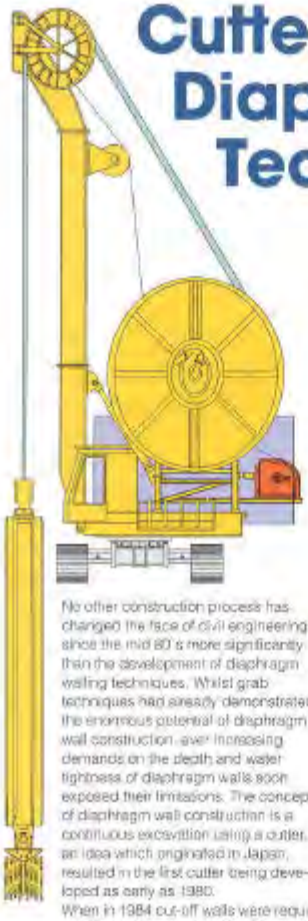
BAUER Trench Cutter Systems

BAUER

Bauer Trench Cutters revolutionise Diaphragm Walling Technique



No other construction process has changed the face of civil engineering since the mid 60's more significantly than the development of diaphragm walling techniques. Whilst grab techniques had already demonstrated the enormous potential of diaphragm wall construction, ever increasing demands on the depth and water tightness of diaphragm walls soon exposed their limitations. The concept of diaphragm wall construction is a continuous excavation using a cutter, an idea which originated in Japan, resulted in the first cutter being developed as early as 1980.

When in 1984 cut-off walls were required for the Brombach reservoir as part of the Rhein-Main-Donau Canal project, Bauer Spezialtiefbau developed their first trench cutter BC 30 in just 6 months. The prototype of this cutter was deployed with great success in the construction of a 40 m deep diaphragm cut-off wall in moderately hard sandstone.

During subsequent years the cutter was continuously improved. Both the development of a shock absorption system between cutter wheels and drive gears and the deployment of a flapper-tooth were significant improvements. In 1987 a new concept of a smaller cutter was developed specifically for restricted inner-city sites. It resulted in the versatile 'City Cutter' BC 15 which was also an instant success.

The frontiers were pushed back further, when in 1989 the first large scale trials in rock were carried out with cutter wheels equipped with rock-roller bits. The trench depth also reached new records when in 1990 the first cutter was delivered to Japan for a depth of 80 m. Another completely new design concept, which no longer required a heavy base carrier with an extensive boom, was introduced in 1991 with the development of the compact cutter unit MBC 30 which featured a horizontal mud hose reel assembly. An upright hose retracting system, type HDS, for both mud and hydraulic hoses attached to the rear of the mast of the base machine was first deployed in 1991 for a 60 m deep diaphragm wall in Japan and in 1992 for an 80 m deep diaphragm wall in Austria. The development in 1995 of the hose band, allowed the trench depth to be increased to 150 m, whilst the cutter frame steering system, consisting of hydraulically adjustable steering plates, made it possible to limit the cutter's vertical deviation over a depth of 100 m to just 2 cm. 1994 saw the design and construction of the BC 50 providing a torque of 135 kNm per cutter drive, and its first deployment in the diamond exploration on the sea bed off the shore of South Africa. In 1995 Bauer presented the BC 33 on the cutter orientated base machine CBC and in 1998 the CBC 25.

As the range of cutter systems is now so extensive and technically advanced construction problems can now be solved economically by a trench cutter.

Compact Cutter MBC 30 on rails (top).
First jobsite with BC 30 at Brombach Dam (left).
Drilling vessel with Cutter BC 50 (right).

Cutter Technique

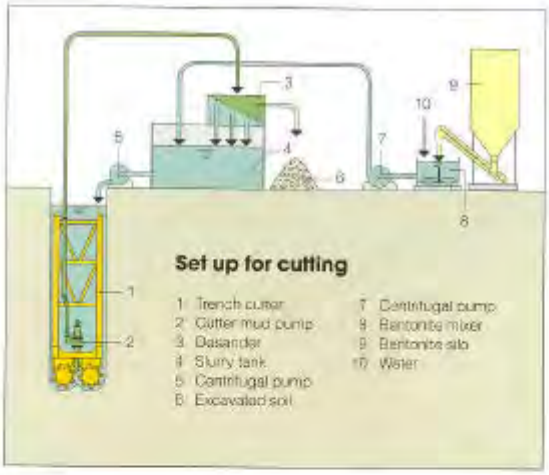
The application of the BAUER Trench Cutter technique in the construction of deep diaphragm and cut-off walls offers advantages over the conventional grab technique in the following key areas:

- economy
- output
- accuracy
- reliability
- environmental compatibility

The cutter continuously removes soil from the bottom of the trench, breaks it up and mixes it with a bentonite slurry in the trench. The slurry charged with soil particles is pumped through a ring main of hose pipes to the desanding plant where it is cleaned and returned into the trench.
The process of installing reinforcement and placing concrete, soilcrete or grout for a cut-off wall is similar to that with grab techniques.

