GÜRALP CMG-3T

BROADBAND SEISMOMETER

- Covers the complete seismic spectrum up to 50 Hz, and a single transfer function defines the sensor response.
- Suitable for local, regional and teleseismic recording.
- Truly portable seismometer with a lifting handle and easy access to electric connection.
- Remote electronic mass locking and unlocking facility.
- Sensor can be operated with ±2.5 degrees of tilt, and microprocessor controlled remote centering is provided.
- Adjustable feet.
- Special design adjustable feet which reduces spurious modes of resonance. Parasitic resonances are above 220 Hz.
- Low power consumption, 0.75 Watts. Operates over 10 to 30 Volt power input range.
- Stainless Steel Construction.

The CMG-3T seismometer is a compact three-component version of the CMG-3 broadband sensor. The sealed three-component stainless steel housing is suited for surface vault (observatory), subsurface vault and post hole installations.

CMG-3T has been designed to provide seismic information over the COMPLETE seismic spectrum from very low frequencies up to 50 Hz. Various frequency response options are provided for the user and optionally the high frequency corner of the sensor response can be increased beyond 50 Hz.

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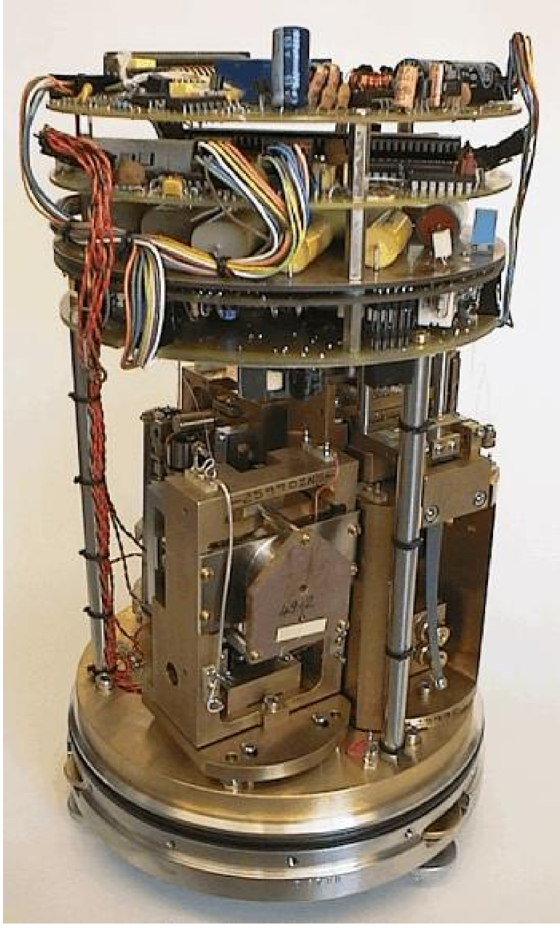
These instruments do NOT require precise leveling of the sensor package to obtain long period mechanical response and can be used without leveling the sensor case up to ±2.5 degrees of tilt.

The scope of the CMG-3T seismometer includes the associated peripheral equipment for borehole applications, including holelock, holelock installer and cable strain relief mechanism. Furthermore, CMG-3T can be installed inside ocean bottom capsules to be used as broadband ocean bottom seismometers.

MECHANICAL SYSTEM DESIGN

The vertical and horizontal sensors are orthogonal to each other with an accuracy better than 0.1 degrees. The beam type sensor boom which defines the frame of reference in both the vertical and horizontal sensor are absolutely identical. The sensor boom with a displacement capacitive transducer and a constant flux feedback transducer are symmetrical.



The vertical sensor inertial mass and the inverted horizontal pendulum are both supported with leaf springs with a natural period of about 0.9 seconds. The beam type sensor boom moves with a single degree of freedom and the parasitic resonance of the complete sensor system is above 140 Hz.

The mechanical construction of the instrument is such that it is compact, rugged and easy to use. The mass clamping mechanism operates on the sensor mass and pushes the mass under controlled spring force with its prongs against the precisely machined cavities such as the mass is restrained to move in six degrees of freedom. The locking mechanism of the sensor mass ensures that under normal conditions, handling and transportation, the sensor pivots are not damaged.

