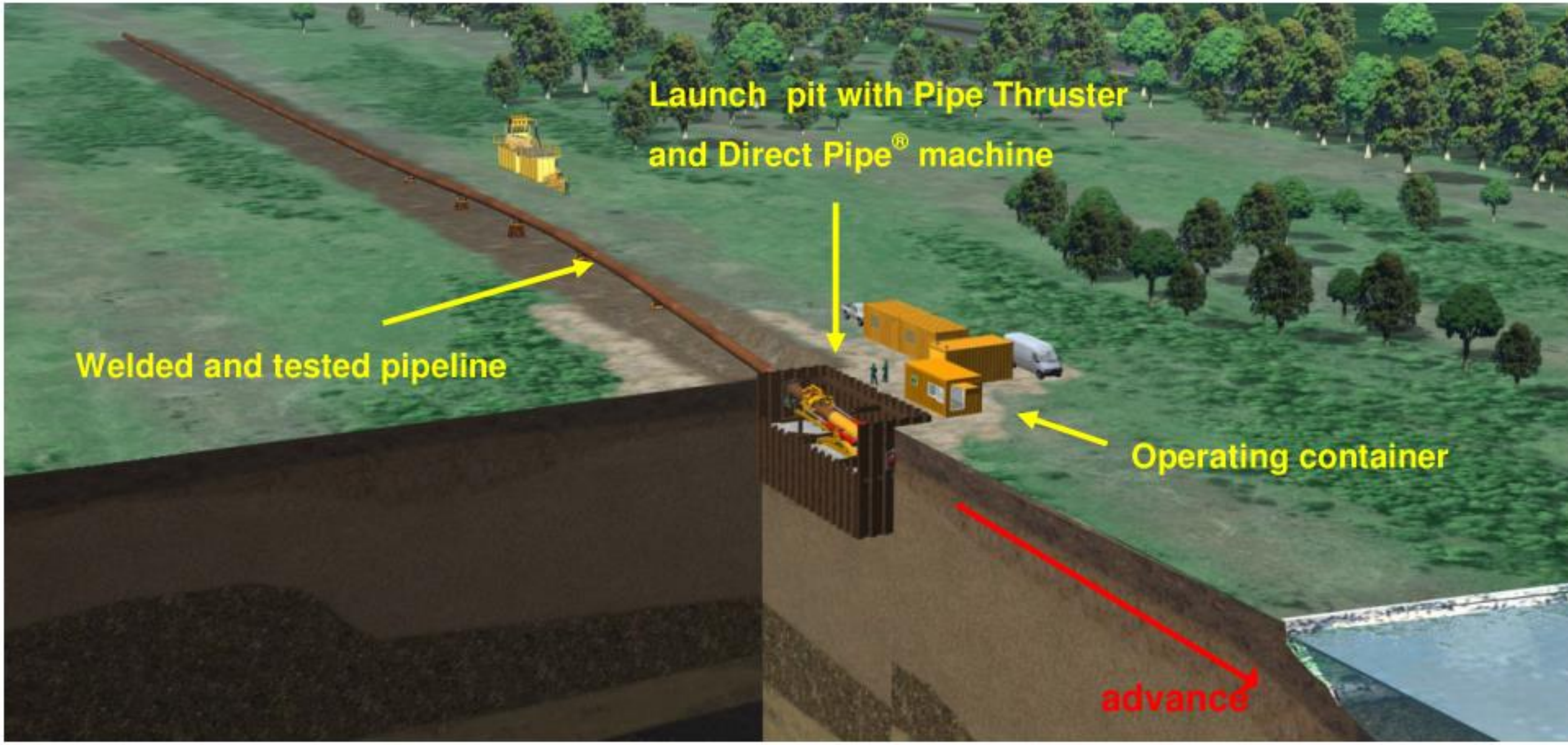
Pipeline diameter (outer Ø)	30" - 32" (762 - 813mm)	34" - 36" (864 - 914mm)	38" - 42" (966 - 1,067mm)	44" - 52" (1,118 - 1,321mm)	54" - 60" (1,372 - 1,524mm)
Direct Pipe® Machine	AVN600XC/ AVN700XC	AVN800XC (B)	AVN800XB (A)	AVN1000XB	AVN1200TB
Torque of machine	33/40kNm	55kNm	90kNm	150kNm	258kNm
Excavation diameter of machine	805/890mm	990mm	1,140mm	1,325mm	1,540mm
Maximum pipeline/drilling length	300m	300m	800m	1,400m	1,500m
Minimum overburden	2 - 3x outer diameter of Direct Pipe® Machine				
Maximum water pressure	≤ 3 bar = Standard; 3 - 4 bar = Modified standard; ≥ 4 bar = Special design				
Geology	Clay, silt, sand, gravel, cobbles, boulders, rock (up to 150MPa = 21.750psi)				
Pipe material	Steel				
Coating material	e.g. PE, PP, GRP**, FBE***, Concrete				

* Values noted are typical and can vary from project to project.
** Glass Fiber Reinforced Plastic
*** Fusion Bonded Epoxy

DP vs HDD – comments

- Traditional slurry transport of the excavated material (AVN - slurry shield), traditional support with bentonite suspension of a shield face;
- The slurry pipes, power and data cables, lubricant hoses are generally assembled in a welded pipeline for the entire length of the passage (staggered possible);
- The bigger length of the microtunneling machine is due to the need to ensure better steering (two active joints);
- Cutting tool adapted to ground conditions (as in traditional microtunnelling) - the ability to crush individual boulders;
- Pipe Thruster construction allows for retracting the head and pulling out the pipeline;
- Transport of the excavated material inside the pipeline gives the possibility of implementation at smaller depths compared to the HDD (in HDD pressure of the slurry transporting the excavated material with danger of piercing the ground);
- Possibility to pass through zones of unstable soils containing stone or gravel admixture - difficult to stabilize with the use of a slurry filling the reamed space in a traditional HDD;
- The gyro-compass control system with a water level shows a significant improvement in drilling precision compared to HDD (information from the creators of the system, not necessarily certain);
- On the exit side, there is no need to prepare the site for the assembly of the pipeline (only space for disassembly of the head is needed);
- The range of installed pipelines from 700 mm;
- Installation length reduction compared to HDD (up to 1.5 km);
- Long period of work preparation and higher technology costs (in relation to HDD), only steel pipes not as in HDD with its various range of solutions.