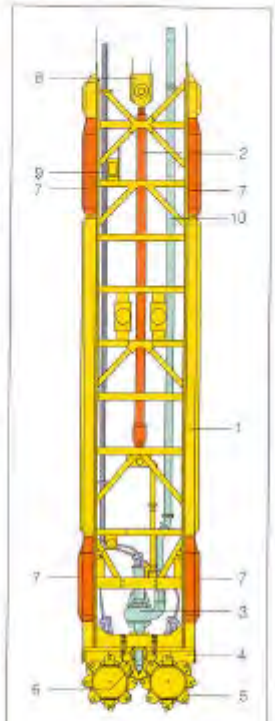
Cutter head

The heart of the system, the actual BAUER **Trench Cutter**, consists of a heavy steel frame with two drive gears attached to its bottom end which rotate in opposite direction round horizontal axes. Cutter wheels, suitable for the soils to be worked in, are mounted onto the **drive gears**. As they rotate, the soil beneath the cutter is continuously removed, broken up, mixed with the bentonite slurry in the trench and moved towards the opening of the suction box.



Set up for cutting

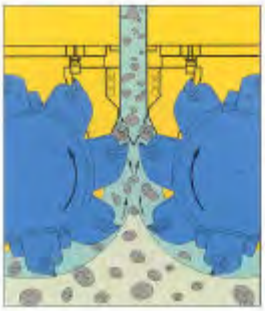
1. Trench cutter
2. Cutter mud pump
3. Desander
4. Slurry tank
5. Centrifugal pump
6. Excavated soil
7. Centrifugal pump
8. Bentonite mixer
9. Bentonite silo
10. Water



Trench Cutter

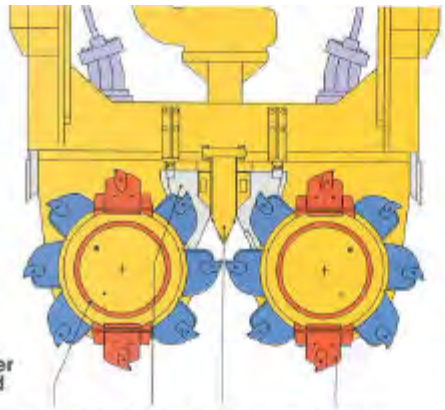
1. Cutter frame
2. Feed cylinder (optional)
3. Mud pump
4. Gear box
5. Cutter wheels
6. Suction box
7. Steering plates
8. Pulley
9. Hydraulic hoses
10. Mud hose

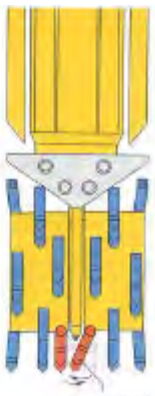
For the construction of different trench widths the cutter wheels can either be extended or replaced by a new set of full-width cutter wheels. Suction box and cutter frame must also be adapted to an increased trench width. **Ejector plates** fitted to the **suction box** clear the space between the tooth holders and break up any boulders thrown up by the teeth to the appropriate size. In order to absorb the impact caused by the crushing of the boulders the drive gears are protected by **elastic shock absorbers** which are positioned between cutter wheels and drive gears.



The ridge of soil remaining between the two cutter wheels is removed by a **flipper tooth**, a patented new feature of all BAUER Trench Cutters.

Flipper tooth on cutter wheel





The **cutter wheels** are equipped with **long tooth holders**. They enable excavation in all types of soil, including plastic clays, without the cutter wheels clogged up. The cut produced by the **teeth**, which are strengthened with tungsten carbide inserts, covers the full width of the tooth holder. Depending on the soil type, different teeth can be deployed, ranging from aggressive teeth for cutting clayey soils to percussive teeth for crushing boulders.

In order to prevent blockages in the mud hose pipe, the openings of the **suction box** are reduced to half the diameter of the hose pipe. The Trench Cutters break up the soil into the following fractions:

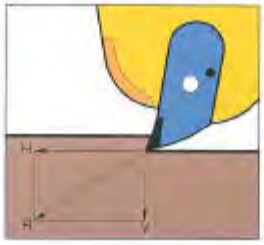
- 40 mm - BC 25
- 80 mm - BC 30 and BC 40
- 120 mm - BC 50

The performance and output of a cutter is crucially dependent on:

- the crowd force V characterised by the cutter's weight, and
- the torque H delivered by the cutter wheels.

Both these components mutually influence each other.

Although, in the case of a high H/V-ratio, the available torque may be **adequate**, the teeth simply scrape along the base of the trench without



making any progress at all. Alternatively, if the H/V-ratio drops too low, then the teeth bite too hard into the soil and cause the cutter wheels to grind to a halt.

