MBAS-A

Analogue Multistation Borehole Acquisition System

Geotomographie GmbH, Am Tonnenberg 18, 56567 Neuwied (Germany)
Tel.: +49 2631 778135 email: info@geotomographie.de

Content

1. Introduction

High-resolution P-wave tomographic investigations between boreholes are routinely applied for the exploration of development sites considered for larger building projects, e.g. power stations, dams and high-rise buildings. However, the geotechnical benefits of P-wave tomography are rather limited and information about S-wave velocity distribution is additionally required to derive geotechnically relevant parameters, such as dynamic soil parameters. Up to now, only little efforts have been made to develop equipment enabling the competitive acquisition of S-wave crosshole tomographic data.

The Multistation Borehole Acquisition System (MBAS-A) is designed for efficient recording of S-waves in dry and water-filled boreholes at different levels. The system is analogue and has to be connected to a seismograph. Each station is equipped with a 3C sensor arrangement and can be pneumatically coupled to the borehole wall by an air packer. All sensor components are aligned to each other. For orientation a magnetic compass is mounted within the bottom station.

2. Parts of the MBAS-A

The Analogue Multistation Borehole Acquisition System consists of up to eight geophone stations each equipped with a tri-axial sensor. All geophone stations are aligned and mechanically connected by a torsional stiff hose to ensure a correct sensor orientation.

A magnetic compass located in the lowest station indicates azimuth to north. The compass readings are displayed on a surface box.

All geophone stations can be coupled to the borehole wall by a pneumatic clamping system (air packer). Air is supplied to the geophone stations via a separate air hose. The borehole geophone string is terminated by a seismograph connector. The operational length is up to 100m.

The MBAS-A system consists mainly of

1. Multi-core cable with **up to eight stations**, each with tri-axial sensor arrangement and split station
2. Cable on drum
3. Control unit mounted on drum

