STS-2 - High-Performance Portable Very-Broad-Band Triaxial Seismometer

world-standard, field-proven - 145 dB dynamic range - mutually-aligned 3-components - robust locking - low power - wide temperature range without adjustment

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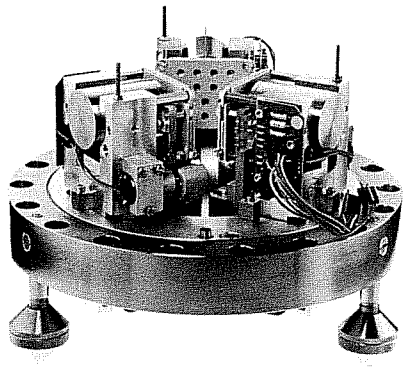
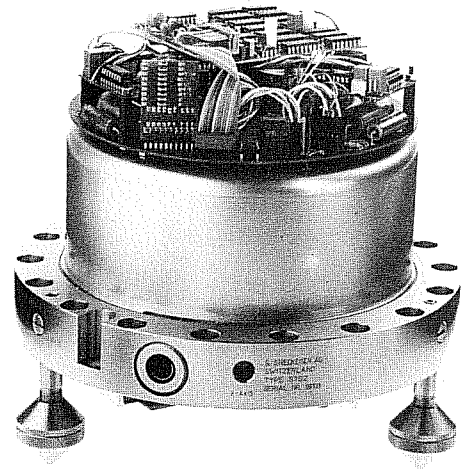
STS-2 PORTABLE VERY-BROAD-BAND TRIAXIAL SEISMOMETER





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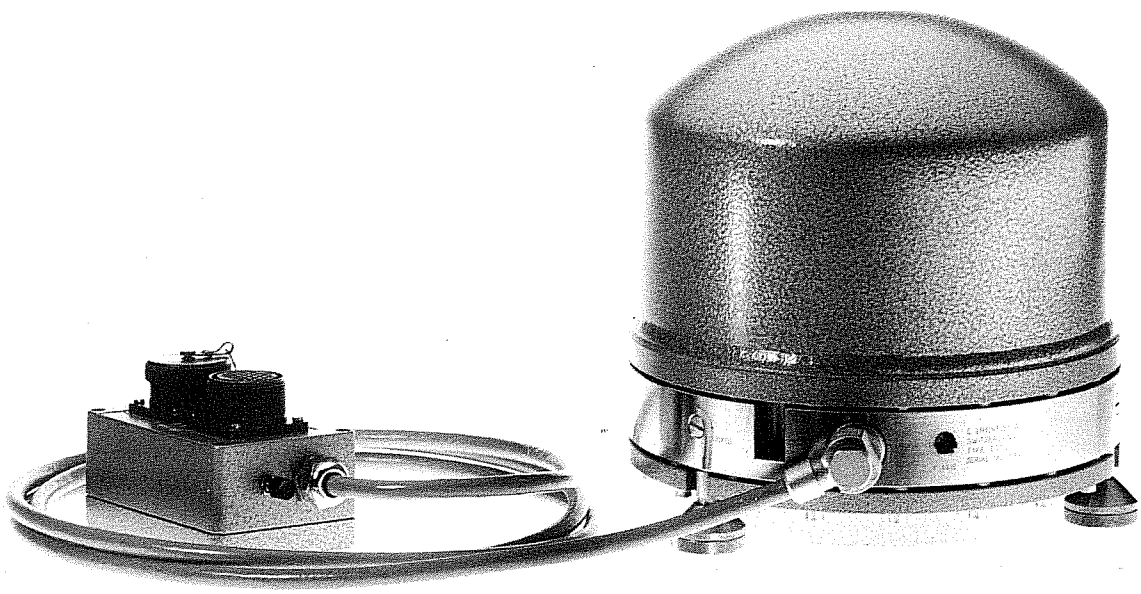


STS-2 SEISMOMETER COMPLETE WITH "HOST-BOX"

FEATURES

The main features of the STS-2 seismometer are:

Bandwidth suitable for general-purpose teleseismic and regional recording: corners at 120 sec and >50 Hz

Small size (235 mm dia. x 260 mm) and low power consumption (< 1.8 W)

The STS-2 is a single sealed, all-metal tri-axial sensor package that includes all essential electronics

Quick installation and setup using no special tools or instruments. Setup features include a built-in bubble level, an automatic recentering circuit, and conversion to 1-second free period operation to reduce transient response time during centering and levelling adjustments

Wide temperature range operation: minimum ± 10° C without recentering

Robust transport locking mechanism actuated by rotation of an externally accessible screw for each sensor without opening the sealed sensor package