The vertical component boom centering is accomplished by moving the end of the load bearing spring with a stable motorized precision micrometer under the control of microcontroller electronics. In the case of the horizontal sensor the centering is accomplished by tilting the sensor base, again with a stable motorized precision micrometer under the control of micro controller electronics.

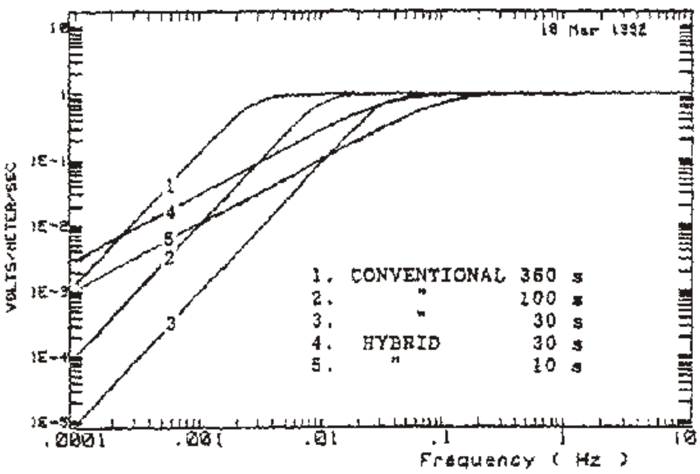
The CMG-3T (three-component) sensors are housed within a completely 'O' ring sealed housing, and all the external components are manufactured from stainless steel.

CMG-3T can also be delivered with a waterproof connector and cabling (see photo opposite). The waterproof connector/sensor can be immersed continuously under water down to a depth of 25 meters (other depth options are also available).

FEEDBACK ELECTRONICS

In a practical broadband seismometer, the natural characteristics of the seismometer are never used. The period and damping of the sensor are completely deterred by a feedback loop which supplies a counter-force to the inertial mass sufficient to oppose any overall motion. The force required to restrain the movement of the mass is then a measure of the inertial force exerted by the mass due to ground motion. By using a suitable feedback network it is possible to obtain virtually any desired frequency response or system gain from a feedback seismometer. Ref 1, Ref 2.

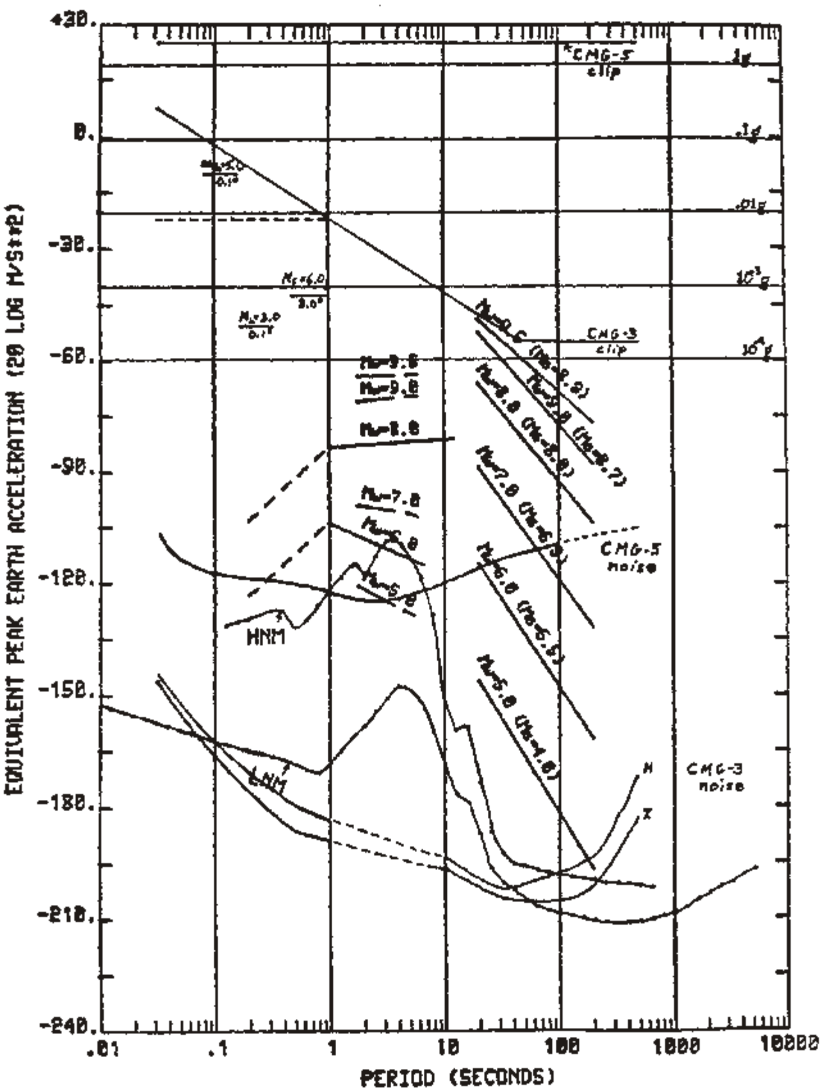
The figure opposite gives the comparative response of a conventional flat velocity output broadband sensor (direct from the feedback loop) and the optional hybrid response of the USGS National Seismic Network..