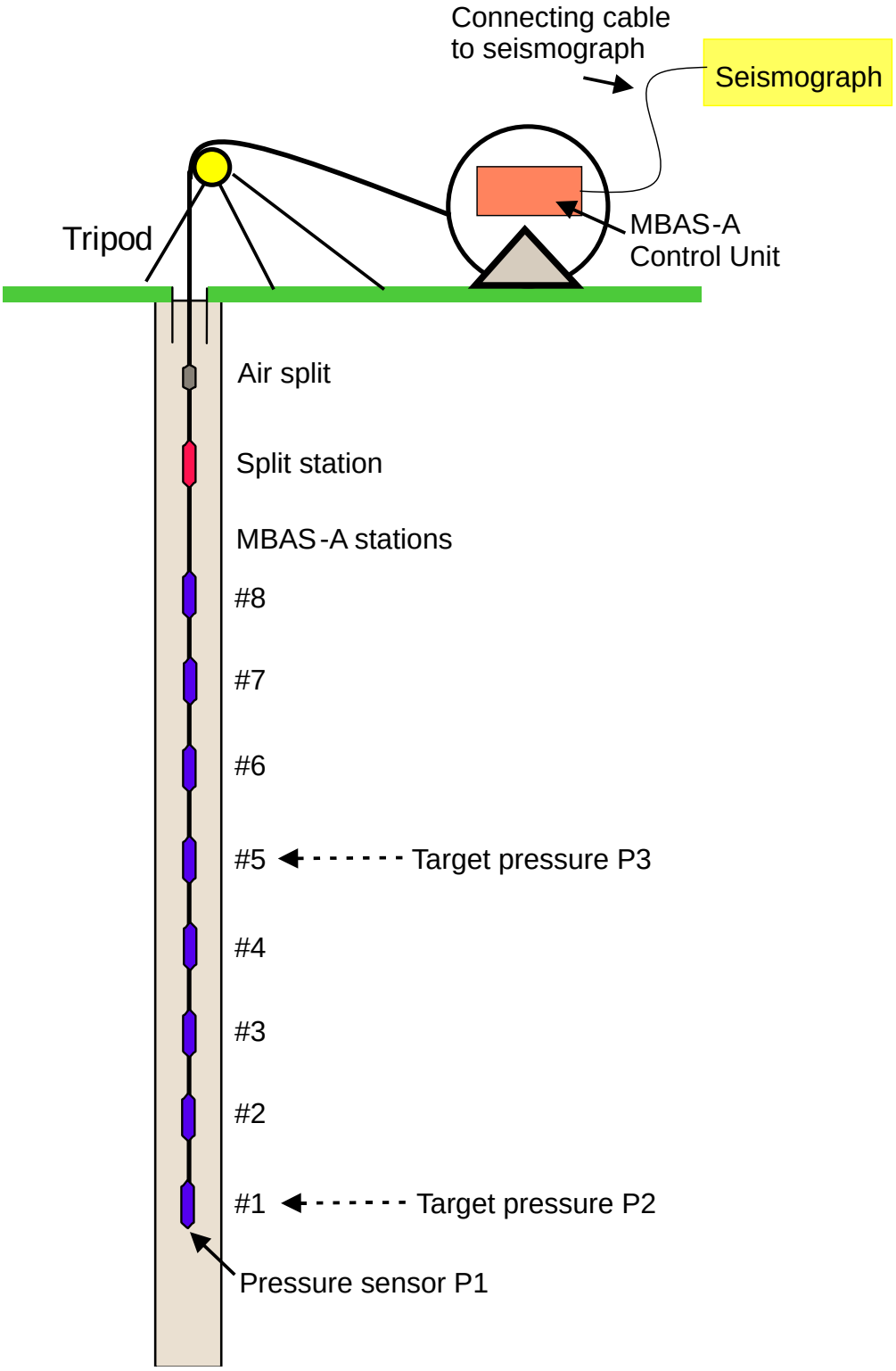

Figure 1: Set-up of measurements with MBAS-A

2.1 Geophone stations

The MBAS-A consists of up to eight 3C stations separated 1 m or 2 m (see figure 1).

Each station has a length of 595mm, an outer diameter of 60mm and a weight of 4 kg. Therefore an eight station system with an operating length of 100m has a total weight of approximately 60 kg in air.

The stations are connected to each other with a rotary pipe string. In this way, all geophone stations are aligned and mechanically connected by a torsional stiff hose to ensure a correct sensor orientation.

Figure 2: MBAS-A stations

The depth reference (z=0m) is the lowest station.

Each station contains three sensors (X,Y,Z) in a tri-axial arrangement. The X-sensor points in the opposite direction to the air packer, the Y-sensor is 90° off and the Z-sensor is vertical (see figure 3).

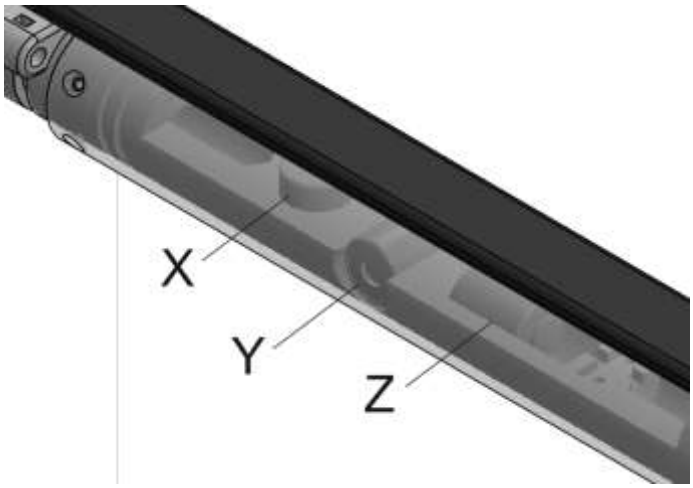

Figure 3: Sensor orientation

The sensors will give a positive rising signal in the direction of the sensor array (see Figure 4, a seismic pulse towards the marker line will give a positive rising signal).