Enhanced resolution of short periods using a capacitive displacement transducer

Strong electromagnetic feedback giving high dynamic range in the mid-frequency range of 0.1 - 10 Hz, where local and regional events generate high peak amplitudes

No external pressure shielding required for most broad-band and long-period applications

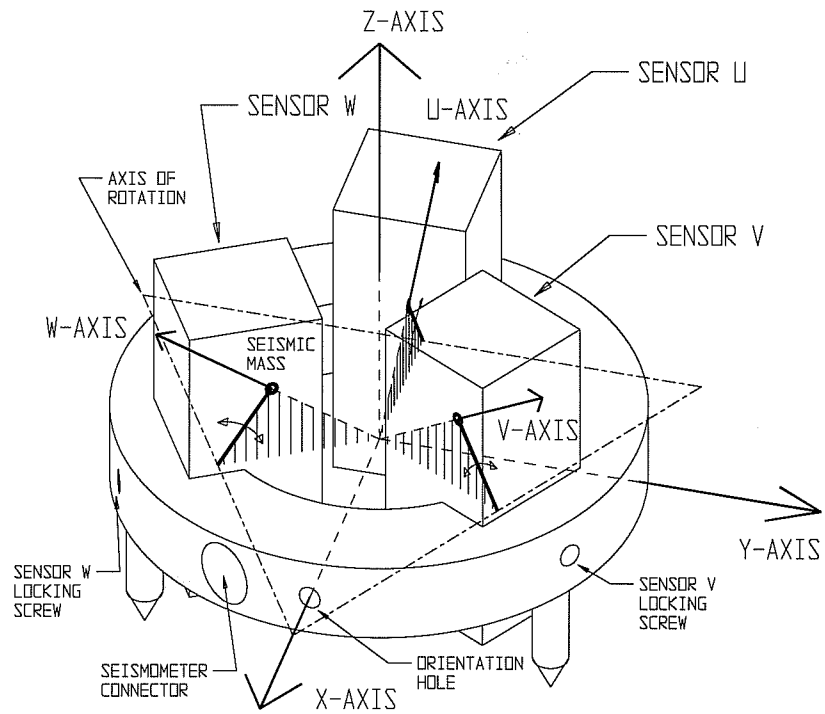
The relevant characteristics of response and gain are fully calibrated by the manufacturer. Neither internal nor external nor computational adjustment is needed for proper operation

INTRODUCTION

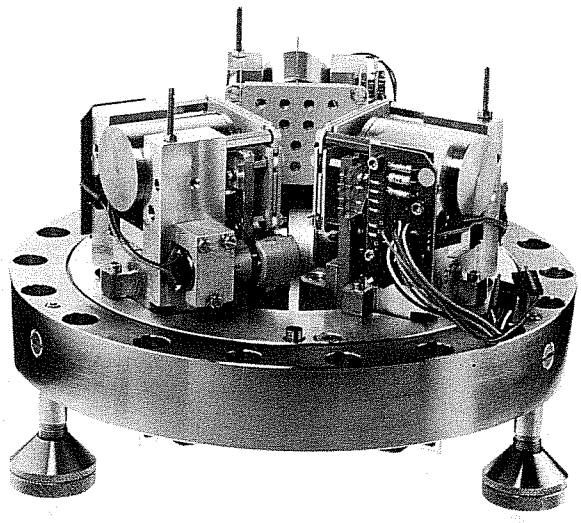
The Streckeisen STS-2 seismometers are sensitive, remotely-controlled, wide-bandwidth seismic sensors. Their high dynamic range and stable transfer characteristics make them ideal for a wide range of applications. The second-generation STS-2 complements the high-performance STS-1 seismometers that have been produced since 1976.

The STS-2 is designed for quick and simple installation, wider temperature range operation, and secure transport, while resolving minimum earth noise levels over the frequency range equivalent to and exceeding traditional long- and short-period instruments. Special shielding is normally not required to resolve levels 10 - 30 times below the limit of World-Wide Standard Seismographs.

The STS-2 uses 3 identical obliquely-oriented mechanical sensors, rather than the traditional separate orthogonal vertical and horizontal sensors. In addition to benefits in standardization of manufacturing, the tri-axial design guarantees that horizontal and vertical components are matched as closely as possible. Standard vertical and horizontal outputs are derived electrically rather than mechanically. To the user, the seismic output signals appear to be those of a conventional three-component seismometer.