Relative Responses to Ground Velocity

The family of curves shows the CMG-3T output response to input velocity in units of V/m/s. Curves 1, 2 and 3 are the conventional 360 second, 100 second and 30 second responses whilst curves 4 and 5 are the hybrid 10 second and 30 second (USGS NSN) responses.

As well as the sensor frequency response the sensor gain (saturation levels) can also be adjusted according to the requirements of the customer. The figure below, taken from Ref 4, shows the dynamic range and clip (saturation level) of the CMG-3 sensor.



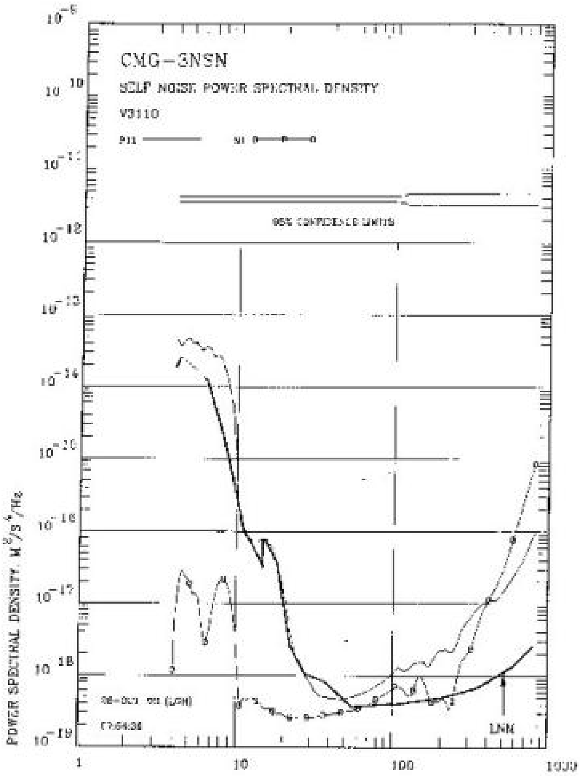
The sensor feedback electronics for three-components is housed within the sensor package. The velocity outputs of the sensor are all differential and capable of driving long cables up to 50 meters. As well as the feedback electronics, all the sensor control operations required to operate the seismometer are supervised internally by a control microprocessor which drives the mass clamping motors and oversees the operation of centering adjustment motors. The power supply is also housed inside the sensor housing.