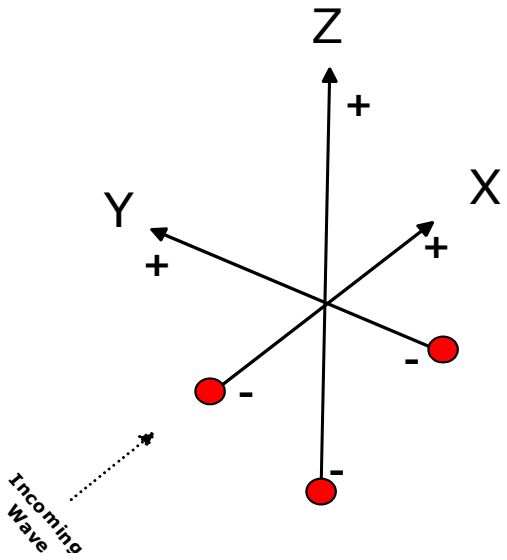

Figure 4: Sensor polarity

Table 1 shows the wiring scheme.

Table 1: MBAS-A wiring scheme

MBAS-A		
Channel	Comp	Station
1	**X**	**1 (lowest)**
2	**Y**	
3	**Z**	
4	**X**	**2**
5	**Y**	
6	**Z**	
7	**X**	**3**
8	**Y**	
9	**Z**	
10	**X**	**4**
11	**Y**	
12	**Z**	
13	**X**	**5**
14	**Y**	
15	**Z**	
16	**X**	**6**
17	**Y**	
18	**Z**	
19	**X**	**7**
20	**Y**	
21	**Z**	
22	**X**	**8 (topmost)**
23	**Y**	
24	**Z**	

2.1 Pressure sensor at bottom station

A water pressure sensor is mounted at the bottom MBAS station (see figure 5). It is hold in place with a spring and protected by a brass screw with in inner hole of 10mm. This allows it to float the cap with water.

Figure 5: Pressure sensor at bottom station

The pressure sensor measures the water pressure, i.e. 10 m below water table it will show 1 bar and so on. The accuracy of the pressure sensor is 0.1 bar. The brass screw is to protect the sensor against mechanical shocks. To check the water pressure **P1** one needs to switch on the compass display at the main control unit (see chapter 5).

Do not touch or mechanically clean the sensor face. Use water to clean the bottom cap and sensor. You may remove the brass screw for better cleaning.

2.2 Air packer system and air supply

The coupling of the geophone stations to the borehole wall is performed by inflatable air packers. The air packers are mounted to the geophone stations. Air is supplied to the lower four stations (1- 4) and to the upper four stations (5-8) by a multi-functional cable containing two air hoses, electrical wires and a Kevlar strength string.

To allow a proper clamping of the stations at the borehole wall the air packers need to be inflated according to the water pressure P_w. **In table 2 the recommended air pressure is listed.**

Table 2: Recommended air pressure for coupling

	MBAS-A (**8** Stations)		MBAS-A (**6** Stations)	
	Spacing 1 m	Spacing 2 m	Spacing 1 m	Spacing 2 m
	if P_w > 0.3 bar	*if* P_w > 0.6	*if* P_w > 0.2 bar	if P_w > 0.4 bar
P2, Lower	P_w + 1.6 bar	P_w + 1,6 bar	P_w + 1.6 bar	P_w + 1.6 bar
P3, Upper	P_w + 1.2 bar	P_w + 0,8 bar	P_w + 1.3 bar	P_w + 1.0 bar
	if P_w < 0.3 bar	*if* P_w < 0.6 bar	*if* P_w < 0.2 bar	*if* P_w < 0.4 bar
P2, Lower	1.6 bar	1.6 bar	1.6 bar	1.6 bar
P3, Upper	1.6 bar	1.6 bar	1.6 bar	1.6 bar

However, in addition to pressure sensor **P1** at the bottom station, there are two additional pressure sensors placed within the general air pressure supply, i.e. for air pressure measurement for bottom stations 1 - 4 (**pressure sensor P2**) and for top stations 5 - 8 (**pressure sensor P3**).
The pressure sensors are mounted inside the surface control unit and monitors the pressure applied to inflate the air packers for stations 1 to 4 (**pressure sensor P2**) and 5 to 8 (**pressure sensor P3**).