2



Cross section of a river crossing using the Direct Pipe method

Michael Lubberger: EXTENDING THE ACHIEVEMENT PORTFOLIO OF HDD RIGS, International No-Dig 2011 29th International Conference and Exhibition, Berlin, 2-5 May 2011

Economic efficiency analyzes of trenchless technologies

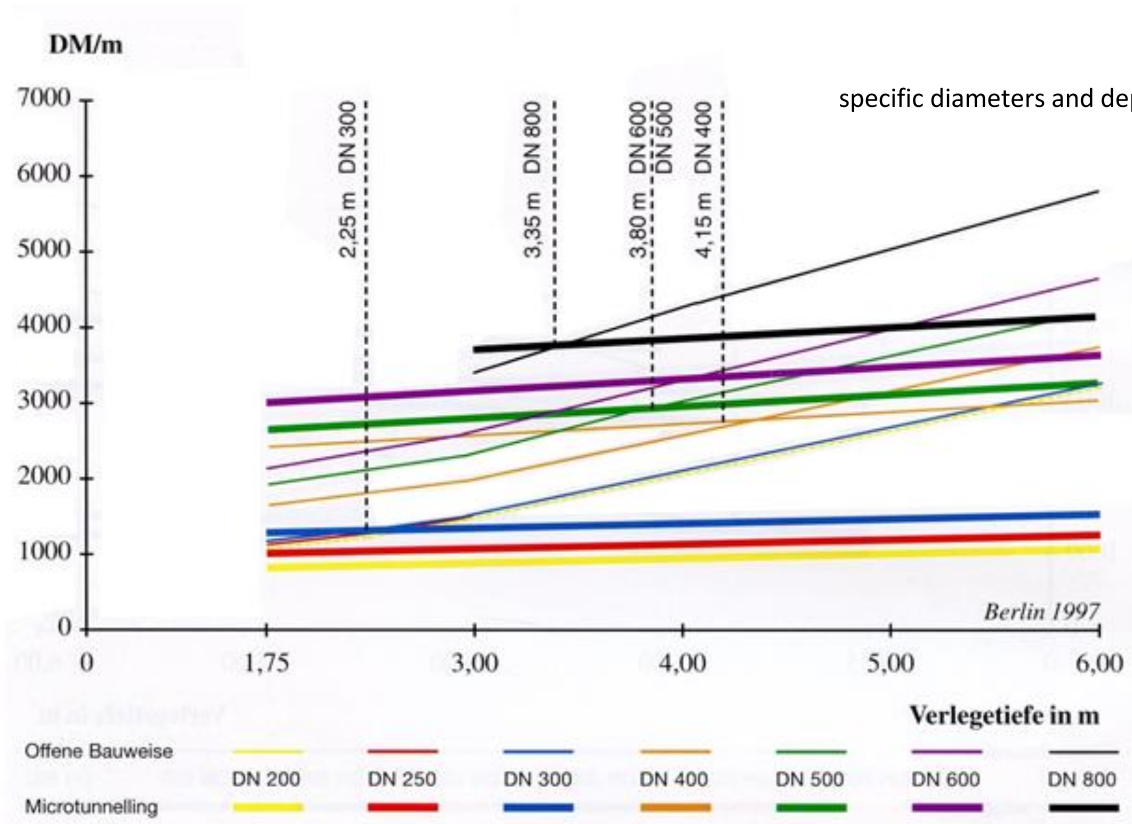
result taking into account direct and indirect costs

Since the beginning of the use of trenchless methods, more or less detailed cost analyzes have been made as regards the profitability of using the method compared to the implementation in an open trench.

Not only direct costs of implementation were taken into account, but also indirect costs (environmental and social) related to noise, air pollution, difficult accessibility to service facilities (shops, restaurants, etc.).

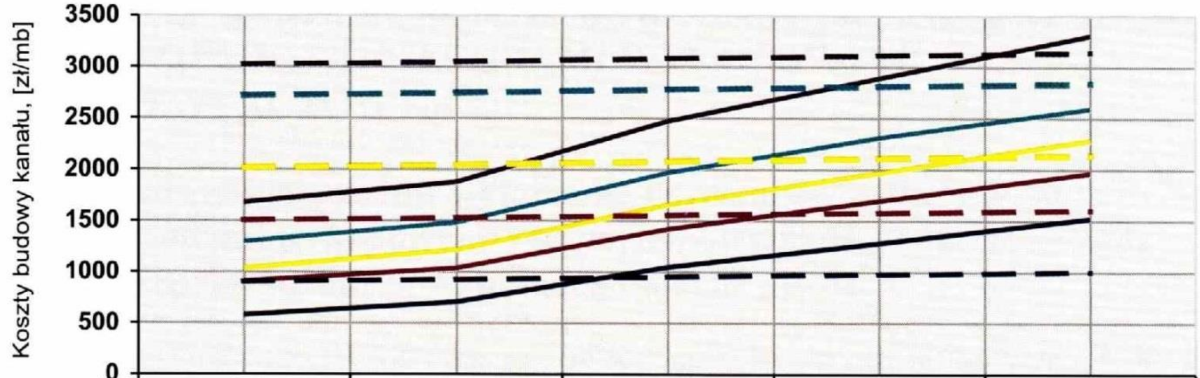
The limit depth of laying the sewer, above which it is profitable to use microtunnelling in the case of bituminous pavements

specific diameters and depth of stoneware pipes installation



Moehring K., *Wirtschaftliche und umweltgerechte Herstellung von Abwasserkanalen und –Leitungen durch Microtunnelbau*, Steinzeug GmbH

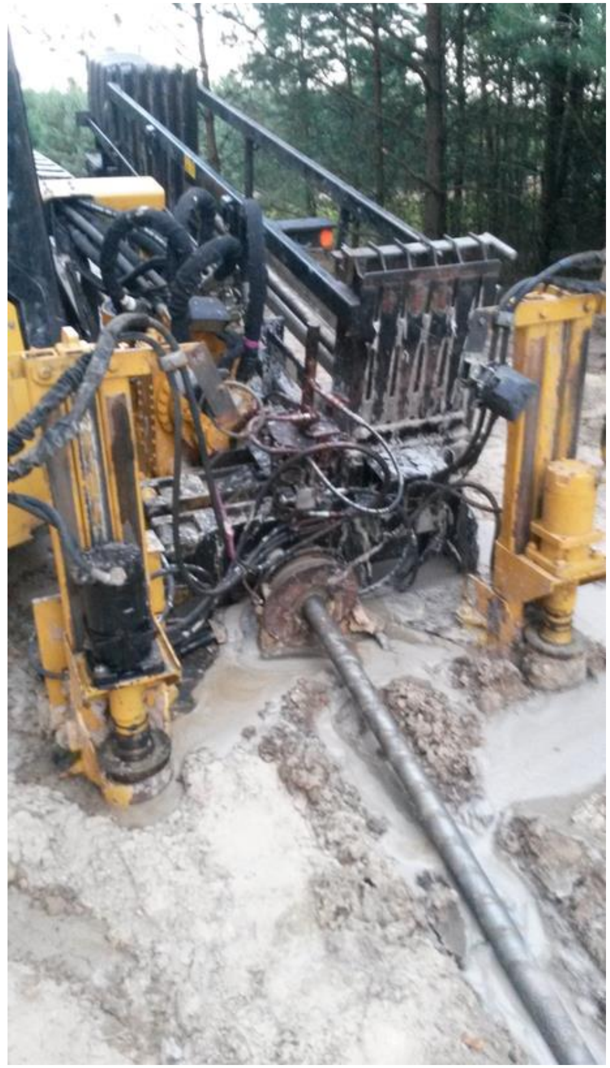
Model AZ -02 (A. Zwierzchowska, Kielce University of Technology, 2003 r.)
one of examples given for solution with direct costs



