

Final Required VBB Borehole Seismometer Specifications

October 22, 2014

Number	Specification Type	Specification Name	Required Specification
1	Operating	Passband (-3dB points between which response shall be flat to earth velocity)	0.00278 to 50 Hz
2	Operating	Passband ripple between -3dB points	Less than 1dB rms
3	Operating	Amplitude response shape at low corner frequency	Damping factor 0.707. Slope at lower frequencies not greater than 12dB/Octave; simple response function such as complex conjugate pair with 0.707 damping
4	Operating	Amplitude response shape at high corner frequency	Damping factor at least 0.35, slope at higher frequencies not greater than -24dB / Octave; simple response function such as complex conjugate pair with 0.707 damping
5	Operating	Noise level for vertical component	≤GSNNM (vertical noise) in the frequency band from 0.0005 to 2 Hz (for GSN Noise Model, see Berger, J., P. Davis, and G. Ekström (2004). Ambient Earth noise: A survey of the Global Seismographic Network, Journal of Geophysical Research 209, B11307.). ALL special installation methods, materials, or configurations required to demonstrate the required noise levels shall be supplied by the vendor with the prototype.
6	Operating	Noise level for horizontal components	≤ USGS NLNM 0.005 to 5 Hz (Low self noise per Ringler & Hutt, 2010, SRL Vol 81, No 6).
7	Operating	Sensitivity of horizontal components to barometric air pressure changes	<1.0E-7 m/s/s per millibar at 200 second period. Based on an input of 2 millibar p-p at 200 seconds period
8	Operating	Sensitivity of vertical component to barometric air pressure changes (excluding the effect of atmospheric gravitational attraction)	<3.0E-10 m/s/s per millibar at 200 second period. Based on an input of 2 millibar p-p at 200 seconds period
9	Physical	Case shape	Appropriate for installation in a round steel casing with 6.5" (165 mm) internal diameter. Edges of ends shall be rounded or beveled to prevent snagging on casing joints.
10	Physical	Maximum horizontal dimension	6.0" (152 mm)
11	Operating	Magnetic susceptibility	Less than 0.08 m/s ² per Tesla.
12	Operating	Components	Must produce 3 outputs that are mutually orthogonal within 0.6° and have available outputs for Z,Y,X (Vertical, North, and East) and U,V,W (selectable)
13	Operating	Accuracy of case alignment marks compared to horizontal sensing axes	At least one mark on the case shall indicate the sensitive direction of the horizontal component of at least one sensing axis or output axis to within 0.6°.
14	Operating	Orientation of sensing axes	Sensing axis orientations (relative to the local gravity vector) shall be as specified to within 0.6° when instrument is installed in a borehole that is inclined up to 5° from vertical.
15	Operating	Frequency of Parasitic Resonances	Outside of the passband
16	Operating	Output Seismic Signal	±20 V, differential, one output for each axis, flat response to earth velocity in the passband. This means that, when the voltage between the + and the - outputs are measured, the voltage can range from +20 volts to -20 volts.
17	Operating	Output Impedance of Output Seismic Signal	125 to 400 ohms, each line to system ground
18	Operating	Maximum Output Current of Output Seismic Signal	Greater than ±2 mA
19	Operating	Maximum Offset of Output Seismic Signal	Less than 1% of full scale (within ±200 mV)
20	Operating	Offset of Output Seismic Signal vs. Temperature	<10% full scale/°C (<2 V/°C)
21	Operating	Input Power Voltage Range	10 to 30 VDC unipolar (power source will have <3dB of ripple)
22	Operating	Power Consumption (Quiescent)	≤2 watts. Power consumption ≤10 watts is allowed for operating centering and levelling motors.
23	Environmental	Operational Temperature Range	-20°C to +60°C
24	Environmental	Storage Temperature Range	-40°C to +70°C.
25	Environmental	Temperature range over which no mass centering required	±2°C change from average operating temperature
26	Environmental	Borehole tilt	Seismometer modules shall be capable of being levelled when installed in borehole having tilt angles up to 5° and remain orthogonal and oriented accurately relative to the local gravity vector as specified under "Orientation of sensing axes" above.
27	Environmental	Corrosion resistance	Will withstand exposure to typical cased borehole environment (100% humidity, condensing) for at least the Expected Service Life of the unit.
28	Physical	Submersion	Shall be capable of operating submersed in up to 200 m of water, including connector.
29	Physical	Maximum operating cable length	Minimum 350 meters. For prototype, vendor shall supply 217m cable with seismometer connector, separate power connector (if sensor design requires it), and Q330 connector installed on cable.
30	Operating	Polarity of Output Seismic Signal	Positive for earth motion UP, NORTH, EAST
31	Operating	Mid-band sensitivity at differential output (V/m/s)	1200 V/m/s ±2%.
32	Operating	Clip level (peak)	≥20 volts
33	Operating	Clip Recovery Time	≤ 30 minutes. This is the amount of time it takes for the output voltage to become a linear representation of input ground motion within the passband after the output is saturated (clipped) by strong ground motion.
34	Operating	Intermodulation Distortion	≤-80 dB. This is tested by calibrating with an equivalent acceleration calibration input (resistive cal) using equal amplitudes of 1.00 + 1.02 Hz. The amplitude should be large enough to drive the seismometer output to at least 10% of full scale at 1 Hz. The specified number is the ratio of the peak amplitude of the 0.02 Hz signal to the peak amplitude of the 1.00+1.02 Hz signal at the seismometer output.
35	Operating	Mass position outputs	±10 volts
36	Operating	Mass centering	Shall occur upon application of a mass centering signal (Logic high signal). Logic High is defined as +3.5V to +5.0V, pulled high relative to ground for at least 2 seconds.