Figure 6: Air split with two air outlets to station 1-4 and 5-8 at about 50cm above the cable split.

Once the split station is closed (all electrical connections are made), the two air hoses leading from the air split to the stations can be connected. The connectors are of the push-pull type. To connect the air hose, simply push the hose all the way into the connector. To disconnect the air hoses, push the yellow ring towards the connector and pull the air hose out at the same time.

Figure 7: Air hose connector

Figure 8: Fix air hoses to cable split using tape

3. Cable split

The cable split is located approximately 2m above the top geophone station. It provides the mechanical connection between the cable from the eight geophone stations and the main supply cable that is coiled up on drum. Inside the cable split are two 55-pin connectors (male&female) to connect the two cables coming from the eight stations and from the upper cable.

3.1 Connect the cables and close the cable split

Figure 9 shows the two cables, the connectors and the stainless steel housing. Always grease O-rings.

Figure 9: Cable split

Figure 10: Push the stainless steel housing towards the geophone stations

Twist the 55 pin connector from bottom cable 1 or 2 times max and push into the stainless steel housing.

Figure 11: Push the bottom cable connector into steel tube and close connectors

Once you have established the connection one may connect the seismograph and check the presence of all channels by using the noise monitor function of the seismograph.

Figure 12: Push housing towards top cable and fix housing at bottom with one screw first

Figure 13: Fix top housing cable and mount all screws

Connect air hoses as described under chapter 3.

3.2 Open the cable split and disconnect cables

First remove all screws and slide the stainless steel housing towards the bottom cable.

Do not pull on the top cable!

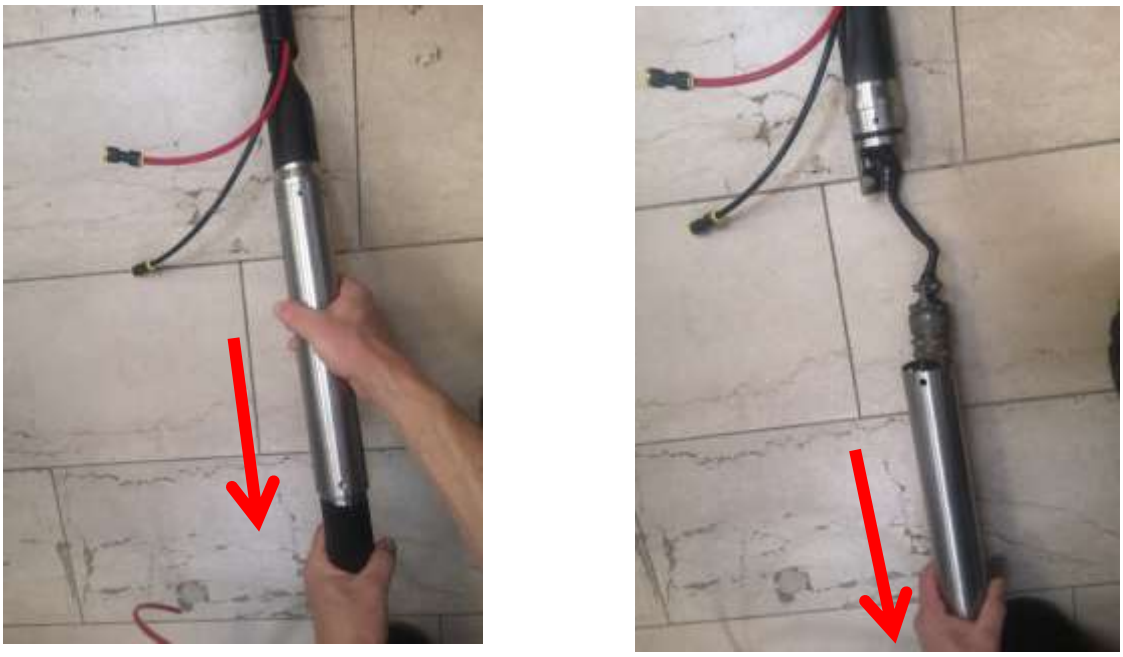

Figure 14: Slide/push steel housing towards bottom cable.