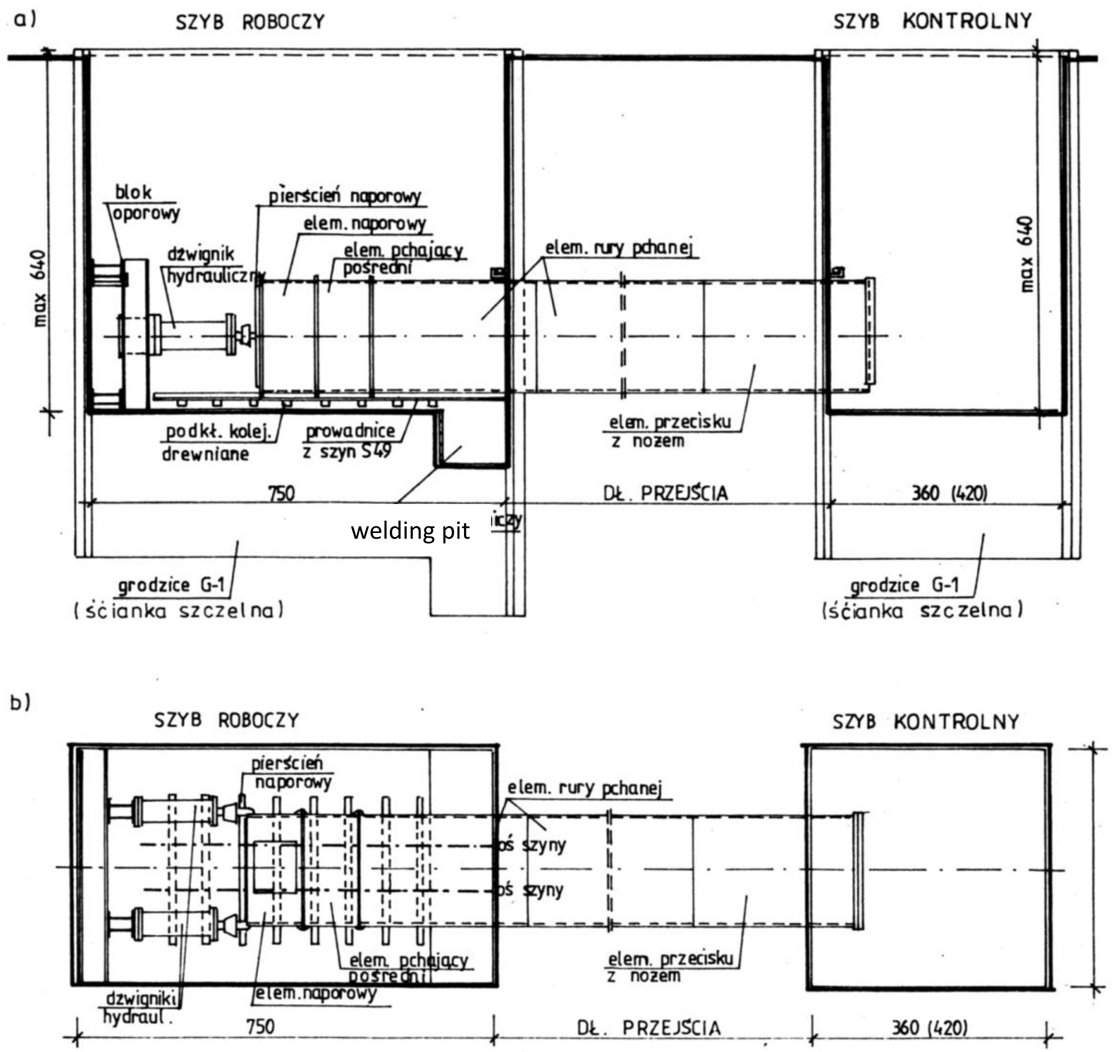
	2 m	3 m	4 m	5 m	6 m
DN 200	570,21	698,1	1038,9	1279,2	1519,5
DN 300	900,81	1028,7	1414,5	1686,5	1958,5
DN 400	1029,07	1210,6	1654,8	1967,2	2279,5
DN 500	1285,52	1476,7	1964,6	2307,3	2587,6
DN 600	1668,67	1869,5	2465	2881,1	3297,2
DN 200 B	893,14	918,69	946,73	972,89	995,58
DN 300 B	1493,14	1518,68	1546,73	1572,89	1595,58
DN 400 B	2009,53	2040,25	2074,11	2105,6	2133,62
DN 500 B	2709,53	2740,25	2774,11	2805,6	2833,62
DN 600 B	3009,53	3040,25	3074,11	3105,6	3133,62

Koszty budowy kanału w zależności od głębokości ułożenia
oraz jego średnicy, [zł/mb]

comparison of the costs of making sewage pipes laid under the ground surface for the Open Trench (solid line) and Trenchless method (the dotted line), depending on depth of pipe laying and its diameter – analises made for various types of road surfaces companies are currently cutting costs and carrying out work in situations inconsistent with the results of previous analyses



simple ground conditions, low depth, no additional restrictions with decision for using of HDD in laying of pressure sewage pipe,
(OT method should be more benefitial according to previous analyses)
(at the same location was laid water supplay pipe in open trench).



