Manual
for
P-wave sparker SBS42
and
S-wave source BIS-SH

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Borehole Sources SBS-42/BIS-SH
and
Impulse Generator IPG5000

Operating and Maintenance Manual

Precautions
for
Operation of high voltage equipment type SBS42 and BIS-SH

Like other seismic sources as explosives, air guns or weight dropping systems, operating of an electrical spark or other high-voltage impulse sources requires several precautions. The most important precautions are:

1. **Impulse generator operation only by authorised personnel.**
2. **Do not connect or disconnect cables whilst impulse generator is switched ON. Switch OFF impulse generator before disconnecting cables or connectors.**
3. **Do not touch cables while the impulse generator is in operation.**
4. **Ground the impulse generator by means of grounding hook before switching ON.**
5. **Do not expose impulse generator or connectors to water or dust.**
6. **Do not charge impulse generator over 5.300 V !**
7. **Do not open impulse generator or remote control. Maintenance has to be carried out by authorised personnel.**
8. **In case of any malfunction or emergency switch OFF impulse generator by pressing the red OFF button at generator or turn key switch OFF at remote control.**

Moreover observe the following:

- Check cables and connectors before and after every field survey for damage.
- Do not use damaged cables.
- Do not open the impulse generator if connected to power source.
- Any repairs or maintenance work has to be carried out only by authorised personnel.
- All connections should be **dry** to avoid a flash over inside the connector.
  Take care that no water e.g. rain can get into connectors.
- If an impulse is released without a spark action the cable can be charged with high voltage like a small condenser. This energy has to be discharged by switching OFF the impulse generator. Check this by observing the HV-meter. Wait until the voltmeter at impulse generator shows a voltage of nearly 0 volt!
- High voltage discharges slowly (about 1 - 2 minutes). Wait until the voltmeter at impulse generator shows a voltage of nearly 0 volt!

1. Impulse generator

The impulse generator IPG5000 is the high voltage power supply to the seismic sparker probe SBS42 or BIS-SH. Figure 1 shows the impulse generator and its remote control RCU.

Fig. 1: Impulse generator IPG and remote control unit RCU.

The IPG5000 needs to be powered by external 230 V / 50 Hz or optional 115 V / 60 Hz. If voltage drops below 210 V the system is not operating. Output energy of the IPG5000 is 1000 J @ 5000 V.

Impulses can be released in single or continuous mode either by using the remote control unit RCU or by using the controls at the IPG5000 control panel. The HV-output has no direct contact to the generator housing, i.e. the terminals +HV and -HV are connected to housing and ground via two resistors of 15 MΩ each.

To prevent electromagnetic interference the generator should be operated in a certain distance to the seismograph. Avoid crossing cables.

Attention:

- **The impulse generator must be protected from any wetness, e.g. rain and dust!**
- **Before switching "ON" the ground terminal of generator must be connected to ground using the grounding hook via the yellow-green cable. If the ground is very dry add water to the grounding hook to enable a good soil contact.**

1.1 Connections at IPG5000 and set-up

Following accessories for operation of the impulse generator are delivered:

1. Grounding hook with cable (colour yellow/green)

2. Power supply cable (grey) with connector (type suitable to national standards)

3. Remote control unit with cable (black)

4. High-voltage surface cable (big red cable) for connection between impulse generator and borehole cable having a length of approx. 6 m equipped with a coaxial quick connector (sleeve part) for connection to surface connector of the borehole coaxial cable.

Please follow the instruction below to connect cables to IPG5000.

- ➔ Connect the cables to the IPG5000 is in same order (from 1 to 4).
- ➔ Do not connect power cable to external power supply. This shall be done at last after setting up all other connections.
- ➔ Disconnect the cables from the IPG5000 is in same order (from 4 to 1) but switch off unit first and disconnect VAC.
- ➔ NEVER disconnect while under operation or while the unit is charged.

Next, the borehole probe SBS42 or BIS-SH can be connected to the IPG5000 through the big red HV cable (see chapter 5.3/5.4).

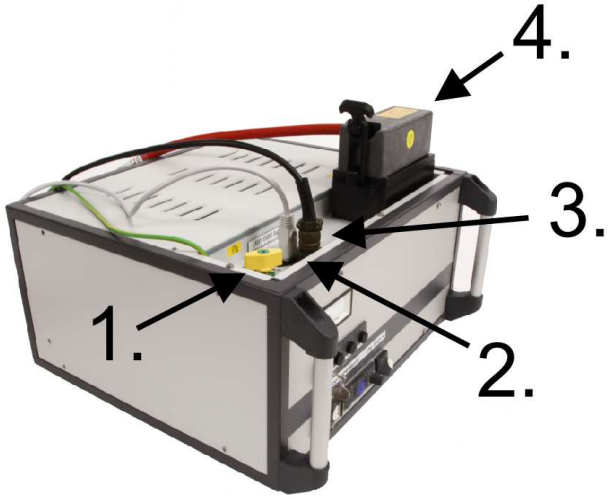


Fig. 2: Cable connections at IPG5000

Fig. 3: Details of connecting points at IPG5000 rear side

Fig. 4: Rubber fixation of HV connector at IPG5000

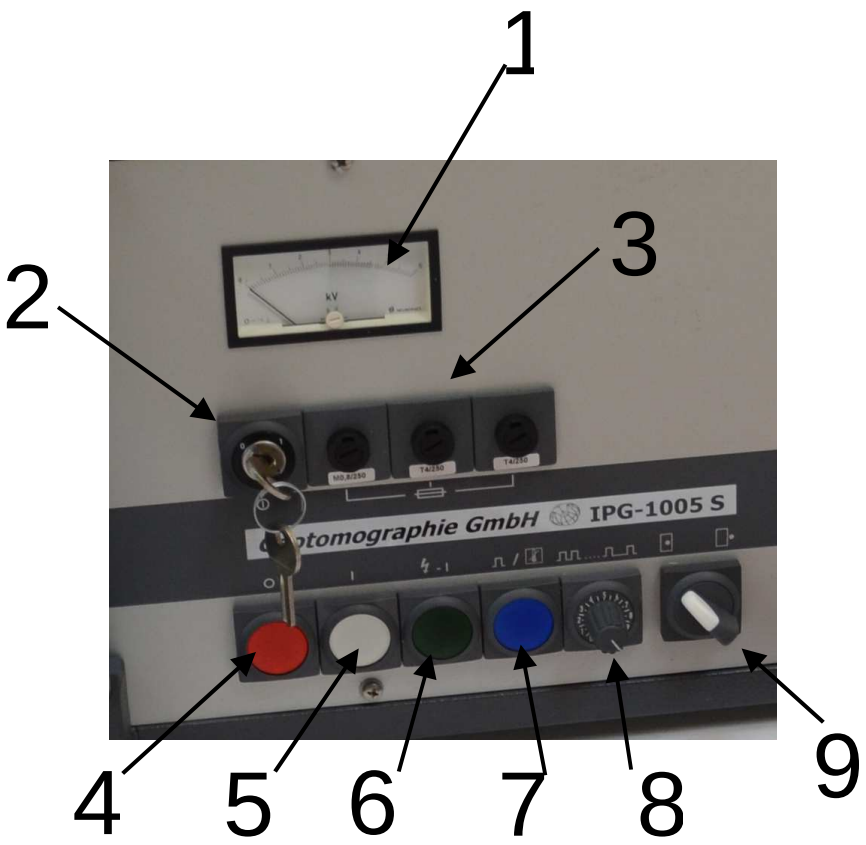


Fig. 5: Control panel at IPG5000

At the front panel of the IPG5000 several control and push buttons are available (see Fig. 5).