Figure 15: Use pliers to secure to connector. Turn ring on bottom connector counter-clockwise to open.

Once disconnected, wrap the connectors and housing in bubble wrap and store securely in a plastic protective case to prevent damage.

4. Control unit

The control unit is mounted on the top cable drum. It contains the electrical connections as well as the air supply to the downhole receiver system.

The top panel is shown in Figure 16.

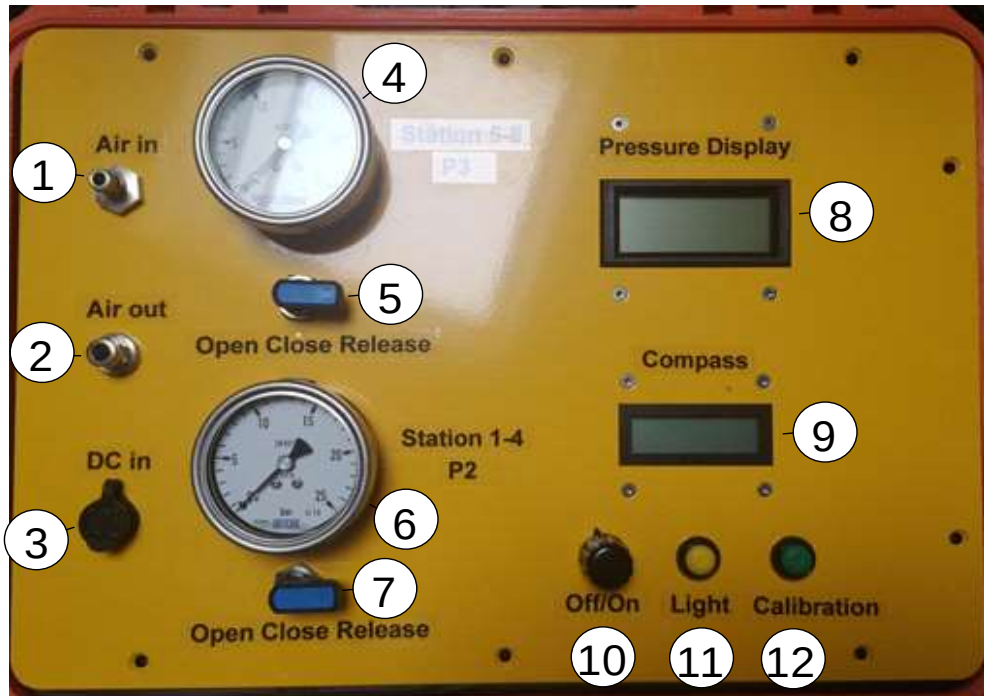

Figure 16: Front panel of the MBAS control unit.

The control panel instrumentation is described as follows:

(1) Main air supply to downhole air bladders
(2) Main air release
(3) Charger connector to charge internal 12V battery (for displays and pressure sensors)
(4) Manometer/pressure gauge for the upper stations 5 to 8 (**pressure sensor P3**)
(5) Main valve to Open/Close/Release air for the upper stations 5 to 8 (**pressure sensor P3**)
(6) Manometer/pressure gauge for the lower stations 1 to 4 (**pressure sensor P2**)
(7) Main valve to Open/Close/Release air for the lower stations 1 to 4 (**pressure sensor P2**)
(8) Pressure display showing the actual water pressure at the bottom station and the pressure inside the two air hoses supplying air to the bottom and top stations.
(9) Magnetic compass reading display
(10) Switch to activate the displays
(11) Display backlighting (press once briefly to illuminate for 30 seconds, press and hold to illuminate continuously, press again to stop)
(12) Calibrate magnetic compass sensor (press to perform hard iron compass calibration, for calibration hold bottom station vertically and rotate twice within calibration time (20sec).