37	Operating	Seismometer Module Control Inputs	Active high logic levels to enable or initiate mass lock/unlock, module leveling, calibration, and/or mass centering, as appropriate or as required. Any control line that is left open (not pulled to ground) shall NOT invoke the command. Logic High is defined as +3.5V to +5.0V, pulled high relative to ground for at least 2 seconds.
38	Operating	Calibration Input	Calibration input required, with capability to calibrate all three components simultaneously and capability to calibrate each component separately. Calibrator input sensitivity: Shall produce an equivalent ground velocity or acceleration known to within 1% and shall be sufficient to drive seismometer output to at least 75% of full scale at 0.1 Hz with a current of ≤ 0.4 mA peak at ≤ 5 V peak input. If the calibration circuit has a non-flat response, this response shall be provided. Also provide built-in calibration capability capable of calibrating the sensor over at least the passband and at frequencies as low as 0.0005 Hz, controllable by user, with calibration drive signal provided for recording by user. Provide at least sine, step, and random calibration modes at amplitudes suitable for the dynamic range of the sensor. Provide an acceleration-equivalent and a velocity-equivalent calibration capability.
39	Operating	Calibration Enable	Calibration for all three sensor components will be enabled when Logic High is applied to the cal enable line. When calibration is not enabled, the calibrator input shall be disconnected. When calibration is not enabled, the calibrator input shall be disconnected.
40	Operating	Common Mode on Output	< 0.1 volt. Common mode voltage is any voltage that appears, with the same polarity, on both the plus and the minus sides of the differential output with respect to ground.
41	Operating	Sensor Ground	If the sensor design requires a sensor ground, and if the borehole casing is the desired grounding point, connection of the sensor ground to the casing shall not depend on contact of the sensor case with the borehole casing. It shall instead be implemented through the use of a separate ground wire that is connected to an appropriate ground.
42	Operating	Mean Time Between Failures (MTBF)	≥ 100 years. MTBF = (Sum over n units of uptime of each unit) divided by (number of failures), where n is large.
43	Operating	Expected Service Life (ESL)	≥ 20 years. ESL = time over which unit is designed to function reliably.
44	Operating	Mean Time To Repair (MTTR)	≤ 180 days after received by manufacturer. MTTR = (Sum over n units of downtime of each unit) divided by (number of failures), where n is large.
45	Operating	Warranty Period	≥ 2 years
46	Physical	Maximum height	39" (1 m). This is the height of the instrument not including connector and lifting hardware.
47	Physical	Maximum overall height including connector, lifting hardware, and other above-sensor hardware	12 feet (3.66 m). This overall height is limited by the mast height used in lifting the instrument and associated hardware.
48	Physical	Maximum weight	145 lb (66 Kg). This is the total weight of the instrument plus lifting hardware. Does not include cable or connector.
49	Physical	Attachment for lifting	Attachment point for 5/32" wire rope capable of withstanding 2000 pounds of tension.
50	Physical	Shock	When in shipping case, instrument shall survive a drop on any face or corner from a height of 2m onto a solid concrete surface. When not in shipping case, instrument shall survive shocks experienced in normal handling and installation.
51	Physical	Shipping container	Sufficient to withstand normal methods of international shipment and to protect instrument from its maximum specified shock rating. Use materials suitable for international shipments. Orientation during shipping shall not be critical.
52	Documentation	Documentation	Fully detailed documentation, including user's manual, drawings, and schematics. Provide individual channel responses accurate to 1% ampl & 1 deg phase within the passband. Installation instructions, operating instructions, mid-band sensitivity, and response poles and zeros shall be provided with the prototype. Detailed documentation includes all required info to connect, interface, operate instr. Also mech drawings of outer case & fittings (computer drawings) and electronic circuit schematics.
53	Operating	Remote lock/unlock capability	Capability to remotely command sensor to lock or unlock masses (if masses are required be locked and unlocked). May be done via logic enable line or by digital interface.
54	Physical	Module Interchangeability	For any up-hole equipment or modules (such as a control box or interface box), modules shall be interchangeable between sensors.
55	Physical	Handling equipment	Appropriately sized for packing for international air shipment. Manufacturer shall identify size and weight of all supplied ancillary handling equipment necessary for sensor deployment. Vendor shall supply handling equipment if government-furnished handling equipment is not sufficient for installing and retrieving instrument.
56	Physical	Removeability from borehole	Seismometer shall be removeable from borehole using either vendor-supplied handling equipment (if necessary) or government-furnished handling equipment. This means that the seismometer shall be designed to be removeable from the borehole if installed according to manufacturer's instructions.
57	Physical	Deployment manpower required	Not more than 2 people required to deploy seismometer in the borehole
58	Environmental	Electromagnetic Susceptibility and Immunity	Vendor shall use best practices in designing the seismometer for immunity to narrowband radiated electromagnetic energy, and shall provide a brief description of their mitigation measures.
59	Operating	Electronically retrievable sensor parameters	Manufacturer name, model number, serial number, and factory calibration parameters sufficient to reconstruct the sensitivity and transfer function of that particular sensor. This shall be done via a common digital interface such as RS422 or other interface capable of reliably communicating with the instrument through up to 200m of cable.
60	Diagnostic	Tiltmeter output	2-axis tiltmeter built into instrument with output available on digital interface.