1. Voltmeter
2. Key switch (0=OFF, 1=ON)
3. Fuses (from left to right with 0.8 A, 4 A, 4 A)
4. EMERGENCY OFF
5. Voltage (230V) switch ON
6. High-Voltage switch ON
7. Single release button (only available for internal operation)
8. Shot sequence timer (fully left for single shots, fully right for 10 s shot release, all other positions intermediate shot timing)
9. INTERN/EXTERN switch (to left = INTERN, to right = EXTERN for remote unit controlled operation)

On emergency situations switch OFF the IPG5000 using the key switch (2) or press red push button (4).

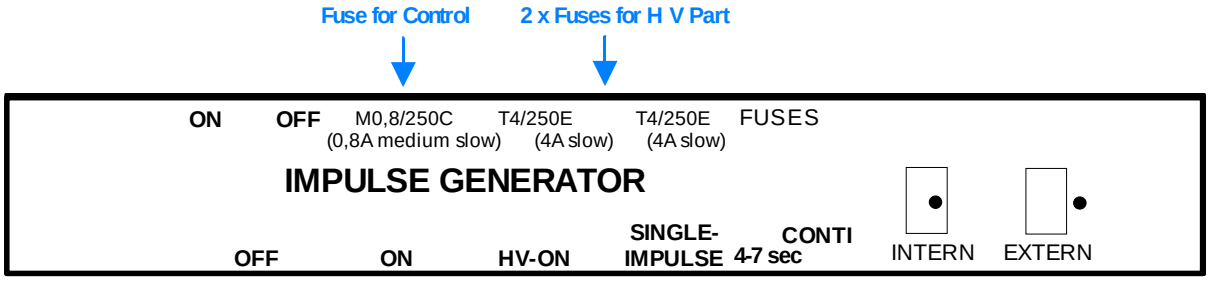


Fig. 6: Schematic diagram of the control panel at IPG5000

If all connections to IPG5000 are made, the remote control unit is connected AND the source is connected and inside borehole one can start the high voltage charging.

➔ **The switching ON sequence at the IPG5000 control panel is as follows:**

1. Key switch to “1” (same at remote control unit)
2. Switch shot control at remote control unit to SINGLE
3. If external VAC is available the white push button lights
4. Press white push-button (5)
5. Green push button lights
6. Press green push-button (6)
7. High voltage charging starts
8. Avoid charging above 5300 V. Switch OFF if charging is above and adjust VAC supply

Connection to downhole probe is established through the “quick” connector at the big red HV cable. Just push in the probes coaxial cable connector and screw tightly.

Fig. 7: Connection between coaxial cable and big red HV cable at IPG5000

2. Remote control unit

The remote control unit fulfils following functions:

1. Switching ON the IPG5000
2. Emergency OFF for interrupting any operation
3. Shot release in SINGLE or CONTINUOUS mode
4. Impulse counting of released shots
5. Trigger signal output to seismograph

The remote control unit is connected to the IPG5000 by one cable. All electronic circuits of the remote control unit (excepted the trigger circuit) are supplied by 24 V delivered by the impulse generator via the cable.

The trigger circuit is supplied by a battery of 9 V.

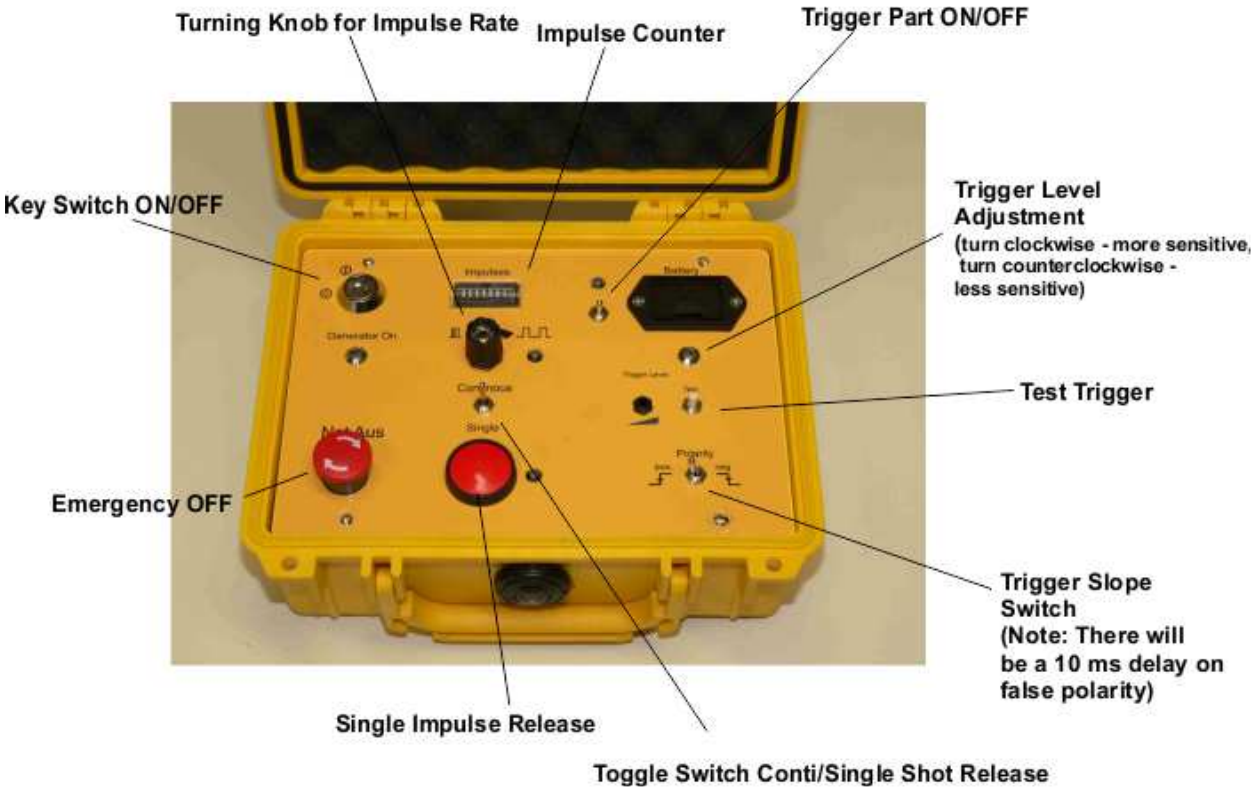


Fig. 8: Controls at remote control unit

Fig. 9: Rear side of RCU with banana trigger and connector to IPG5000

2.1 Function and operation of the remote control unit

To use remote control mode, the switch at the IPG5000 has to be set to position EXTERN. Remote Control is sub-divided into three panels.