In addition to their extensive power reserves the BAUER Trench Cutters are equipped with very sensitive controls in respect of H and V forces, which allow excavation characteristics to be continuously optimised

Cutting teeth

Penetration Control Systems

The cutter is lowered and extracted from the trench by a **winch** mounted on the base machine. The cutter's progress, however, cannot be controlled by a conventional winch as

Feed cylinder

this would not be sufficiently sensitive. In line with soil strengths, it is necessary to control either the **cutter's advancement** – in soft soils – or the **crowd force** applied to the cutter wheels - in hard soils. This is done by the **crowd cylinder**, which is fitted into the cutter frame or by way of a highly sensitive **crowd winch**. Both crowd systems are electronically controlled and can, therefore, easily and reliably be adjusted by the cutter operator.

Mud Pump

Positioned immediately above the cutter wheels is the **centrifugal pump** which pumps bentonite slurry charged with spoil continuously to the surface and from there on to the mud plant. In loose soils and when heavy

muds are being used, as for example in the case of single-phase mixtures the rate of excavation is determined by the capacity of the pump. 5", 6" or 8" pumps with a nominal output of 250, 400 and 700 m³ per hour are available for installation in the cutters.

Verticality Control

Built into the cutter is an electronic **inclinometer** which measures the cutter's vertical deviation in two directions. The deviation is continuously displayed both in degrees and in centimetres on the monitor inside the operator's cab.

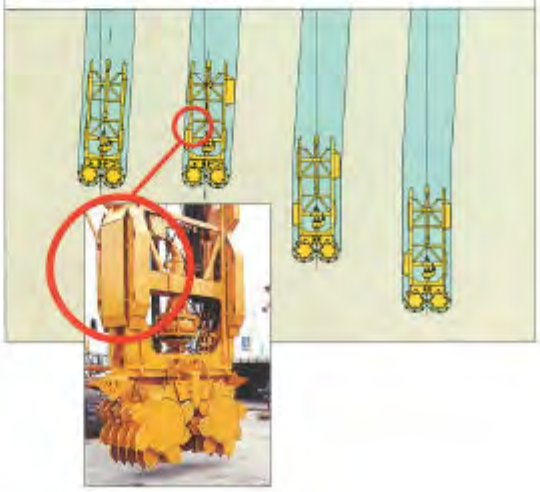
If the cutter deviates from its vertical axis, its position can be adjusted with the help of the hydraulically operated **steering plates**.

Hose Guide Systems

Both hydraulic and mud hoses have to follow all movements of the cutter with the tension on the hoses remaining constant. The original system of **hose guide wheels** and **constant tension winches** proved uneconomical for greater trench depths because of the need for an extensive boom resulting in a heavy base machine. For deep diaphragm walls and for walls to be constructed in confined area, hoses can be rolled onto **hose drums**. Hydraulic hoses - and mud hoses for extensive trench depths only - are guided in special linked hose trays in order to reduce hose tension.

Hose guide system with hose guide wheels (left).
Hose drum system HDS (right).

Cutter with steering plates

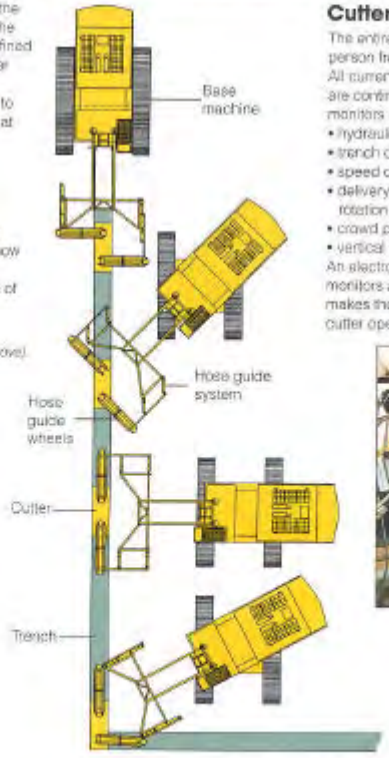


In general the base machine and the cutter travel **parallel** to the line of the cut-off or diaphragm wall. For confined sites, it is possible to turn the cutter with the help of a special device enabling the base machine either to straddle the trench or approach it at an angle.

Base Machine

Thanks to the advances in the development of power packs and special hose guide systems, it is now possible to operate a cutter from almost any **standard crawler crane** of adequate capacity.

Compact Cutter MBC 30 on tracks (above)