STS-2 AXES



STS-2 INNER SHIELD REMOVED

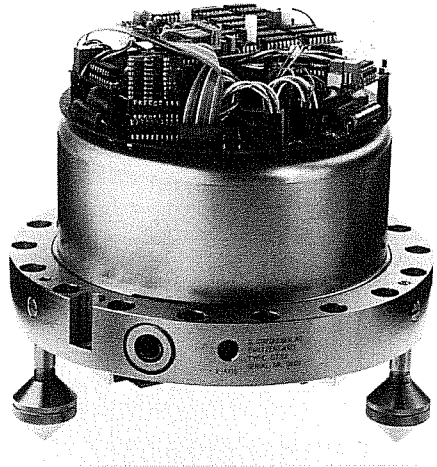
PHYSICAL

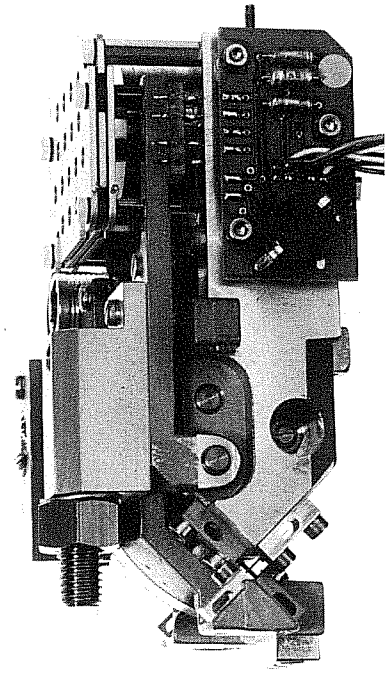
Three sensors with electronics and power conditioning are mounted in a cylindrical package. The electrical access to the STS-2 is provided by a single 18-line connector. Three threaded mounting feet allow levelling of the seismometer package. A screw to actuate the transit lock of each sensor is accessible along the edge of the base ring. The top and bottom of the STS-2 have aluminum covers that are gasketed to the base plate.

The STS-2 is vacuum-tight. The construction is further designed to minimize the distortion of the package by barometric pressure changes by insulating the top and bottom covers from the massive base plate, in a way similar to the insulation of a seismograph pier from its surrounding building. The top and bottom covers are secured to the base plate with compliant O-rings, allowing the covers to compress without stressing the entire package. The sealed construction and massive metal base plate provide thermal insulation and inertia.

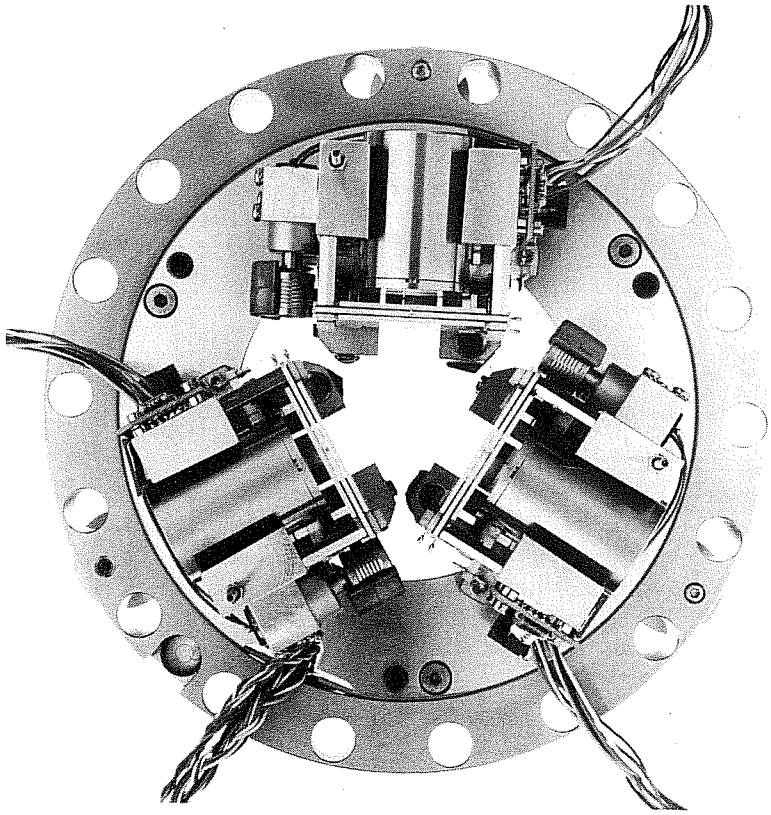
Since the complete package is factory-calibrated, it is necessary to orient and level only a single package in the field.