Przejście rurociągu pod przeszkodą: a) przekrój pionowy, b) rzut poziomy (wymiary w centymetrach)

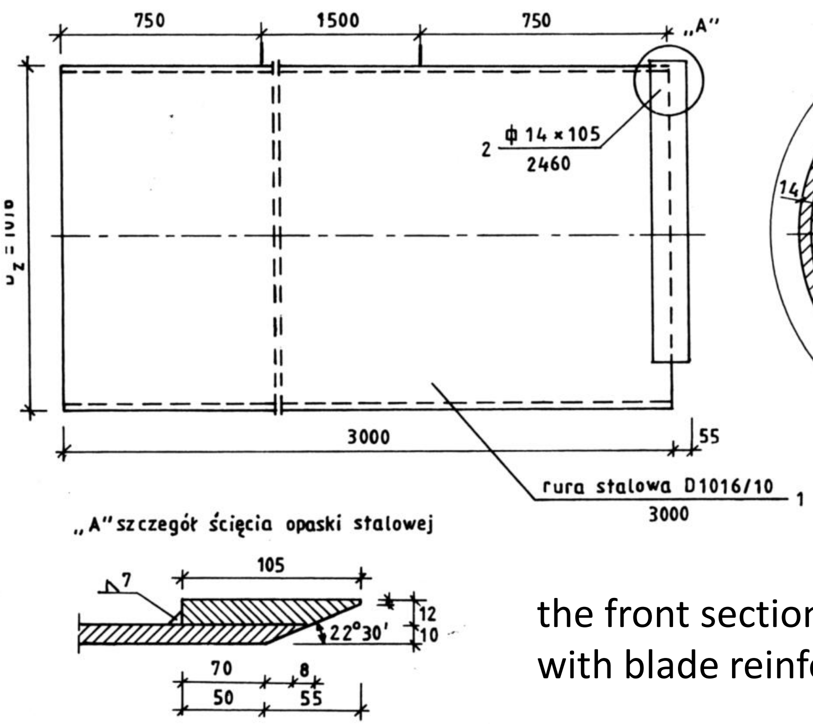
longitudinal section
and
plan view for welded
steel pipe

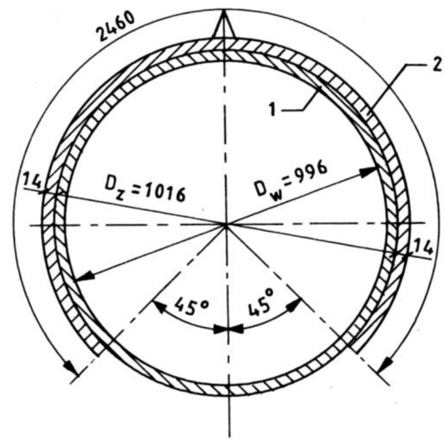
from the internal guidelines of the company carrying out work in the 1970s.

the width of the shafts

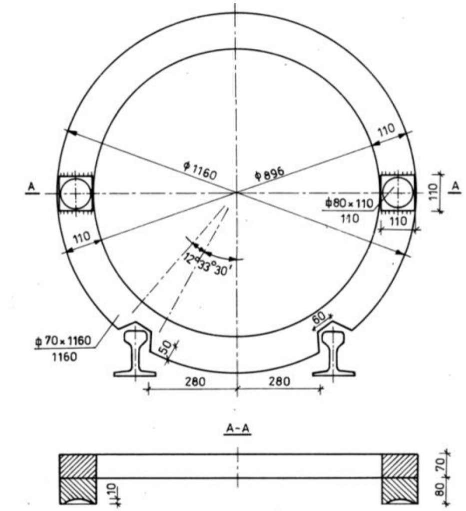
szerokości szybów:
360 dla rur 500-1400
420 dla rur 1600, 1800, 2000

Kalisz H.: Wybrane zagadnienia budownictwa komunalnego, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa, 1994;



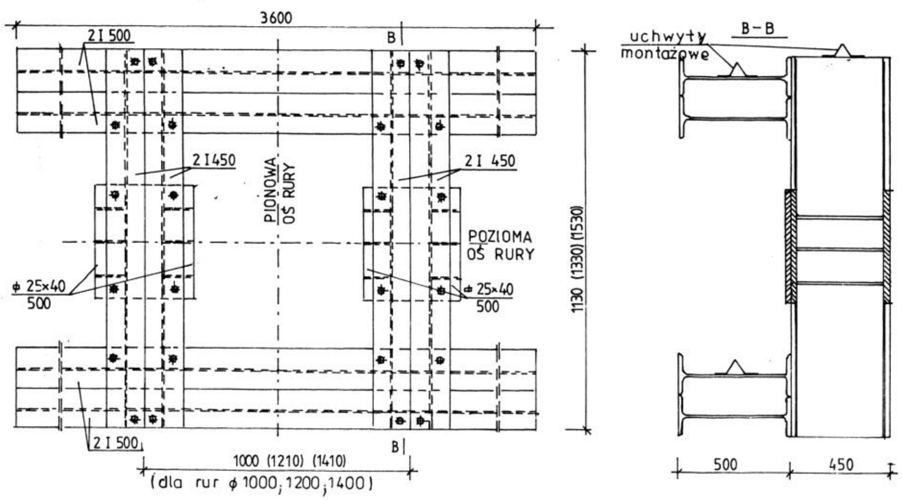


the front section of the jacking pipe
with blade reinforcement



Pierścień naporowy (wymiary w milimetrach)