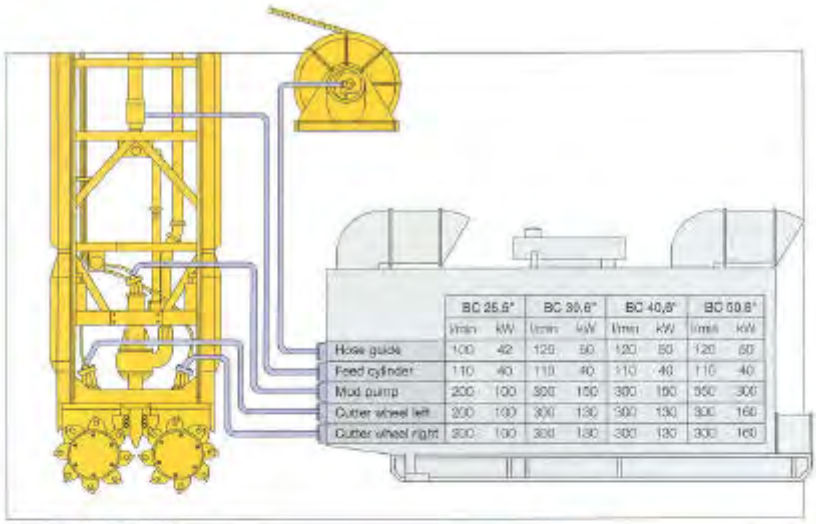


Cutter Operation

The entire unit is controlled by one person from inside the operator's cab. All current operating data of the cutter are continuously displayed on the monitors of the **control panel**:

- hydraulic pressures
- trench depth
- speed of cutter wheel rotation
- delivery volume and speed of rotation of mud pump
- crowd pressure on cutting teeth
- vertical deviation in x- and y- axis.

An electronic processor constantly monitors all these parameters and makes them visually available to the cutter operator.



	BC 25,6°		BC 30,6°		BC 40,6°		BC 50,6°	
	l/min	kW	l/min	kW	l/min	kW	l/min	kW
Hose guide	100	40	120	50	120	50	120	50
Feed cylinder	110	40	110	40	110	40	110	40
Mud pump	200	100	300	150	300	150	350	300
Cutter wheel left	200	100	300	130	300	130	300	160
Cutter wheel right	200	100	300	130	300	130	300	160

Hydraulic System

In line with the **hydraulic output** of the base machine, it is possible to choose between three alternative systems:

- Total power supply to cutter and additional systems from **base machine**
- Partial power supply to cutter - i.e. cutter wheels - from **base machine**, power supply to mud pump and additional systems from **hydraulic power pack**.
- Completely independent power supply to cutter from **hydraulic power pack**.

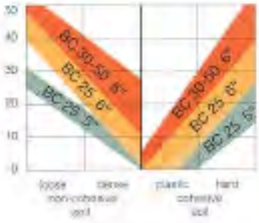
The diagram illustrates the main circuits together with the hydraulic ratings necessary for optimum operation. Due to the fact that mud pump and cutter wheels are only occasionally required to work under full load together, it is possible to reduce the overall supply by the installation of a load limiter device.

Production Rates

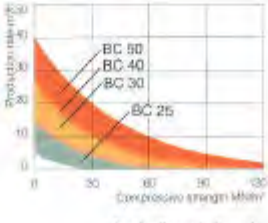
In comparison with conventional methods of excavation, the BAUER cutter techniques enable **high outputs** to be achieved in almost all types of soil. Outputs of up to 40 m³/h have been realised. For hard rocks with strengths in excess of 100 N/mm² special cutter wheels equipped with **rock roller bits** are available.

Mud Plant

The bentonite mud charged with spoil passes through the **desander unit**, where all soil particles are removed, and the clean bentonite slurry is returned into the trench. After the cutter itself the mud plant is the second most important component in the cutter technology. Throughput and desanding capacity have to be closely matched with the soil and the cutter performance.
BAUER have developed an overall concept for mixing and regenerating muds. Mixing and desanding units, including centrifuges, form the major components of this concept.