2.1.1 Generator control (left panel at remote unit)

The key switch at the remote control unit must be set to "1" to start operation at the IPG5000. Further, the EMERGENCY button must be in UP position.

In emergency case press "EMERGENCY OFF" button or switch to "0" the key switch.

2.1.2 Impulse control (middle panel at remote unit)

The remote control unit is equipped with a counter for counting impulses. Shots can be released in continuous or single mode.

To release a single shot switch to "Single" and press the red button shortly.

The red LED (on right panel of the control unit) lights shortly on triggering.

For starting continuous impulse operation switch to "Continuous". You may select faster or longer impulse rates by turning the turning knob. After a delay of several seconds the first impulse (shot) will be released if "Continuous" was selected. The impulse rate can be selected by the controller between about 4 and about 9 seconds.

Continuous shot operation is stopped by switching to "SINGLE".

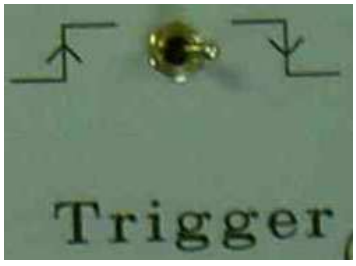
2.1.3 Trigger (right panel at remote unit)

For trigger operation switch ON toggle switch. A red LED indicates the trigger circuit is ON.

The signal level of the impulse reference signal, transmitted from impulse generator, can be adjusted by means of the trimmer Trigger LEVEL. Turn to right to make trigger more sensitive and turn left to make trigger insensitive. Anyhow, the level is already adjusted. New adjustment should only be carried out be well experienced users.

To test correct triggering of the seismograph one can push the “Test” button.

Trigger impulse polarity can be selected positive raise or negative raise by means of the switch. Polarity setting has effect on trigger output. If a seismic recorder needs a short circuit for triggering down going slope has to be chosen (from high to low).



Trigger polarity (TTL Active Low = right switch position, TTL Active High = left switch position)

3. Downhole equipment

The IPG5000 outputs its energy to the borehole sources SBS42 or BIS-SH.

The borehole source SBS42 generates compressional waves (P) in water filled boreholes. Energy released by the IPG5000 discharges through a coaxial cable terminated by two adjacent spark electrodes placed in a water filled chamber. The spark discharge vaporizes the water by high pressure plasma. This generates vapour bubbles which expand and collapse, thereby generating high-frequency seismic waves.

The borehole source BIS-SH generates horizontally polarized shear waves (SH) and compressional waves (P). The source works in dry or water filled boreholes and can be used in vertical or horizontal boreholes. Energy released by the IPG5000 discharges through a system of electromagnetic coils adjacent to a copper plate. When the plate is rejected a mechanical impact to the borehole wall is generated. The borehole source is coupled to the borehole wall by a pneumatic clamping system (inflatable bladder). The orientation of the source is controlled from surface by a torsional stiff hose.

3.1 P-Wave probe SBS42 (sparker)

The downhole sparker probe SBS42 consists of the probe head, an exchangeable spark electrode and the housing (see Fig. 10).

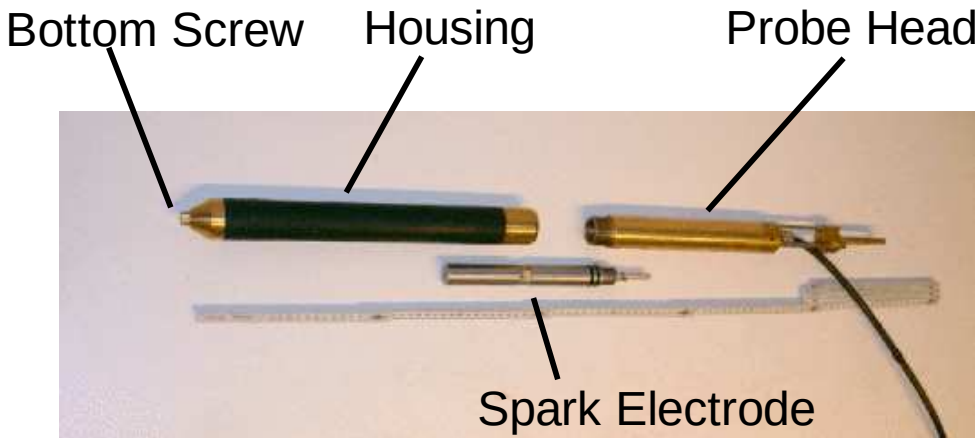


Fig. 10: SBS42 downhole probe

The probe head connects the probe electrically with the coaxial HV cable. The exchangeable electrode is a high duty long life spark electrode made of stainless steel and a tungsten-copper alloy inner electrode. The housing is made of a plastic tube with a rubber protection around. Openings made in the plastic tube allow an omnidirectional pressure release into the rock formation. The lower end is sealed by a bottom screw.

The housing can be filled with water through the bottom screw thread. Just remove the screw and fill with water. You may add some salt to the water to increase electrical conductivity (1/2 table spoon to 500 ml water). Close bottom screw. In case the water conductivity is low enough that a spark is generated you may also just remove the bottom screw and lower the probe below the water table. After a few seconds the housing gets filled with water.

A small amount of gas produced by the effect of electrolysis of the current impulses pass slim channels and can escape the probe through openings in the probe head.

The spark electrode is constructed for long-time operation and has a total working life of several thousands of shots. It is recommended to flatten the front electrode surface after about 1000 to 2000 shots using a mechanical file tool.

In case of a replacement of the electrode make sure system is switched OFF. Hold electrode downwards while replacing to avoid water migrating into the probe head. Put grease only on O-rings.

Grease spark electrode O-rings only. Do not grease the spark electrode thread.

If the sparker probe is filled with water do not shot in free air. Due to lack of sufficient static counter pressure the rubber hose can be overloaded by to large

extension. For this reason the minimum operation depth should be no less than about one meter below water table.

The rubber tube section can be dismantled for repair or maintenance works, e.g. of the spark electrode.

3.2 S-Wave probe BIS-SH

The BIS probe consists of the probe head, two half sleeves, the rubber protected and sealed active probe part, an air packer and the lower probe part (see Fig. 11).