4.1 Magnetic compass

Main part of the compass unit is a three-component magnetometer sensor placed in a non-magnetic housing. The compass unit is mechanically connected to the lowest geophone station.

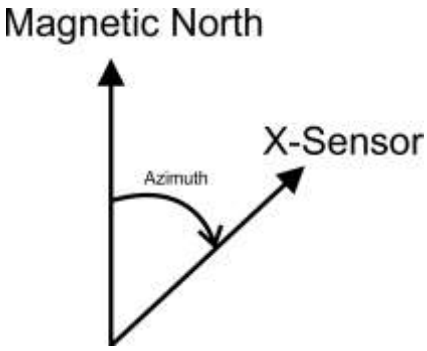

Figure 17: Schematic sketch showing angle measure

The angle between magnetic North and the direction of the X-sensor can be measured correctly and is displayed. Resolution and accuracy of the compass reading is +/- 1°.

4.2 Pressure display and how to apply air pressure

The pressure display shows the pressure readings at the bottom sensor P1, the actual pressure P2 applied to the air supply system for lower stations 1 to 4 and the actual pressure P3 inside the air supply for upper stations 5 to 8.

Figure 18: Pressure display

On the right hand side of the display is the working pressure that must be reached to establish a proper coupling in the borehole. It is 1.6 bar above the actual pressure of P2 and P3 for a MBAS station 8 stations and 1 or 2 m station distance.

If the MBAS is below the water table, a pressure P1 above 0.00 bar will be displayed. Consequently, the required coupling pressure at P2 and P3 must be increased.

An increase (packer inflation) is marked with an UP arrow. ↑

A decrease (packer deflation) is marked with a DOWN arrow. ↓

Figure 19: Pressure Display with P1 greater 0

In the example (MBAS 8 stations with 2m station distance), the pressure at P1 =1.41 bar. The recommended pressure at P2 is given with 1.41+1.6 bar = 3.01 bar and at P3:1.41 +0.8 = 2.21 bar (see table 2). Thus, one needs to apply air pressure through the main air supply until the actual pressure at P2 & P3 reaches the target pressure or coupling pressure.

One can adjust the pressure through the valves #5 and #7 shown in figure 16.

As long as the arrow shows ↑ one can increase the pressure. Adjust slightly only.

If the arrow shows ↓ one has to release air pressure. Do not over pressure. There is a distinct flexibility on the packers but one should not go to more than **0,2 to 0,3 bar over rated pressure** !

4.3 Connection to the seismograph

Outside the control unit a connector to the seismograph is mounted. This is a 55pin male socket connector.

Figure 20: 55 pin socket at the control unit

A connecting cable is supplied terminated with a 55pin female connector to the seismograph matching connector.

Figure 21: Connecting cable to the seismograph

5. Maintenance

- Seismic sensors do have a natural frequency of 10Hz +/- 2.5%. Coil resistance is 375 Ohm +/- 2.5% with a spurious frequency of larger 240Hz.

Figure 22: Pressure sensor

- **Pressure sensor P1** is located at bottom station. Special care has to be taken to avoid blocking the pressure sensor by mud. Clean the opening but do not touch the sensor surface in any case.

- Grease O-rings at split station each time.

6. Handling instructions

6.1 Cable:

- Do not bend seismic cable below a radius of 15 cm. This applies even if the stations are placed on the ground.
- Do not cut cable.
- Do not override.
- Use a tripod or a suitable clamping device to lower the MBAS-A system into the borehole.

Figure 23: Handling in field

- If there is sufficient space in the field, we recommend that the MBAS stations are placed straightened on a level surface.

6.2 Battery charging

- Charge internal battery using the provided charger.

6.3 Stations packer

- Do not over pressure the packer of the stations. There is a distinct flexibility on the packers but one should not go to more than 0,2 to 0,3 bar over rated pressure !

6.4 Cleaning pressure sensor opening

- Do not touch or mechanically clean the sensor face in any case.
- Use water to clean the bottom cap and sensor.
- You may remove the brass screw for better cleaning.