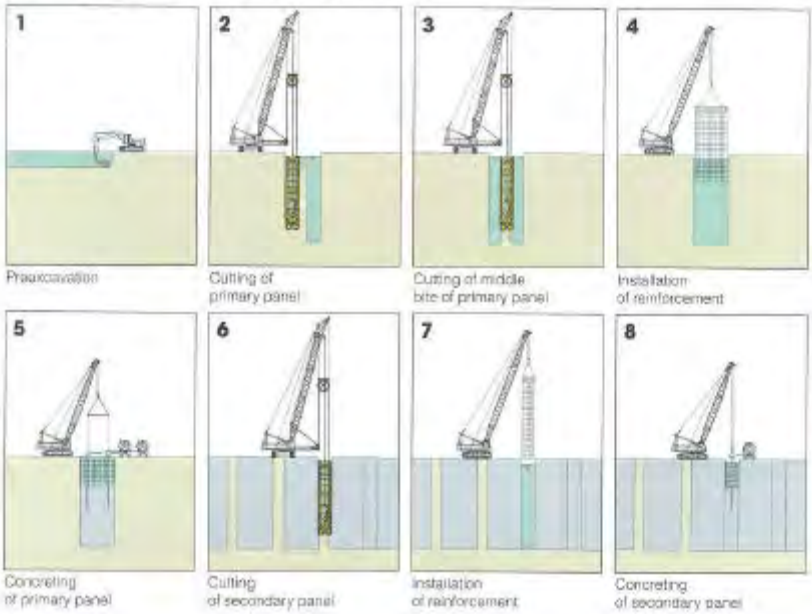


Production rate in soil



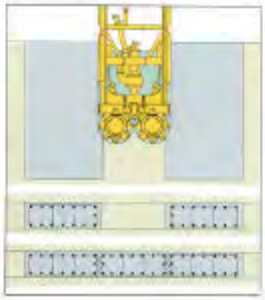
Production rate in rock

Working sequence in the cutting technique



Wall Joints

The BAUER Trench Cutters allow all types of joints to be constructed. Besides the conventional method of using stop-end tubes or sheet piles BAUER cutters can form **overlap cutter joints**. During excavation of the secondary panel, a few centimetres of the hardened concrete on both adjoining primary panels is chipped away by the cutter. Subsequently the secondary panel is concreted against the newly formed rough edge with each primary panel forming a watertight concrete joint.



Environmental Factors

The cutter operation is **extremely quiet** and completely **vibration free**. Chiselling in hard soil formations is no longer necessary with the cutter. The formation of deep trenches immediately adjacent to sensitive adjoining buildings is possible.

BC 20 with hose drum system for 60 m cutting depth (right)


LIEBHERR

Hard Rock Cutter

Cutting into rock with cutting wheels armoured with tungsten carbide teeth becomes uneconomic when the **rock strength** exceeds 50 - 80 MN/m², and cutters can even be brought to a standstill when working in rocks with strengths of 100 MN/m² or more. To overcome this problem Bauer has developed cutting wheels fitted with **roller bits** which can excavate into hard rock such as granite, basalt, etc., with strengths of up to 250 MN/m².

The lay-out of roller bits on a rock roller cutter wheel ensures that the entire rectangular cross section of the diaphragm wall is cut by the cutter. The ridge remaining in the area of the gear shield is effectively broken up by

Cutting wheels with roller bits

Rock Cutter on Shiokawa Dam in Japan

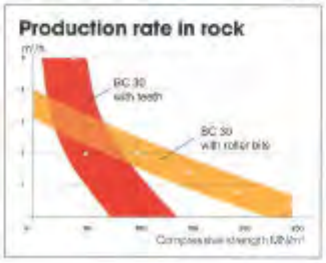
flipper-roller bits. In order to apply adequate crowd pressure on the roller bits, the cutter frame can be surcharged with **additional weights**. Trench widths of up to 1200 mm are possible.

In non-cohesive loose soils overlying bed rock, such as overburden deposites, rock roller cutter wheels are capable of achieving a similar output to that of cutter wheels equipped with teeth. As a result it is neither necessary to change wheels nor pre-excavate such layers.

Following several test runs, the hard rock cutter was the first time deployed in volcanic andesites with an single-axial strength in excess of 200 MN/m² during the construction in 1990 of the Shiokawa Dam project in Japan.

Excavated trench in lime stone

Flipper roller on cutting wheel



Mud Circulation

In addition to the equipment used for the construction of diaphragm walls, the BAUER equipment programme also includes the entire range of ancillary equipment from bentonite mixing plant and desanding units to the disposal of muds.

Mixing

To produce a workable bentonite slurry the bentonite powder must be thoroughly mixed with water. This can either be achieved by **pump mixers**

Bentonite mixer

or **colloidal mixers.** Single-phase mixes for cut-off walls comprising several components, such as rock powder, cement, bentonite and water are produced by **continuous mixers** with a capacity of up to 50 m³/h.

Desanding Plant

BAUER **desanding plants** are being developed specifically for use with BAUER Trench Cutters. Their main features are:

- Modular construction of the entire plant unit and, therefore, the option of adapting the desanding capacity to soil conditions and cutter output
- Secondary circulation c/w desilter or centrifuge possible
- Compact units for small volumes e.g. for a concreting cycle
- Short dismantling and erecting times
- All dimensions are standardised for containerised transport

Desander for 500 m³/h

Decanter BD 50

Mud Disposal

Protection of the environment and, therefore, constantly rising costs for the disposal of muds from diaphragm walls play an ever increasing part in the construction of diaphragm walls. **Decanter** enable smallest particles to be extracted from drilling muds. In combination with deflocculent agents, complete seperation of solids and water is now possible.