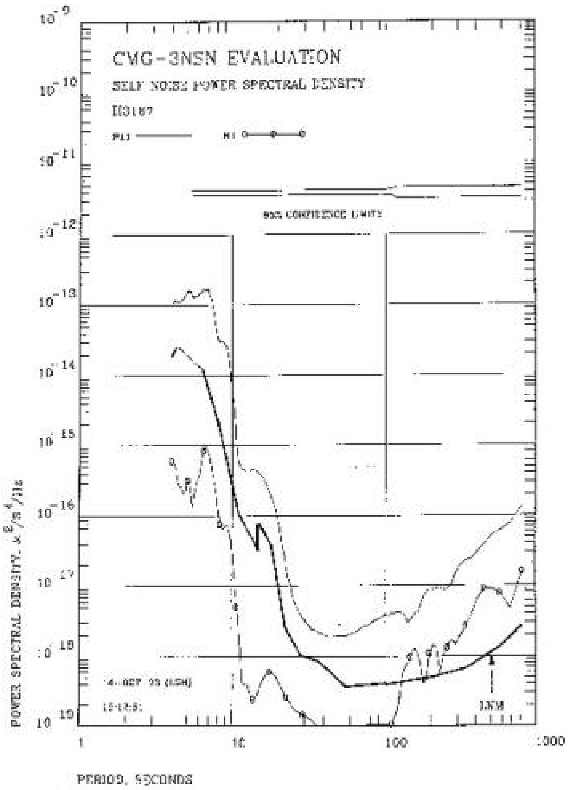
SIGNAL AND NOISE LEVELS

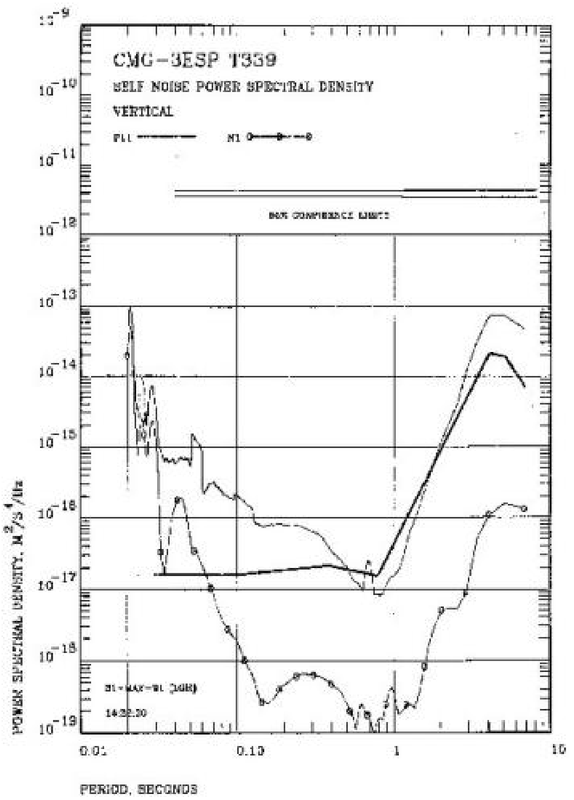
The noise equivalent input acceleration of the seismometer transducer and the Brownian noise of CMG-3T sensors are well below the background noise level encountered at the quietest site on earth.

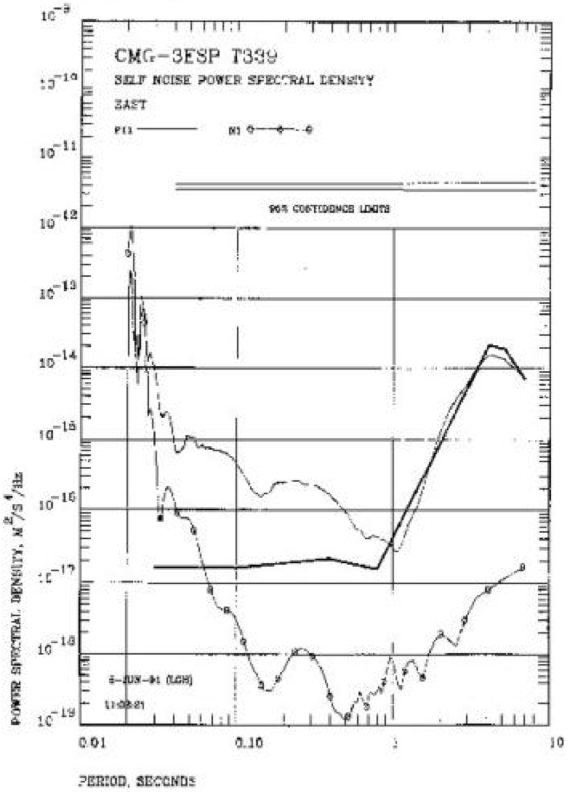
A discrete component pre-amplifier circuitry with a high responsivity capacitive transducer sets the sensor electronics noise level well below the Brownian noise level of CMG-3T sensors. The electronics noise level of the sensor transducer is at least 20 dB (factor of 10) below the Brownian noise of the instrument.