STS-2 COVER REMOVED





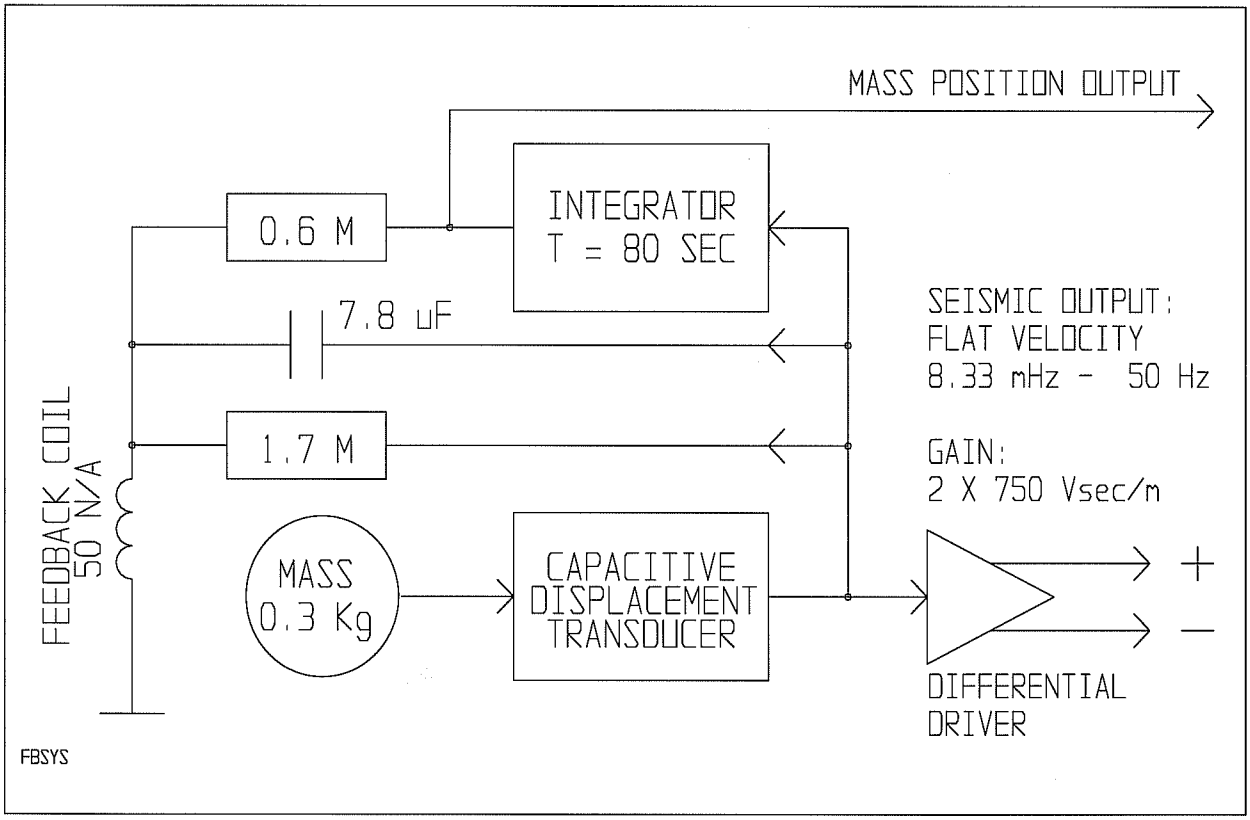
STS-2 SINGLE SENSOR



STS-2 THREE SENSORS IN FRAME, TOP VIEW

ORIENTATION

The orthogonal output signals are factory-adjusted using a standardized 3-dimensional shake table. So they represent motions in the geometrical X, Y, and Z axis of the seismometer with an accuracy of 1 % (0.6°) at a period of 6 sec. Physical orientation of the STS-2 by the user requires the adjustment of only two parameters: the verticality and azimuth of the package. Each STS-2 package is equipped with an integral bubble level for vertical orientation. To facilitate horizontal orientation, a rod is supplied with each instrument that represents the X axis when fitted into the accordingly labelled hole in the edge of the base ring.



STS-2 FEEDBACK SYSTEM

STS-2 FEEDBACK SYSTEM

Electronic force feedback permits a near infinite variety of seismometer responses. Feedback systems can be derived to optimize individual parameters such as saturation level, sensitivity, bandwidth, or frequency response. The feedback system for the STS-2 is chosen to be a compromise suitable for most general applications.

The STS-2 feedback system is basically identical to that of the STS-1/VBB (Wielandt and Steim, Annales Geophysicae, 1986) although the feedback is stronger at short periods improving linearity and extending the high-frequency flat-velocity response. The low-frequency - 3 dB corner of the initial version of the STS-2 is set at 120 sec.

No filters, which limit dynamic range, are used to derive the velocity-proportional output; the STS-2 feedback system delivers velocity directly from the feedback loop.