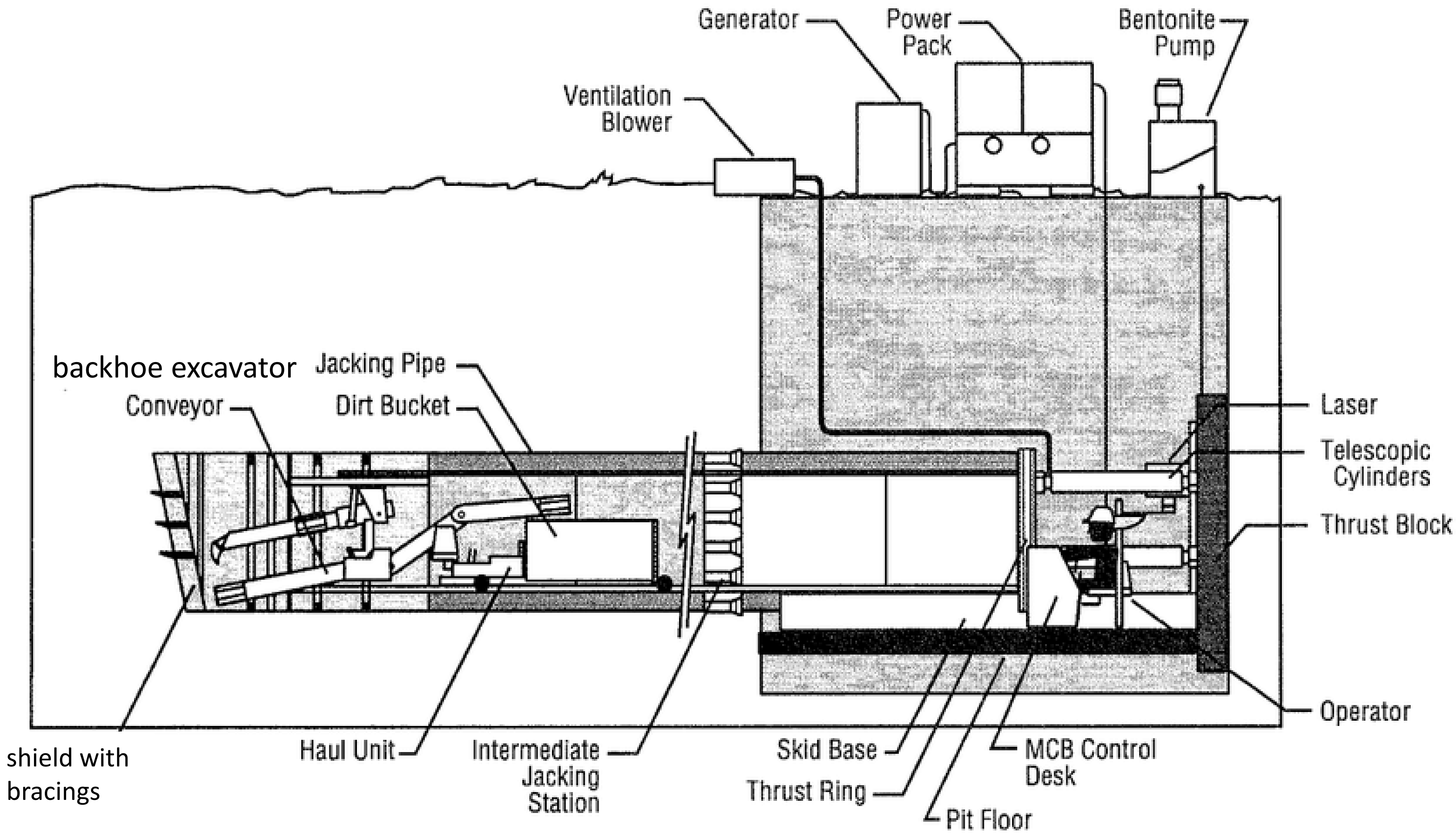
thrust ring
adapted to the railing

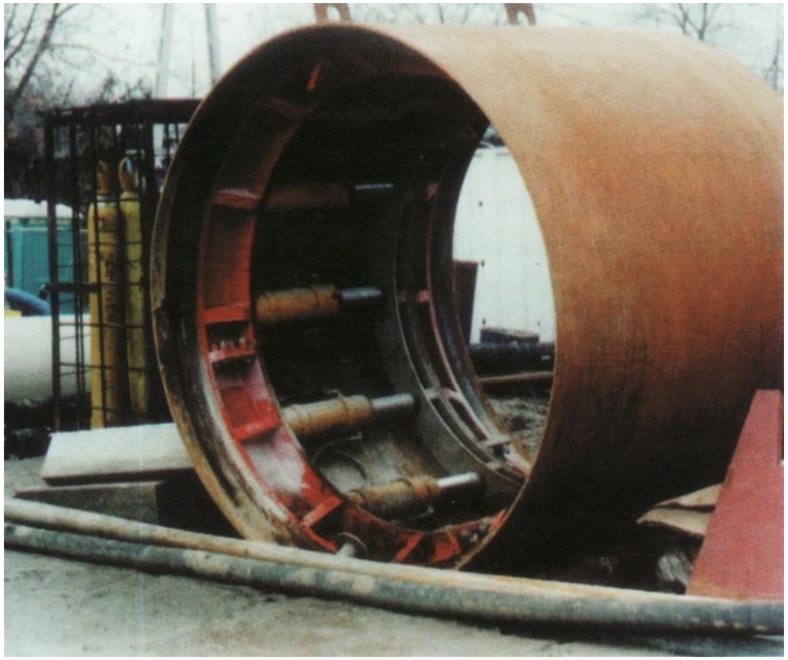


thrust block made of steel sections

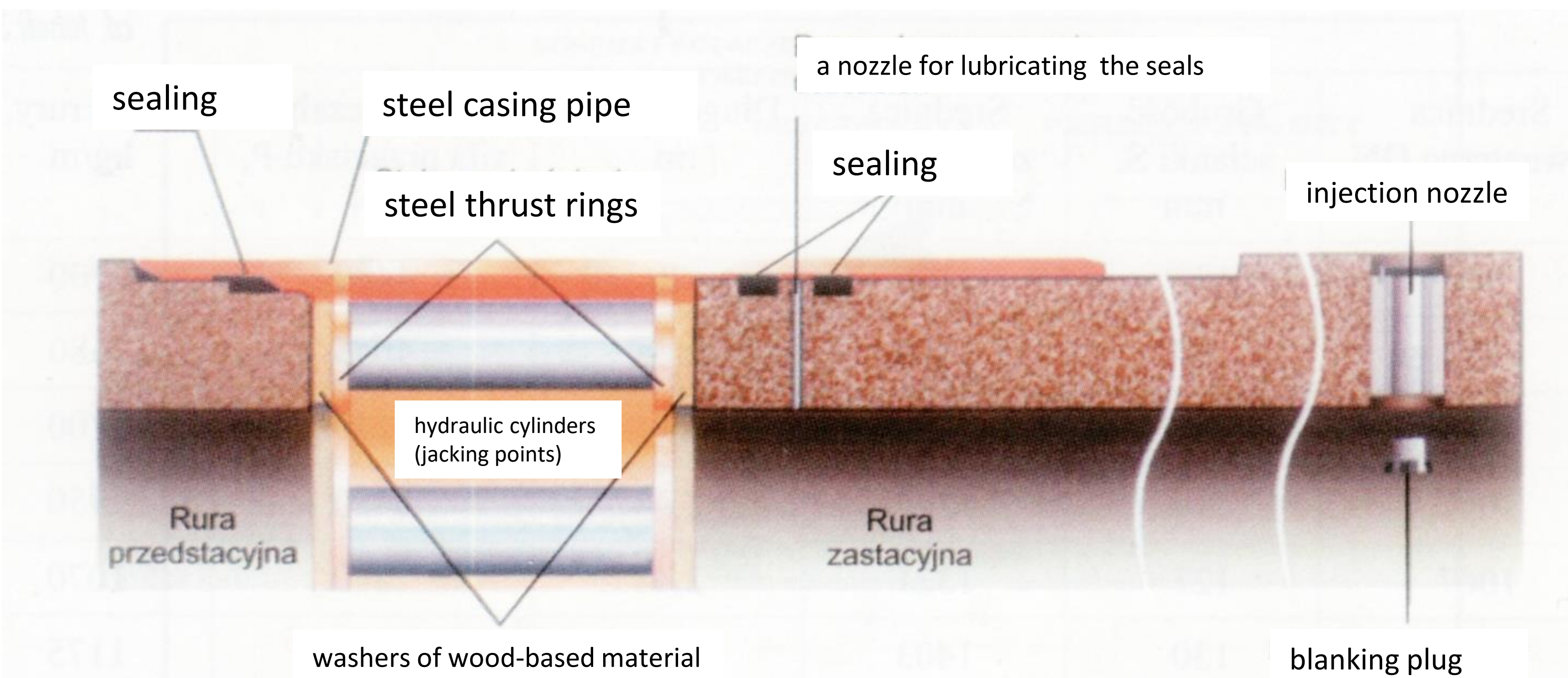
Blok oporowy (wymiary w milimetrach)

pipe-jacking or microtunneling system?