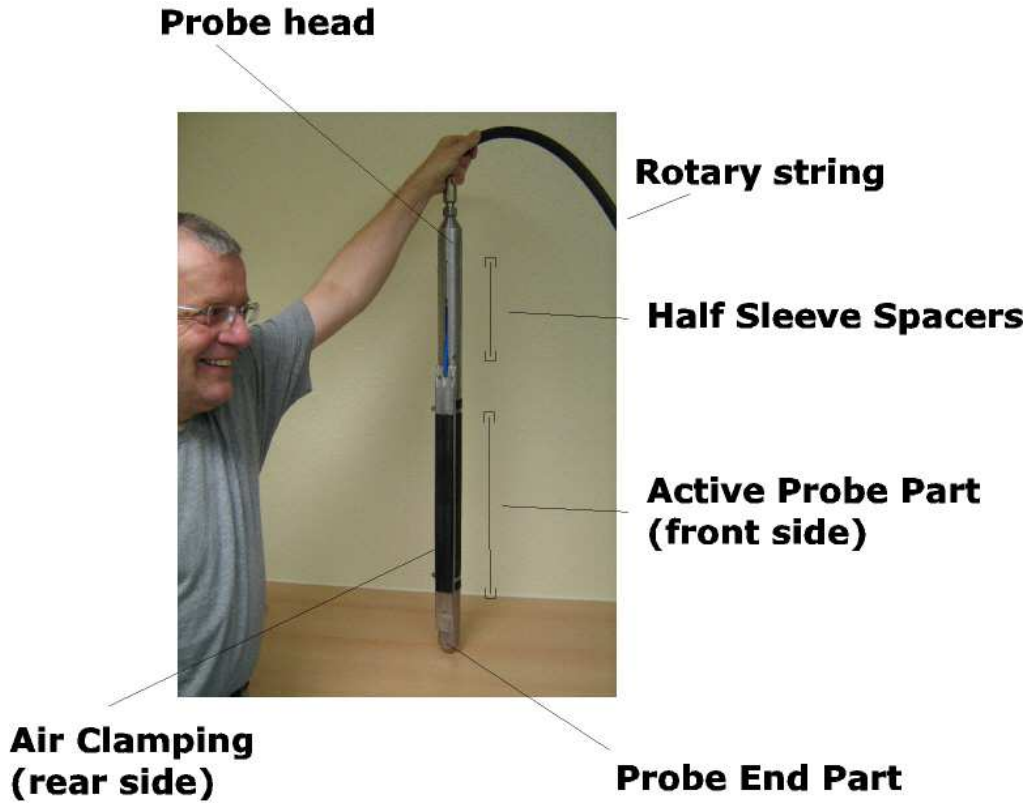


Fig. 11: BIS-SH downhole probe

The probe head is connected to the rotary pipe string. Always check this connection if tight. The rotary pipe string has three functions, i.e. to (1) protect the inner coaxial cable, to be used for orienting the source (2) and to guide air to the packer (3).

The two half sleeves connect the probe head to the active probe part. To maintain cable connection (cleaning) and to connect/disconnect air hose one may open one side for operation (see Fig 12.).

The active part of the source contains a seismic source working after the eddy current principle. A high duty rubber tube (3 mm wall thickness) protects the HV part from water and dust.

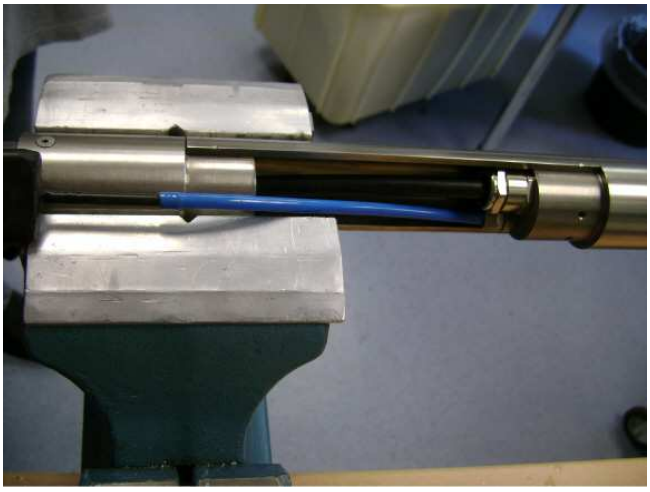


Fig. 12: Half-Sleeves with HV cable and pressure hose connector

The probe active probe part (shooting direction) needs to be aligned to the rotary string marking (see Fig. 13).

Fig. 13: Rotary string alignment (points towards shooting direction)

Fig. 14: Rotary string depth markers

The air clamping part can easily be removed by unscrewing from the active part.

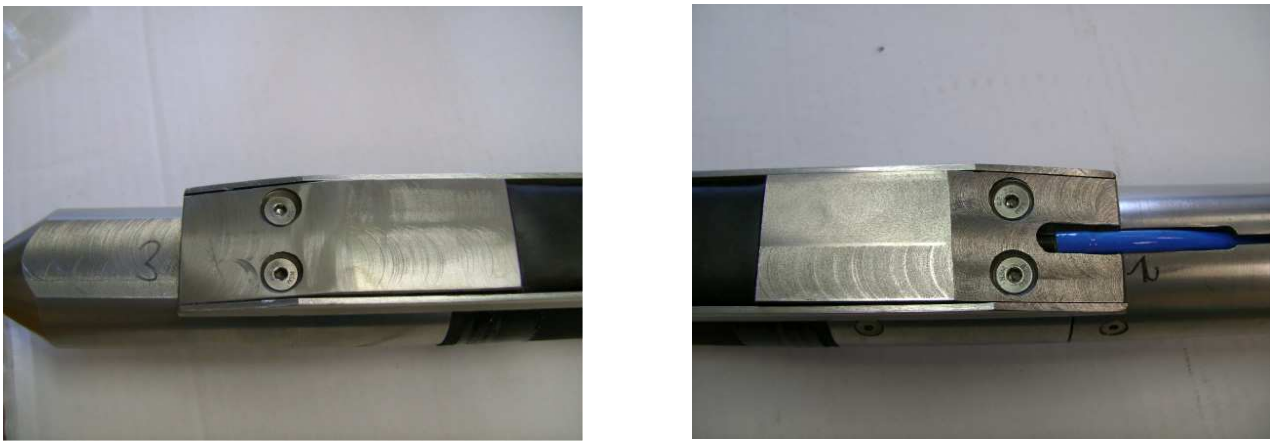


Fig. 15: Unscrew to replace air bladder

The BIS-SH probe can work in water filled and dry boreholes.

Anyhow, while working in dry holes inner temperature of the coil system raises fast up (to 100°C). Make sure that no overheating occurs (for example: after a 30...50 shots in continuous mode without stopping). On normal operation (5 stacks per direction) no overheating should occur.