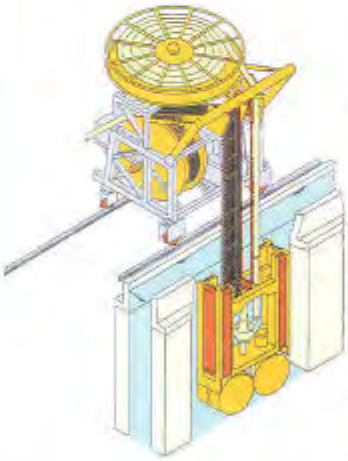
Hose Guide Systems

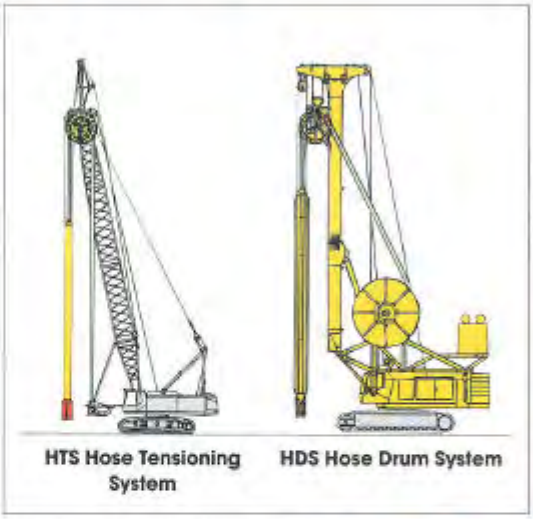
Hose Guide System with Guide Wheels HTS

The original method of lowering mud and hydraulic hoses into the trench uses **guide wheels**, which keep both hoses under equal tension with the help of tension winches. The achievable cutter depth is equal to twice the available travel of the hose guide wheels. The boom height and the weight of the cutter determine the capacity required for the base machine.

Horizontal Drums for Mud Hoses

By installing the mud hose drums in a **horizontal position**, it has been possible to keep the dimensions of the compact cutter unit MBC 30 to a minimum for cutting depths of 53 m.





HTS Hose Tensioning System **HDS Hose Drum System**

Hose Drum System HDS

The possibility of collecting the hoses onto drums **Hose Drum System** reduces the height needed for the boom and hence the capacity of the crane required. This also makes it possible

hose drum system HDS

Hydraulic hose band

to reduce all the other dimensions of the rig. The hose drums can be moved up and down the mast, extending the possible depth of excavation to 150 m.

Rotation Device Systems

The cutter is generally operated perpendicular to the upper carriage of the base machine. For the construction of corner wall panels or for narrow dam construction sites, it is, therefore, necessary to rotate the cutter relative to the base machine.

Rotation Device for Cutter Systems equipped with a single Hose Guide Wheel System

For cutter systems with a single hose guide wheel system rotation of the hoses is achieved by a parallelogram attached to the mast head and the mast foot. With this device the cutter can be rotated by up to 90°.

Rotation device on upper carrier (middle). Rotation device on mast head (left)

Rotation Device for Cutters with HDS

For cutter systems of the HDS type (hose bands) the cutter frame is rotated in the trench relative to the hose

bands. The maximum angle of rotation possible is, therefore, dependent on the trench width and amounts to about 20° for a trench width of 1000 mm.

Cutter Base Machines

Cutter Base Machines CBS

For excavation depths of up to 150 m Bauer has developed the CBS system

Chain system for mud hoses

which can be mounted on any standard crane. This consists of

- Hose Drum System HDS for both mud and hydraulic hoses.
- Steel sub-frame for HDS
- Mast and sledge for guide wheels.

Quality Assured Foundation Equipment

Bauer Spezialtiefbau **continuously** develop, modify and improve the cutter systems in accordance with the **specific needs** and the experiance of its **Foundation Engineering Divison**. All equipment, which is designed by experienced mechanical engineers, is first tested and proven in extreme conditions on Bauer jobs before being offered to the open market. Many of the requirements and improvements suggested by customers around the world have been incorporated in the development of Bauer equipment.

The cutters are manufactured **in house** to the most stringent quality requirements. Bauer's Foundation Equipment Manufacturing Division is already operating a quality management system and the company received full accreditation to DIN ISO 9001 in July 1994.

On delivery of a new cutter system specially trained customer service engineers set up and adjust the equipment specifically for the prevailing site conditions. This procedure allows operating conditions and production output to be optimised.

CERTIFIED DIN ISO 9001 QUALITY SYSTEM

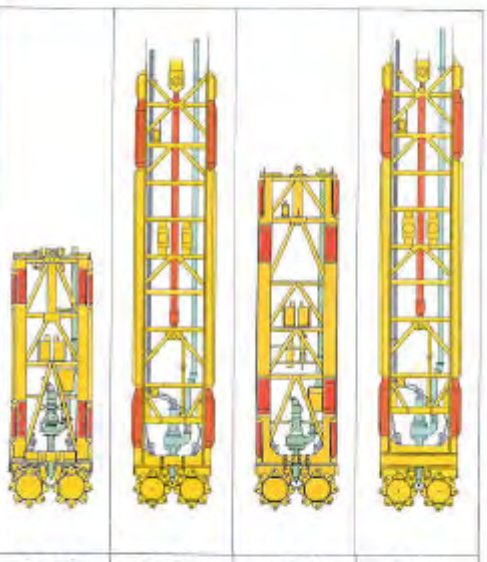
REG. NR. 2256-01

CERTIFIED E⊙Net QUALITY SYSTEM

Standard Cutters

The standard cutters **BC 25, BC 30, BC 40** and **BC 50** are all of a similar construction. Their main features are:

- Long cutter frame
- High cutting force resulting from high torque produced by gear drives
- Crowd control through long crowd cylinder
- Verticality control by way of 12 independently adjustable steering plates.
- Power pack which can be seperate or integral to the carrier.