THE SEISMOMETER'S RESPONSE TO GROUND MOTION

FREQUENCIES BELOW 1 HZ

At low frequencies the STS-2 seismometer may simply be considered as a long-period, velocity-transducer, three-component seismometer with a free period of 120 sec, damping 0.707 of critical, and generator constant 2 x 750 Vsec/m. These parameters are factory-adjusted to within 1 % (generator constant at a period of 6 sec).

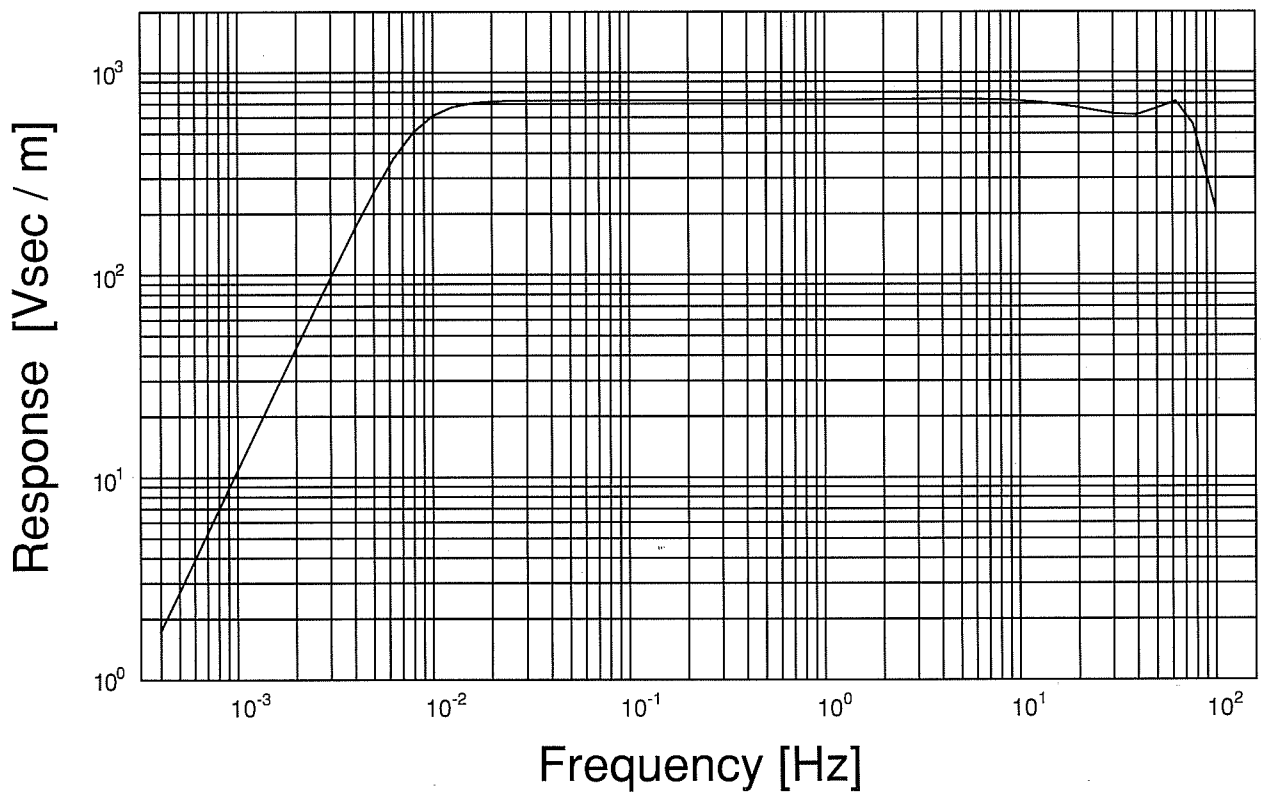
FREQUENCIES BETWEEN 1 AND 10 HZ

Between 1 and 10 Hz, the velocity response of the STS-2 is flat within ± 0.15 dB (about ± 1.5 % in amplitude). The group delay time in this frequency range is nearly constant, about 4 ± 1 msec.

FREQUENCIES ABOVE 10 HZ

The flat velocity response of the STS-2 extends somewhat beyond 50 Hz. However, the overall response at high frequencies depends not only on the seismometer but also on its coupling to the ground. While coupling may influence the amplitude and the phase of the transfer function noticeably, its influence on the signal delay time is small. The group delay time observed on a shake table is a nearly constant 3 ± 1 msec at frequencies between 10 and 50 Hz. The amplitude response may be expected to be constant within ± 1.5 dB (15 % in amplitude).