Check rubber tube at active probe part regularly. If rubber is damaged water might migrate into the coil system. This causes a short in the coil system and leads to a total damage of the inner coil system.

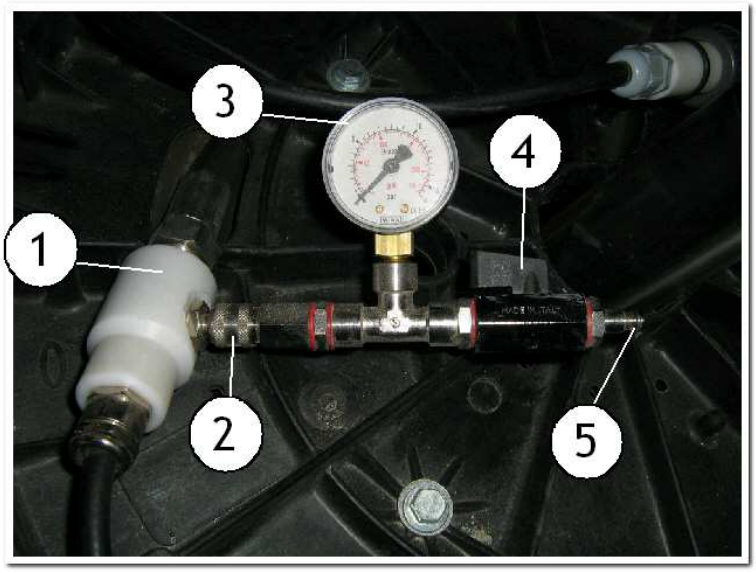


Fig. 16: BIS-SH surface splitter arrangement

The borehole rotary string ends in a white plastic cylinder typically directly mounted on the drum (see Fig. 16). This end terminator splits off the HV cable and the air connection (to inflate the BIS-SH packer).

The description of Fig 16 is as follows:

1 : Splitter
2 : Push-Pull connection at valve-gauge adapter
3 : Pressure gauge
4 : Valve
5 : Connector to air pump

A special adapter with gauge and valve can be connected to the air-in connector. It's a push-pull connection at the gauge-valve adapter. An air pump is provided to inflate the packer for clamping the source to the borehole wall. Also here it's a push-pull connection.

Once air pressure is applied to inflate the packer close the valve and disconnect the air pump. Without disconnecting air cannot being released. Keep the push-pull connectors always clean!

4. Operation and maintenance instructions

4.1 Impulse generator and remote control unit (surface equipment)

4.1.1 Preliminary works

→ Plant earth hook to ground. In case of dry soil pour some water around the spike to improve conductivity. Connect earth hook with green/yellow cable to impulse generators ground (rear side).

→ Accomplish all cable connections for surface and subsurface equipment according to the instructions

→ Connect AC power cable (but do not switch on the AC generator till the end of all preparation operations)

→ Put downhole probe into borehole and fix with clamping device.

4.1.2 Impulse operation control (EXTERN) - controlled by remote unit

- Key switch at remote control unit to “1” and emergency button is UP
- Set toggle switch at remote control unit to SINGLE
- Switch trigger on at remote control unit and set trigger type (low, high)
- Connect the impulse generator to mains or other AC-current source
- White lamp lights and indicates readiness for switching on the IPG5000
- Switch to EXTERN () at IPG5000
- Set key switch at IPG5000 to “1”
- Press white push-button (green lamp lights).
- Press green push-button at IPG5000

  (Now, the high voltage circuit is switched-on internally and charging of the condenser bank is started (see voltage meter). The Impulse generator is ready for impulse operation by remote unit controlling.
- System is ready to work
- If SINGLE shot release is set at remote unit press red button at middle remote unit panel to release single shots.
- If CONTINUOUS shot release is set at remote unit shots are automatically released. You may set repetition rate at turning knob.
- Stop continuous shooting by switching to SINGLE.

4.1.3 Impulse operation control INTERN

When using the generator without operation from remote control, following steps have to be carried out:

- Follow steps described under 4.1.1
- Shot sequence timer at impulse generator for select shot cycle rate fully left!
- Switch toggle switch at impulse generator to INTERN ( )
- Switch key switch at IPG5000 to "1"
- Press white push-button ON at IPG5000
- Press green push-button HV-ON (impulse generator charges now)
- You may release single shot by pressing the blue push-button shortly !!!

Note: As long as you press the blue button impulse generator discharges via downhole cable! Danger, do not touch any parts of the downhole probe or electrically connected parts to it.

- Alternatively, you may release continuous shots by selecting an impulse rate at shot sequence timer
- For shut down press red button OFF or use key switch.

4.1.4 Setting OFF operation

- Turn key switch at remote control unit to position "0".
- Alternatively and equivalent
  - press red button at impulse generator
  - press emergency button at remote control unit
  - switch key at IPG5000 to position "0"

4.2 SBS42 probe (sparker)

Before starting any maintenance work make sure the probe is disconnected from IPG5000.

In case of a damaged housing rubber tube, the electrode sparker function is not disturbed under normal conductivity conditions of the borehole fluid (water). Anyhow, the rubber hose can be easily exchanged.

Do not use probe without housing.

It is recommended to flatten the front electrode surface after about 1000 to 2000 shots using a mechanical file tool.

Check coaxial cable for damages, i.e. breaks and cuts. Do not pull cable over sharp edges. Do not drive over cable or step on it.

To repair such cable damages for short time wind some self-vulcanic tape or insulating tape around the damaged spots to avoid a penetration of water.

For checking cable isolation use a multi-meter.

4.3 BIS-SH probe

Before starting any maintenance work make sure the probe is disconnected from IPG5000.

Check rubber tube for damages.

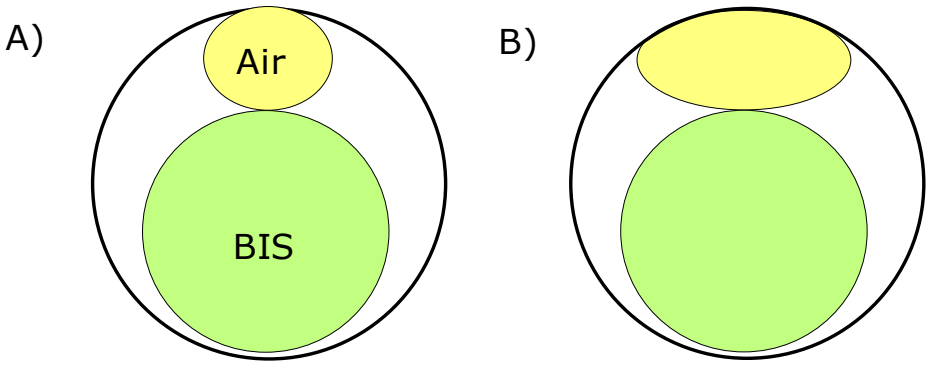
Do not work with damaged rubber tube.