Technical Data	BC 25	BC 30	BC 40	BC 50
trench length	2800 mm	2800 mm	2800 mm	2800 .. 3200 mm
trench width	640 .. 1500 mm	640 .. 3200 mm	800 - 2100 mm	1200 .. 3200 mm
height of cutter	9,0 m	15,4 m	11,50 m	16,0 m
weight of cutter	25 to	25 .. 40 to	30 .. 45 to	40 .. 50 to
max. torque				
per gear box	81 kNm	81 kNm	100 kNm	135 kNm
pulldhesil force	109 kN	109 kN		135 kN
revolution of cutter wheel	0 .. 25 rpm	0 .. 30 rpm	0 .. 25 rpm	0 .. 25 rpm
mud pump	5"	6"	6"	6" oder 8"
quantity	300 m³/h	450m³/h	450 m³/h	450 or 700 m³/h
pressure height	65 m	65 m	65 m	65 m
stroke of feed cylinder	winch	9,6 m	winch	6,5 m
steering plate system	optional	optional	optional	optional

Note: The achievable cutting depths are dependent on hose guide system and the capacity of the base carrier.

BC 30 on 80 to - base machine, cutting depth 45 m

BC 30 on drilling BG 40, cutting depth 80 m

Guidelines for Cutter Selection

BC 25

c/w 5" mud pump

- trench widths of 640 to 600 mm in hard soils (q_u < 20 MN/m²)
- trench widths of 640 to 1000 mm in very stiff soils (SPT < 30)
- gravelly soils with a maximum grain size of 50 mm

BC 30

- trench widths of 640 to 2600 mm in stiff soils (SPT < 20)
- trench widths of 640 bis 1000 mm in very hard soils (q_u < 40 MN/m²)
- gravelly soils with a maximum grain size of 100 mm
- rock cutter wheels for trench widths of 640 to 1000 mm for rock strengths of 50 to 200 MN/m²

BC 40

- trench widths of 800 to 2100 mm in stiff soil (SPT < 20)
- trench widths of 800 to 1200 mm in hard soil (qu < 40 MN/m²)
- gravelly soil with a maximum grain size of 100 mm
- rock cutter wheels for trench widths of 800 to 1200 mm for rock strengths of 50 to 200 MN/m².

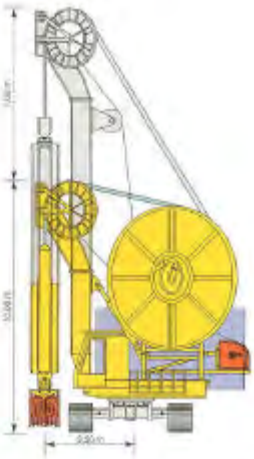
BC 50

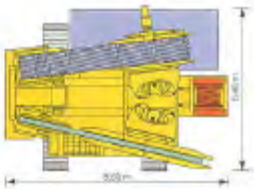
- trench widths of 1200 to 3200 mm in very stiff soils (SPT < 30)
- trench widths of 1200 to 1500 mm in very hard soils (q_u < 40 MN/m²)
- rock roller cutter wheels for trench width of 1200 mm for rock strengths of 50 to 200 MN/m2
- 6" mud pump for gravelly soils with a maximum grain size of 150 mm or a trench width < 2000 mm.
- 8" mud pump for gravelly soils with a maximum grain size of 200 mm or a trench width > 2000 mm

CBC 25, cutting depth 80 m

Compact Cutter CBC 33

The compact Cutter System CBC 33 was specially developed for operating in confined site conditions. Due to its dimensions the CBC 33 is best suited for the construction of diaphragm walls in inner-city areas in virtually all types of soil. Cutter drive gears, cutter wheels and mud pump have been adopted from the wellproven BC 30 cutter. The cutter's rate of penetration can be controlled with the crowd winch system, by controlling either the speed or the crowd pressure.





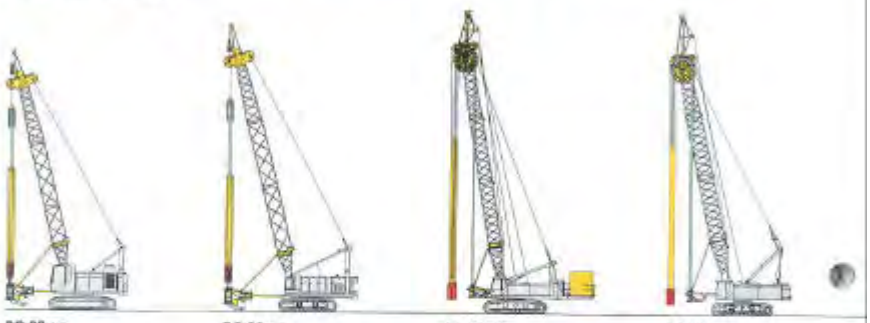
Technical Data	CBC BC 33 short Version	CBC BC 33 long Version
Cutter		
trench length	2800 mm	2800 mm
trench width	640 .. 1800 mm	640 .. 1800 mm
height of cutter	6.0 m	12.0 m
max. torque		
per cutter wheel	81 kN	81 kN
revolution of cutter wheel	0 .. 30 RPM	0 .. 30 RPM
peripheral force	109 kN	109 kN
mud pump	6"	6"
quantity	450 m³/h	450 m³/h
pressure height	65 m	65 m
winch system	yes	yes*
steering plate system	yes	yes
weight of cutter	20 to	35 to
Base carrier	crawler	crawler
height	10.0 m	17.0 m
width**	6.4 m	6.4 m
length**	8.5 m	8.5 m
crawler system	B 6 B	B 8 B
operating weight	120 to	130 to
Cutting depth	80 m	80 m