STS-2 VELOCITY RESPONSE



THE OPERATING RANGE COMPARED WITH THE SEISMOLOGIST'S REQUIREMENTS

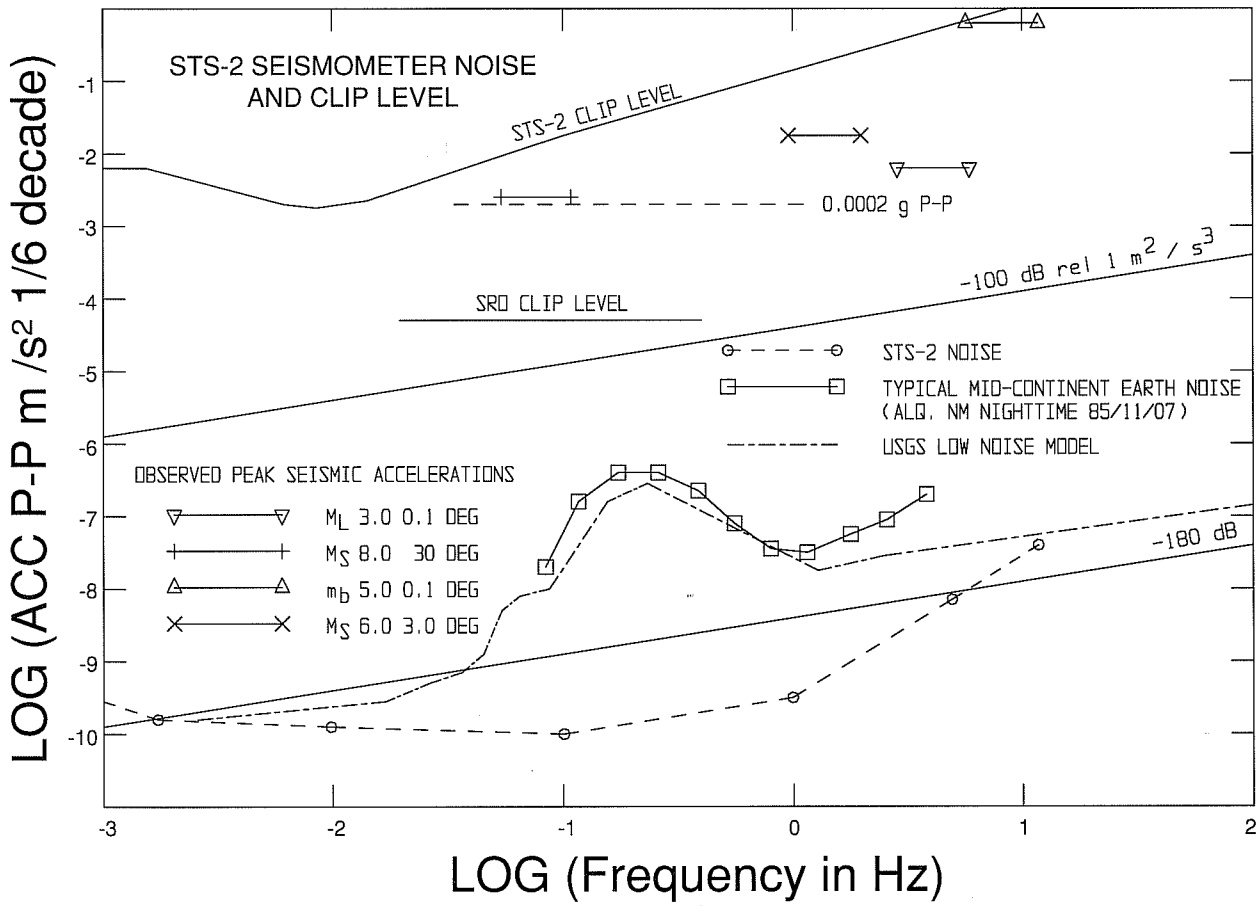
The figure below shows the clip level and typical noise of the STS-2 compared with the USGS Low-Noise-Model (LNM) and the required minimum clip level for high-gain seismometers. Also shown are "typical" intermediate-period earth noise and peak signal levels from regional and teleseismic events spanning 5 orders of magnitude and epicentral distances from 0.1° to 30°.

The figure represents noise and signals on a common scale so that overall operating range can be shown. RMS noise is converted with 99% confidence to equivalent peak-to-peak values by multiplying the RMS values by 6. Peak-to-peak signal levels are derived from 1-octave filtered broad-band accelerograms derived from VBB recordings made by Quanterra / Streckeisen systems. Some estimate of dynamic range as a function of frequency can be read directly from the figure.

The STS-2 electronic self-noise is below the equivalent level of the USGS Low-Noise-Model (LNM of Peterson and Tilgner, USGS OF Report) from > 10 Hz to 200 sec provided that the instrument is additionally protected against air pressure variations by means of a pressure jacket (see chapter "SUGGESTIONS FOR OPERATION").