Avoid extensive shooting in dry boreholes as the probe might heat up quickly.

4.3.1 Clamping pressure for BIS-SH probe

The BIS-SH source needs proper clamping to generate good quality shear waves. Please follow suggested procedure:

- Put the source in the boreholes only say half a meter and fix at surface.
- Pump air to the source and stop if the bladder reaches the casing. Check that pressure (A).
- Add about 0.8 to 1 bar more for full clamping (B). Remember that pressure. This is the clamping pressure in the borehole under atmospheric conditions. Below water table you have to add hydrostatic pressure (1 bar = 10 m).



Example:
(1) Water table at 5m
(2) Clamping pressure at surface measured with 1.6 bar
(3) BIS-SH at 20 m depth (equal to 1.5 bar water pressure)
(4) Clamping pressure at 20 m is 1.6+1.5=3.1 bar

4.3.2 Orienting the BIS-SH probe

The BIS-SH generates SH waves. These waves have a particle motion perpendicular to the propagation direction. The propagation direction is assumed to be the line direction from borehole to borehole. Thus, the source strike direction shall be perpendicular to that (see Fig. 17).

The rotary pipe string is used to orient the source. It is recommended to align the marking of the pipe string -/+ 90° to the line direction between boreholes.

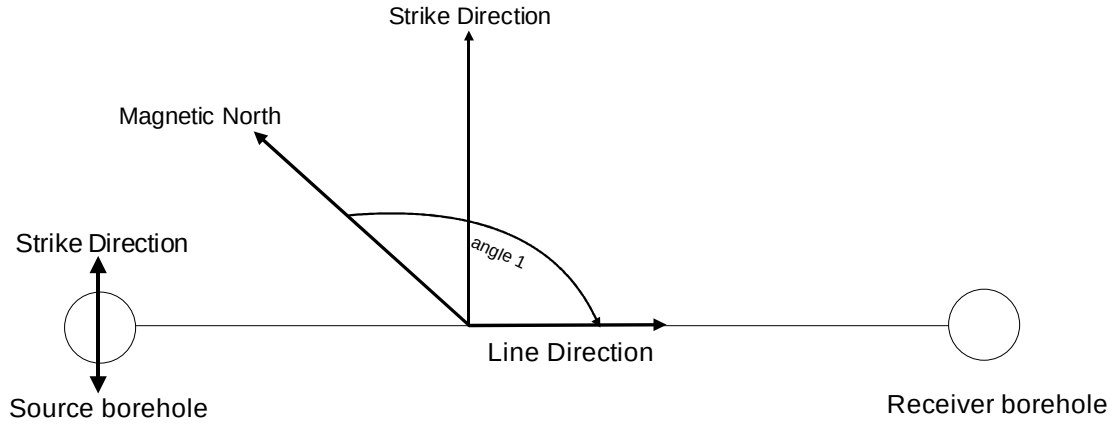


Fig. 17: Orienting the BIS-SH

Once the rotary pipe string is rotated clamp the string using a work bench (see Fig 18).

Fig. 18: Fixation of the BIS-SH using the work bench

4.4 Surface cable and quick connector

Keep connectors away from dust, moisture and water.

Do not bend the cable in strong manner.

Insert plastic seal plug into the quick connector after disconnection.

5. Trouble shooting

If at any time function at remote unit or impulse generator do not work switch off system and disconnect from AC power.

5.1 Check triggering

Switch ON trigger at remote control unit. Red LED should light.

Check 9 V battery if fresh. False triggering might occur on low battery.

Connect trigger to seismograph and arm seismograph.

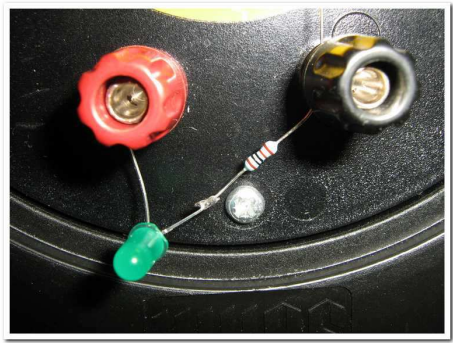
Press “Test” button at remote control unit. Red LED should flash. Flashing indicates that a trigger pulse is sent out. In principle the LED should flash once a real shot is released too.

If the LED flashes only if “Test” is pressed but it is not flashing if a shot is released you have to adjust the trigger level at the remote control unit. Use a small screw driver and turn to more sensitive level (see fig 8.). Adjust the level while shooting with the SBS42 or BIS-SH.

If LED flashes red but no trigger is received by seismograph check the trigger cable connecting seismograph and remote control unit (cable might be broken).

Last but not least you may check the output of the banana plugs itself if a trigger is outputted.

Instruction: You will need a resistor of R=1 kOhm and a red or green LED. Remember the long leg of the LED is the Anode (+). On the remote control unit...the red banana plug is (+) and the black banana plug is (-). Red LED is always better visible! Release a test trigger and check whether the LED flashes or not.



If finally all efforts fail to get a trigger signal out of the remote control unit there is a very last chance of getting a trigger signal. Take a 1 m isolated copper wire and wind 4 … 6 times around the big red HV cable coming from the IPG5000. Connect both ends to the input of your seismograph. Check if this works. Note, the more windings the more voltage! Be careful not damaging the trigger input of your seismograph.