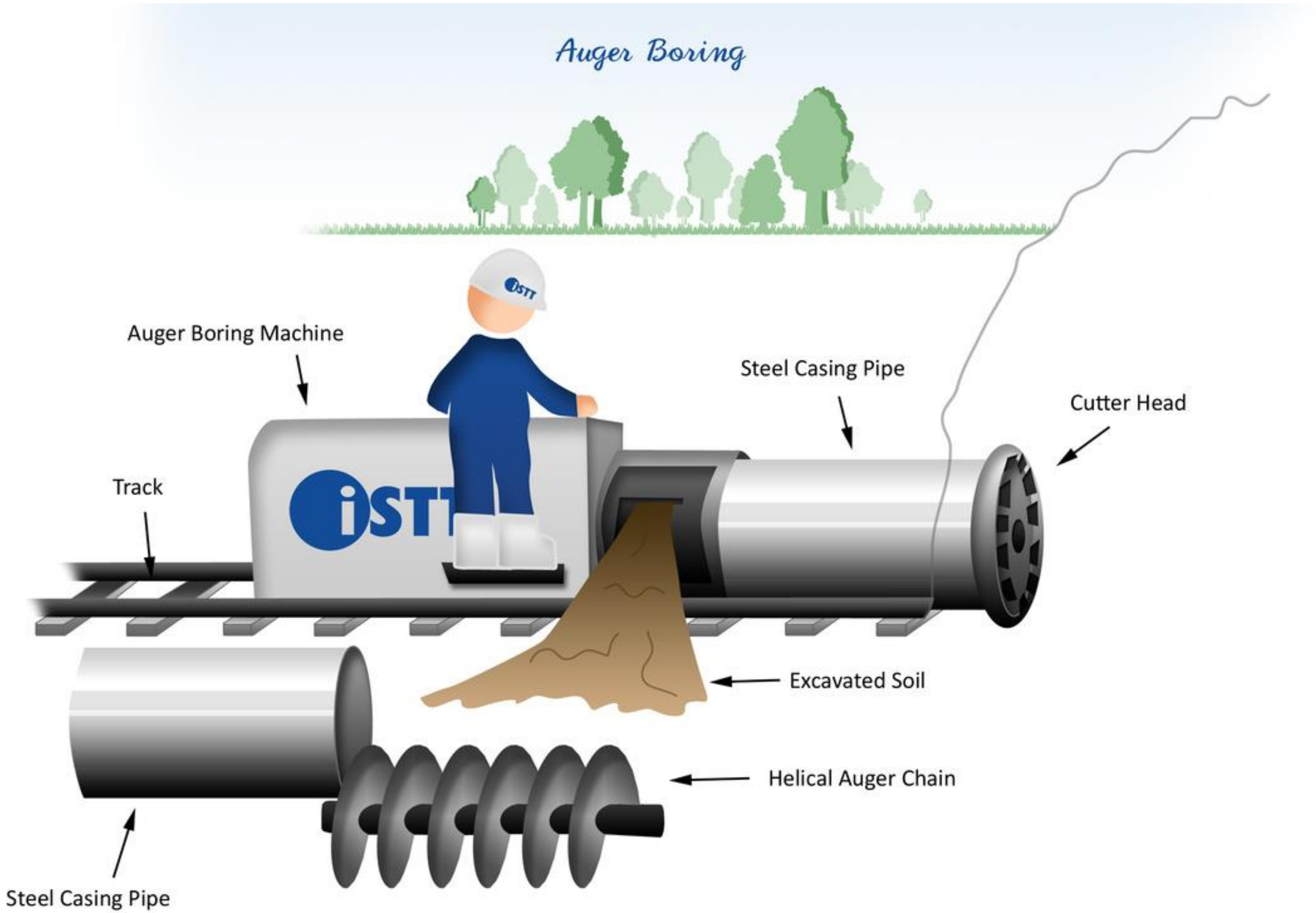




a thiner section of a pipe

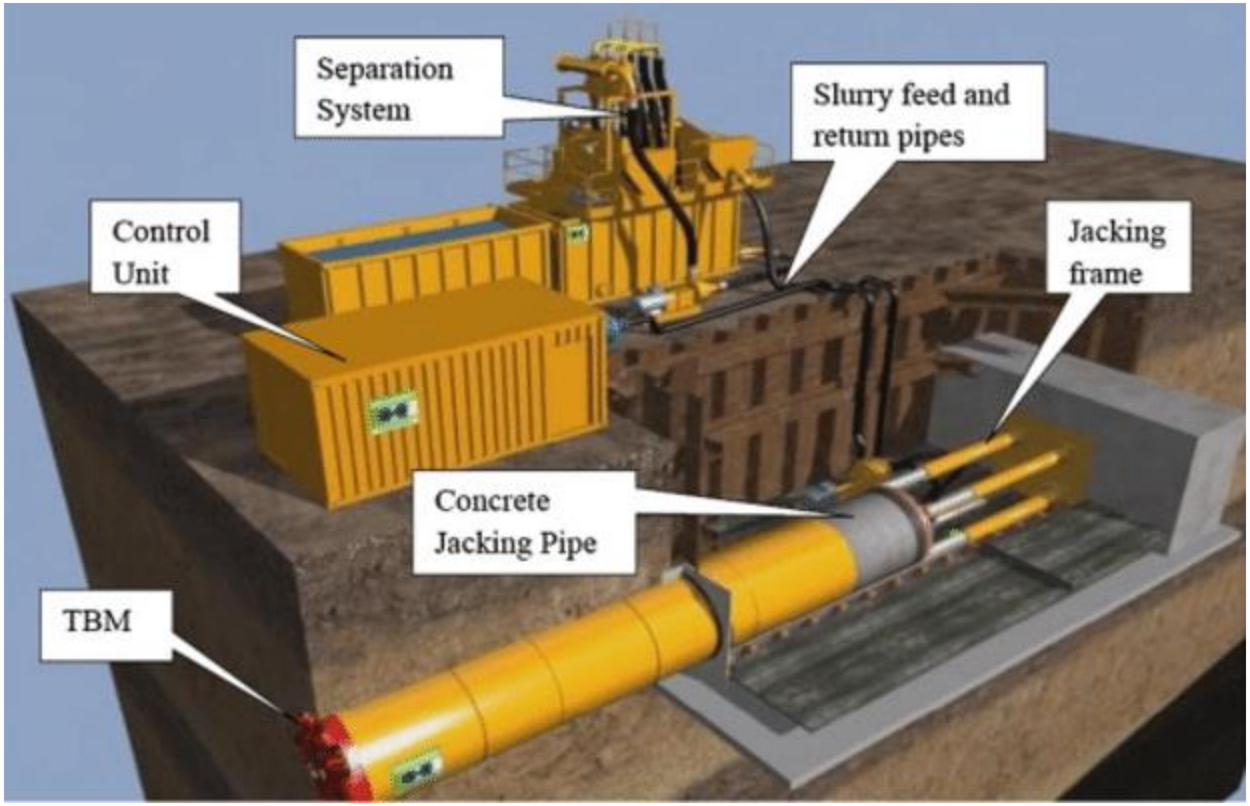


two stages for Auger Boring methods:
first – steel casing pipe, second – finnal jacking pipes pushing with casing removal

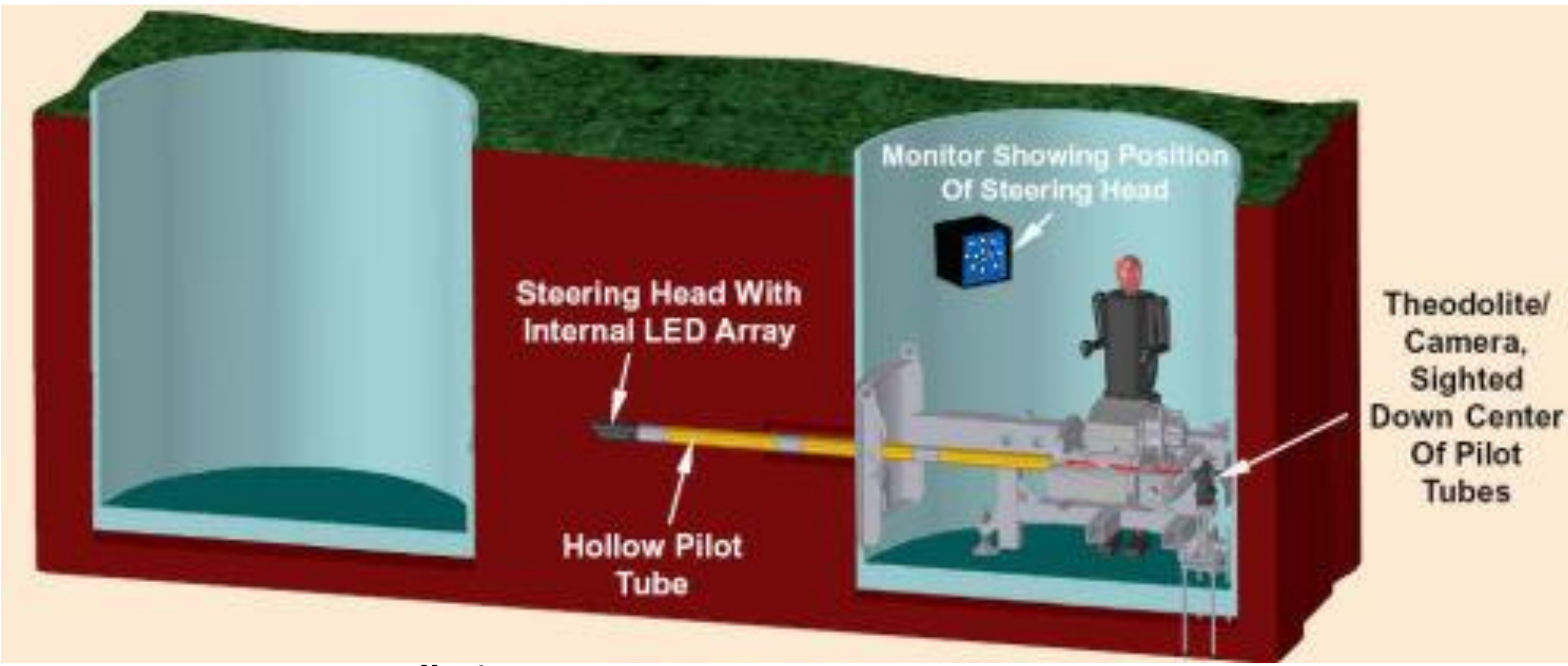


in the second step, the casing pipes are pushed out and the final jacking pipes are put in their place *most common solution - bentonite suspension for transport of soil*

slurry feed and return pipes as characteristic element for Slurry MTBM for the transport of excavated soil in the form of liquefied pulp.
Separation system to separate the spoil from the bentonite suspension, cleared supension is returning into circulation system.