The flat-velocity STS-2 also covers the critical frequency-amplitude range from 10 sec to 10 Hz with a high acceleration-equivalent saturation level, up to > 0.1 g at 10 Hz. The high saturation level of the STS-2 allows capturing on-scale even moderately large local and regional events.

Because typical short-period earth noise levels (represented in the figure by a wind-free nighttime sample taken at Albuquerque, NM) often substantially exceed the LNM levels, the STS-2 has been optimized for high dynamic range rather than substantially lower self-noise at frequencies beyond 10 Hz. High-frequency resolution is controlled principally by the displacement transducer resolution. The standard STS-2 is more than 1 order of magnitude better than the STS-1, whose short-period resolution has not proven limiting in world-wide deployment for general-purpose earthquake recording.



INPUT AND OUTPUT

The STS-2 comes supplied with a 3-meter interface cable that is terminated at the sensor end in a seismometer connector and at the other end in a "host-box" with two waterproof connectors. Power, control, output signals, and calibration signals are accessible at the "host-box". The "host-box" also contains a DC/DC converter, input protection circuits, and other signal distribution.

POWER INPUT

The "host-box" contains an isolating, regulated DC/DC converter. Primary power is applied through a overvoltage and false polarity protection network consisting of a thermal current limiter and a voltage limiter. Primary DC operating voltage is 10 - 30 VDC. Power consumption is 1.8 W.

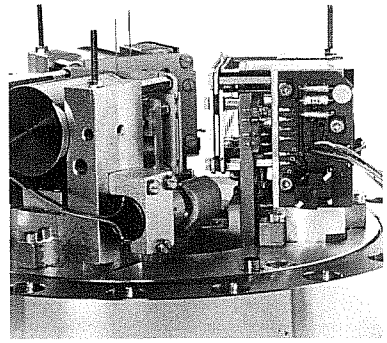
CONTROL INPUTS

Logic-level inputs are provided on the STS-2 "host-box" to control 4 functions: monitor-signal selection (POSITION or raw sensor outputs), initialization of mass recentering, selection of low-frequency corner period, and connection or disconnection of calibration lines.

The STS-2 can automatically recenter the boom position. The autozero cycle requires about 30 sec. To reduce installation and mass centering or recentering time, the STS-2 has the ability on command to change its low-frequency corner period from 120 sec to 1 sec and vice-versa without destabilizing the equilibrium state of the electronic feedback system. The autozero command automatically initiates switching to 1 sec corner period and returning to 120 sec after the autozero cycle has finished.

CALIBRATION CURRENT INPUTS

The STS-2 provides separate inputs to the calibration coils to allow individual excitation of the three sensors.



STS-2 THREE SENSORS IN FRAME, SIDE VIEW

OUTPUT SIGNALS

The raw electrical output of each of the STS-2's obliquely-mounted sensors contains both vertical and horizontal components of motion. These raw sensor signals are electrically summed within the STS-2's electronics to provide standard vertical and horizontal output signals (electrically realized coordinate transformation: U, V, W into X, Y, Z). Cross-coupling between components is suppressed electrically during manufacturing, rather than by mecanical adjustments. The output stage of the feedback electronics for each component provides a high-level (40V p-p, max) differential output signal, suitable for direct connection to a high-resolution A/D converter, such as the Quanterra Q52K-1 (20 Hz sampling) or Q52K-80 (80 Hz sampling).

Three auxiliary output lines are used to monitor either the mechanical balance or the raw broad-band output signals of the individual sensors. The broad-band output signals are selected by applying an external logic control signal.

SUGGESTIONS FOR OPERATION

A double styrofoam box is recommended for isolation against rapid temperature changes and air currents; it will substantially improve the long-period noise level. Satisfactory results may also be obtained with a single box. We have found that in a typical seismic vault with still air and relatively constant temperature, an STS-2 covered by a single box without special sealing can resolve minimum earth noise to about 50 sec period. Operating under these conditions, the STS-2 will produce long-period, narrow-band records (with a peak magnification at 25-35 sec) that are virtually identical to those from a properly installed set of STS-1 seismometers.