5.2. SBS42 test arrangement

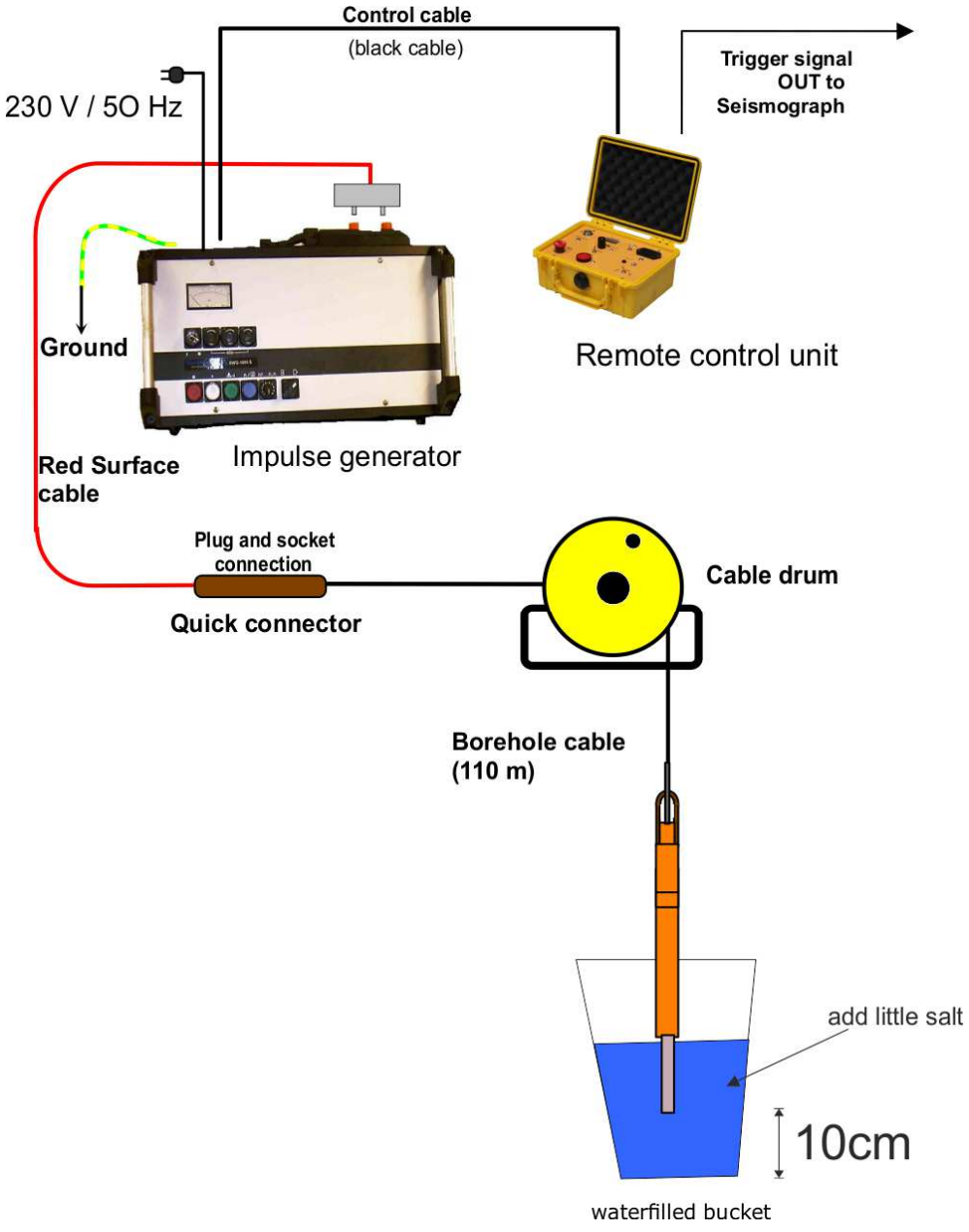
To check if the system works one can perform a small “water bucket” test at surface.

Please be careful and stay away while the system is operating.

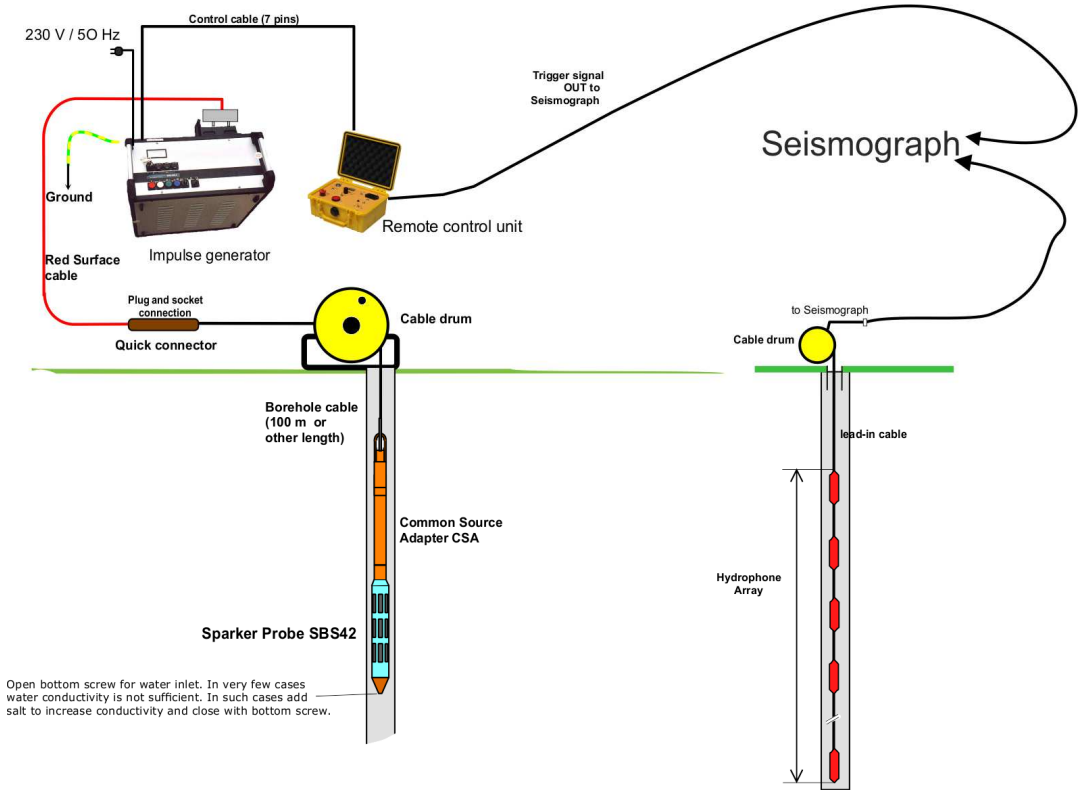
Do not perform the test indoor as the bucket might break and water will flow out.

You can remove the housing from the SBS42 probe. Be careful do not touch un-isolated parts.