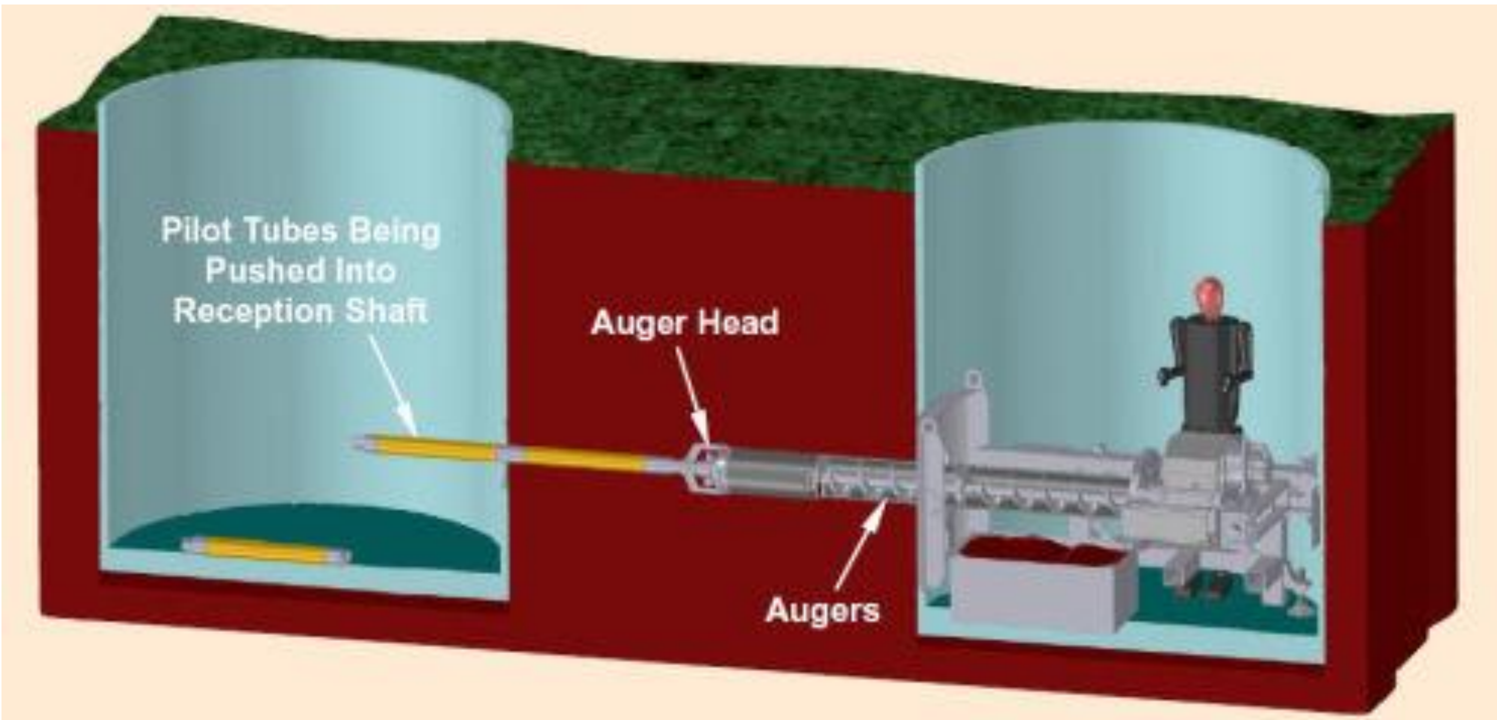
The first stage of the process is the pilot tube installation. It employs a rotating slanted-faced head for steering and a specially designed theodolite guidance system. Accuracy is achieved through video surveillance of an illuminated target at the head. Pilot tubes are installed sequentially behind the steering head.



Installation Process
STEP:1 Precise installation of pilot tubes

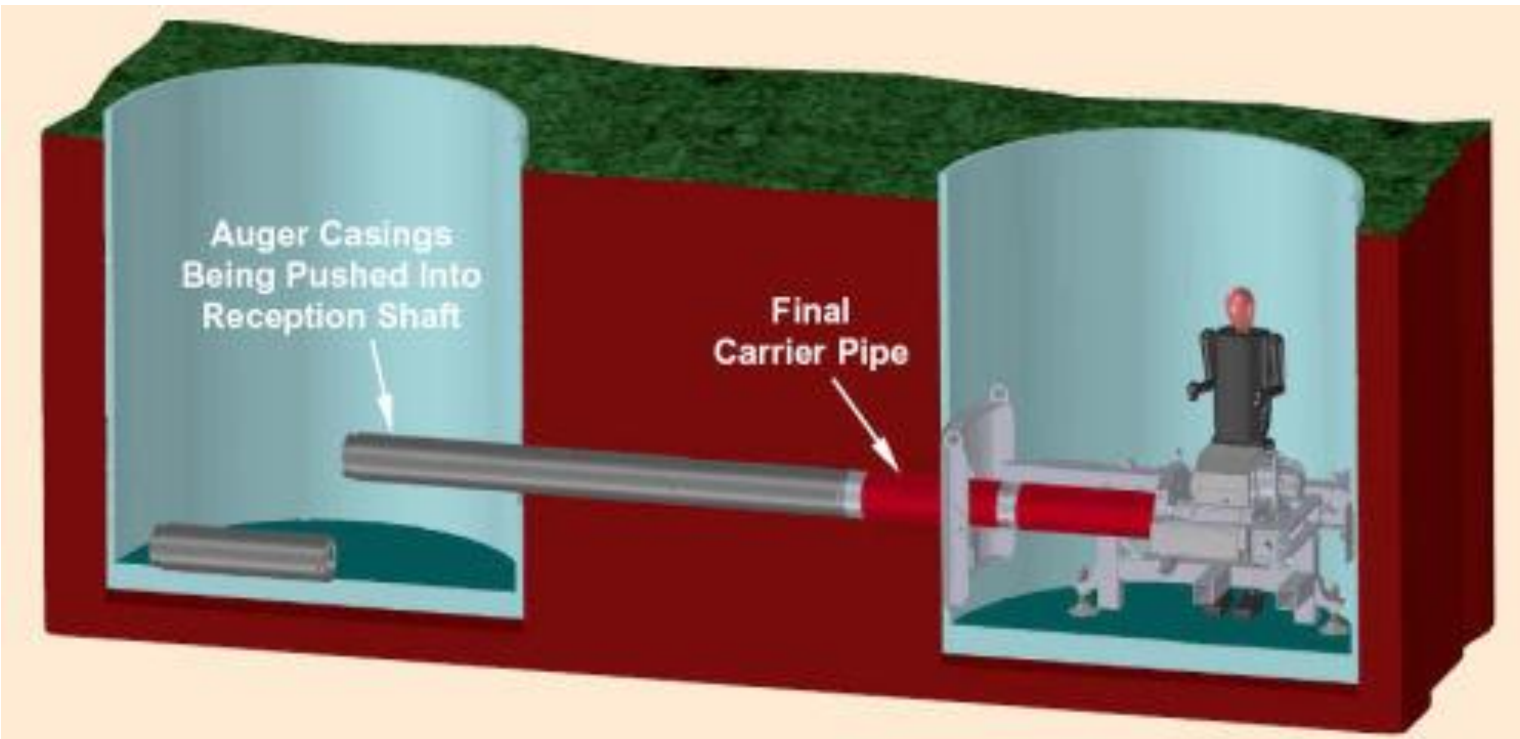
https://www.nadapacific.com/guided-boring.html

After the steering head has reached the reception shaft, a reaming head and auger tube sections are installed behind the pilot tubes. With the addition of each section of auger & tube in the launch shaft, a section of pilot tube is removed in the reception shaft. The process is repeated until all pilot sections have been removed.



STEP: 2 Advancing augers along pilot tube page

The third stage is the product pipe installation. A pipe adapter is installed on the last section of auger casing and subsequent product pipes thrust into place while the auger tubes are removed from the reception shaft.



STEP:3 Installation of final carrier pipe


STALOWA WOLA
25