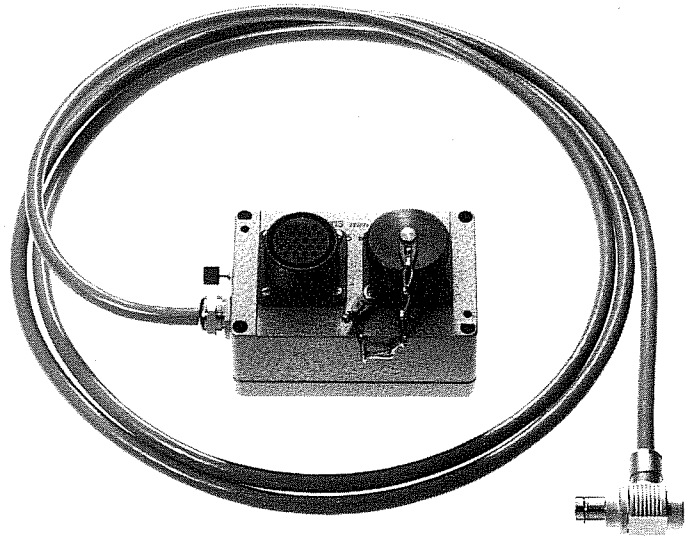
For recording with substantial gain at very long periods, the STS-2 requires some additional protection from air pressure fluctuations. We recommend in this case to provide a simple pressure jacket which needs not be air-proof for more than a few hours. Evacuation is not required and not recommended.

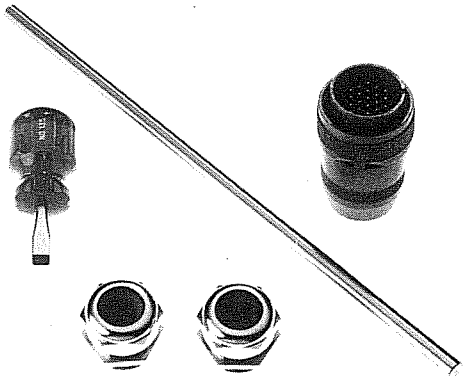
Styrofoam box and pressure jacket are not part of the STS-2 shipment. They must be evaluated, constructed and installed by the user. Detailed information for customers who are interessed in the pressure jacket which we have applied in our test equipment is available on request.

COMPONENTS DELIVERED

TRIAXIAL SEISMOMETER STS-2

"HOST-BOX"
with a 3- or 5-meter detachable
interface cable terminated
in a seismometer connector





ACCESSORIES

Rod for horizontal orientation of the STS-2

Screwdriver

Connector for "host-box" with 2 cable-glands

SPECIFICATIONS

General

Item	*Standard + Low-Power*
Principle of operation	Force Balance
Mechanical sensors	3 identical inertial pendula in a cube-corner geometry. The mechanical free period is virtually infinite.
Seismic output signals	2 horizontal (X,Y) and vertical (Z); broad-band velocity response
Size	Cylindrical package 235 mm diameter, 260 mm high
Weight, complete with "host-box"	13 kg
Environmental protection	Vacuum-tight, low-stress construction

Electro-mechanical

Item		*Standard Power*	*Low-Power*
Generator constant		2 x 750 Vsec/m	
Response		Ground velocity between corners 8.33 mHz (120 sec) and > 50 Hz.	
Seismic signal output		± 20 V differential range, 220 Ohms serial resistance per line	
Auxiliary outputs		± 10 V single-ended, 1 kiloohm serial	
Electronic self-noise		typically 6 dB below USGS low-noise model between 5 mHz and > 10 Hz	typically 6 dB below USGS low-noise model between 5 mHz and 1 Hz, below USGS low-noise model between 1 Hz and 10 Hz
Clip level		± 13 mm/sec ground velocity up to 20 Hz, linear derating from 20 Hz to 50 Hz down to 5.3 mm/sec at 50 Hz	
Clip level normalized to gravity	*Frequency [Hz]*	*Fraction of g (peak-to-peak)*	
	20 - 50	0.34	
	10	0.17	
	1	0.017	
	0.1	0.0017	
	0.03	0.00055	
Dynamic range		see figure "STS-2 SEISMOMETER NOISE AND CLIP LEVEL"	
Parasitic resonances		vertical: > 140 Hz horizontal: > 80 Hz	
Power input		10 - 30 VDC, galvanically isolated	
Power consumption		Average: 1.0 W, deteriorated state: up to max. 3.0 W (saturated outputs)	Average: 0.55 W, deteriorated state: up to max. 2.0 W (saturated outputs)
Control inputs		"high": 3 - 30 V, 0.5 mA; "low": < 0.5 V; optically isolated	
Calibration inputs		Calibration coils 30 Ohms each, approx. 0.002 g/mA (oblique), maximal current 50 mA each	
Temperature range		± 10 degrees Celsius without mass recentering	
Operating temperature limits		0 to 40 degrees Celsius with guaranteed specifications On demand: -30 degrees Celsius with proper functioning guaranteed, but specifications not guaranteed	
Mass centering		Automatic on external command	

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