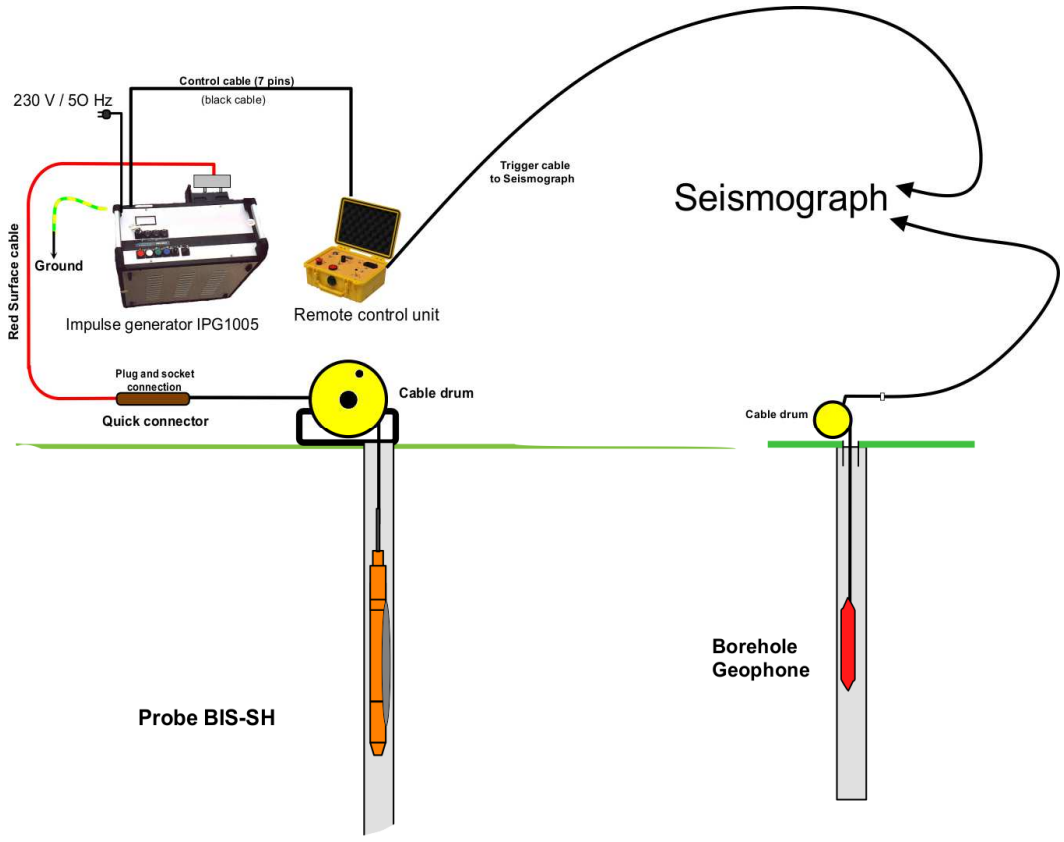
Make sure the electrode tip is about 10 cm above the bottom of the bucket and away from the sides.



5.3. Tomography arrangement



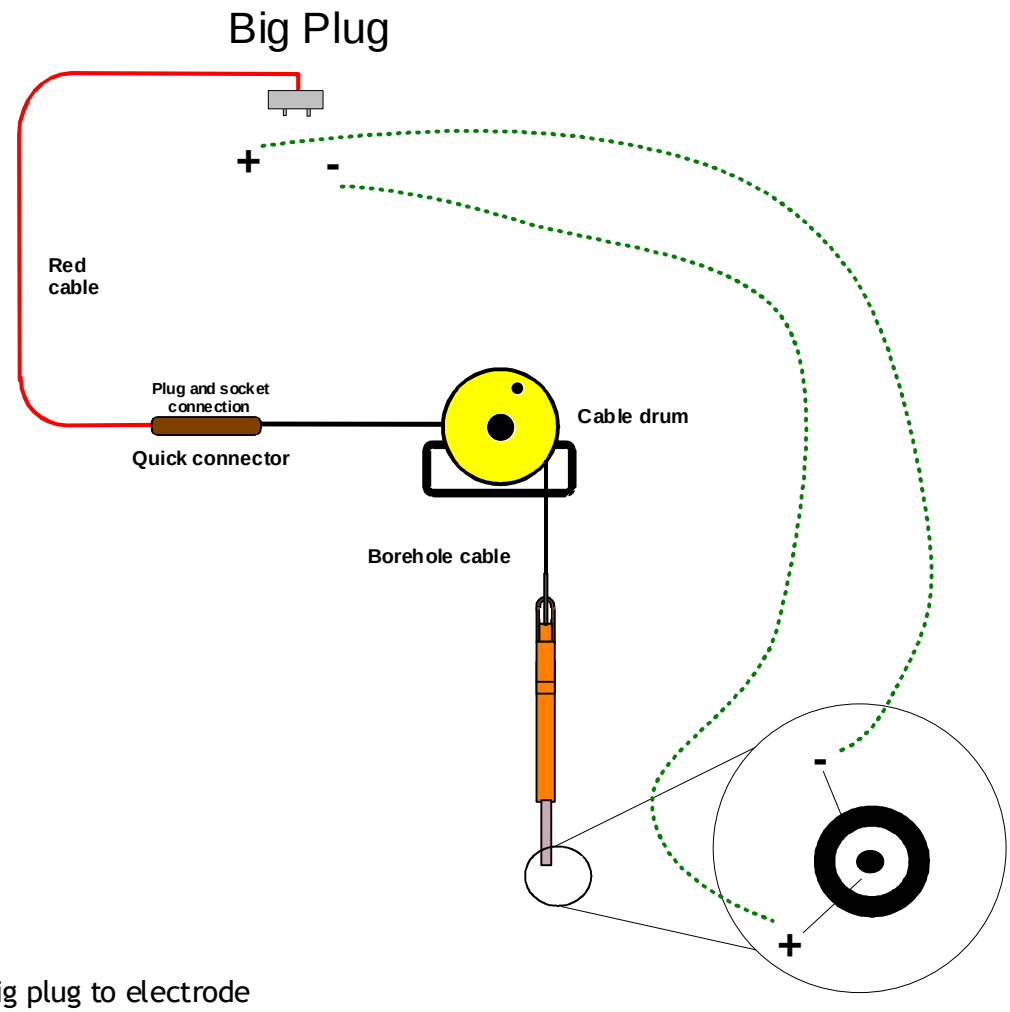
5.4 Crosshole arrangement



5.5. General checks

Check all cable connections if pins are in correct position and no pins are broken or has not correct length.

Check continuity of all cables.



Big plug to electrode
1. Measure continutity between each +/- pole
2. Cross-check with the other pole

Quick connector to Electrode
1. Measure continutity between each +/- pole
2. Cross-check with the other pole

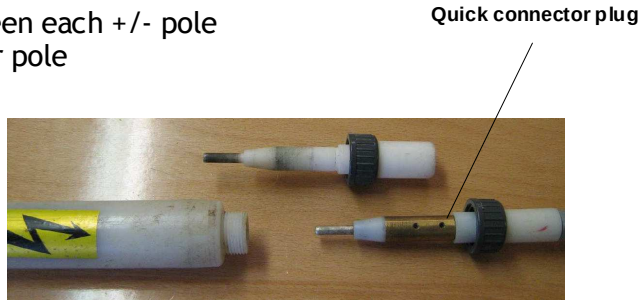


Fig. 19: Check continuity for SBS42

Case 1: IPG5000 does not charge (operated in extern mode)

- Check VAC supply voltage if perhaps too low.
- Check fuses if OK.
- Key switches all to "1"?
- Emergency button UP at remote control unit?
- Big connector properly fixed with rubber at IPG5000?

1. Green lamp lights continuous.
2. Switch to INTERN and try again.
3. Still NO, disconnect remote control cable from IPG5000 and connect blind plug. Try again.

Case 2: IPG5000 does not discharge

This is a typical case if no spark can happen (for SBS42) because there is a too high resistance.

- Check if all connections are established and OK
- Perform test described under 5.2 by adding salt to water
- Check continuity shown in Fig. 19
- Check cable if cutted