Hydraulic power pack	HD 1200 / 6
total performance	634 kW
main circuits	
cutter wheel right	320 l/min
cutter wheel left	320 l/min
mud pump	320 l/min
winch system	320 l/min
HDS	2 x 110 l/min
auxiliary circuits	190 l/min
working pressure	320 bar

* optional with feed cylinder
** crawler parallel to trench

Summary of the Trench Cutter Systems

Standard Cutters



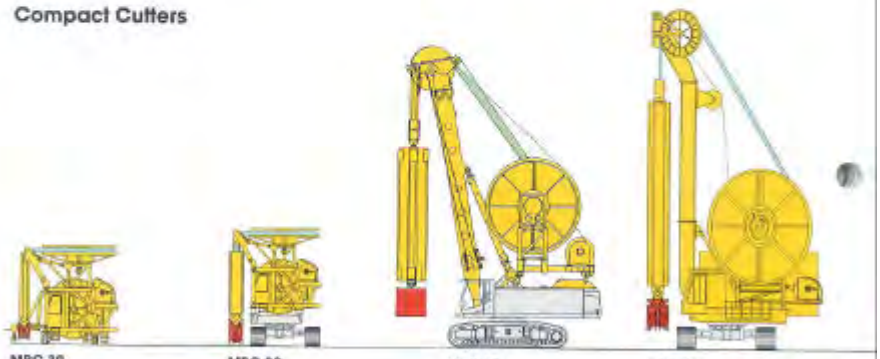
BC 20 on
50 to base machine
Height: 24 m
Cutting depth: 30 m
Operating weight: 220 + 70 to
Installed power: 270 kW

BC 20 on
70 to base machine
Height: 27 m
Cutting depth: 44 m
Operating weight: 20 + 90 to
Installed power: 300 kW

BC 30 on
80 to base machine
Height: 29 m
Cutting depth: 45 m
Operating weight: 25 + 95 to
Installed power: 298 + 238 kW

BC 30 on
100 to base machine
Height: 37 m
Cutting depth: 60 m
Operating weight: 35 + 165 to
Installed power: 894 kW

Compact Cutters



MBC 30
on rails
Height: 9 m
Cutting depth: 59 m
Operating weight: 20 + 30 to
Installed power: 75 + 400 kW

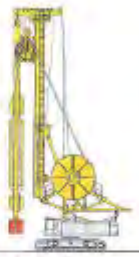
MBC 30
on crawler
Height: 8.5 m
Cutting depth: 51 m
Operating weight: 30 + 60 to
Installed power: 75 +400 kW

CBC 25
Height: 16 m
Cutting depth: 80 m
Operating weight: 120 to
Installed power: 895 kW

CBC 33
Height: 20/17 m
Cutting depth: 90 m
Operating weight: 125/135 to
Installed power: 634 kW

BC 20 with
hose drum system
on 70 to base machine

Height 33 m
Cutting depth 40 m
Operating weight 30 + 100 to
Installed power 300 kW



BC 30 with
hose drum system
on 100 to base machine

Height 34 m
Cutting depth 60 m
Operating weight 180 to
Installed power 485 kW

BC 30 with
hose drum system
on drilling rig BG 40

Height 34 m
Cutting depth 60 m
Operating weight 35 + 115 to
Installed power 300 + 265 kW

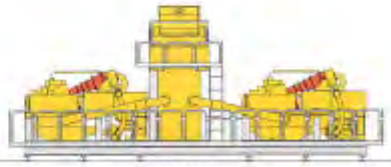
BC 30 with cutter
base system and
base drum system
on 120 to base machine

Height 34 m
Cutting depth 60 m
Operating weight 35 + 165 to
Installed power 634 kW

Mud handling systems

Bentonite mixer
screw conveyor

Installed power 5 – 22 kW
Feed capacity 1 – 50 cbm/h
Weight 434 – 1950 kg



Desander
BE 500

Installed power 94 kW
Feed capacity 500 cbm/h
Weight 14.6 to

Decanter
BD 80

Installed power 45 kW
Feed capacity 30 cbm/h
Weight 9 to