The figures given below contain a typical estimate of the system noise power plotted as (small circled line) non-coherent power for vertical and horizontal sensors in the long period and short period bands separately. The power spectral estimates have been corrected for the system response and gain representing the sensor input power (continuous thin line) in units of acceleration. In these plots the Low Noise Model is plotted as the thick continuous line.









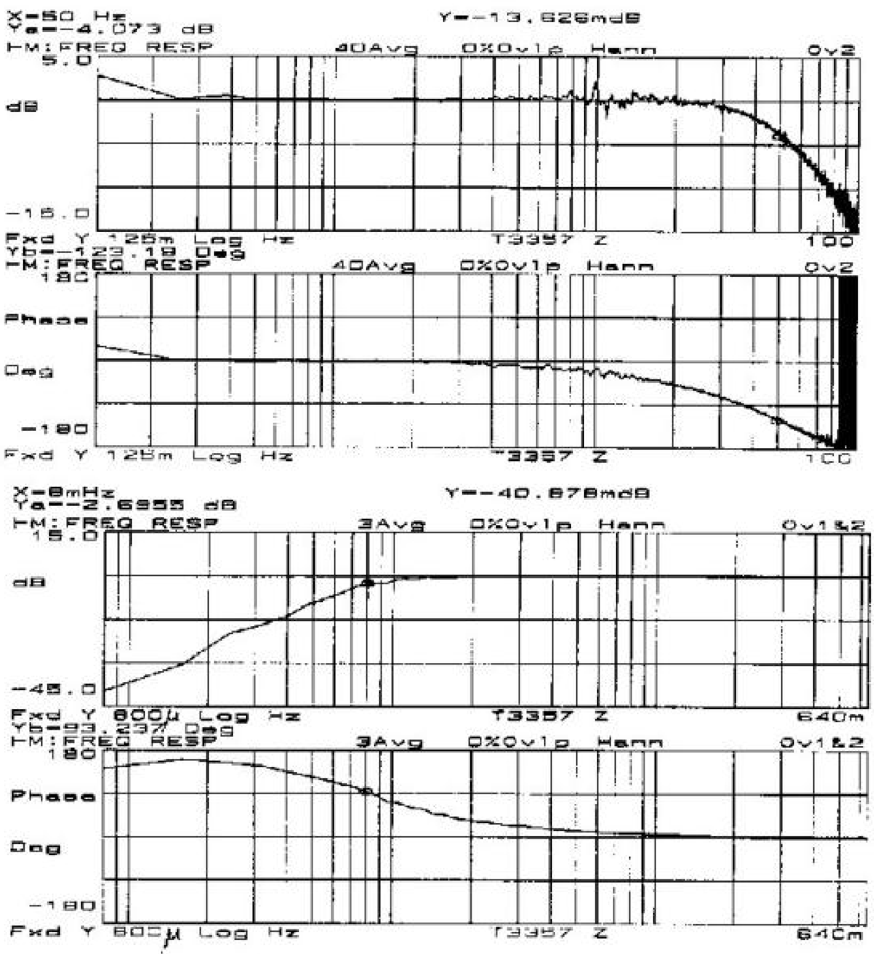
The theoretically calculated Brownian noise (Ref 1) of the sensor is set at -195 dB relative to 1 m^2/s^4/Hz of input ground acceleration. However, it is well known that the main practical problems in long period instruments arise from thermal, magnetic field, pressure effects in the mechanical system and more importantly the mechanical instability of the overall construction. In order to show the true practical noise estimates of the CMG-3 instrument, two identical sensor output signals are measured. The coherence function is used to estimate the signal power coherent between the two sensors and signal power non-coherent between the sensors which is considered to arise from the total inherent sensor noise.

Tests show that the CMG-3T noise estimates are below the Low Noise Model up to 18 Hz and down to 0.0125 Hz (80 seconds).

Please Note: CMG-3ESP type sensors results have been used as the high frequency noise estimates. The performance of CMG-3ESP and CMG-3T sensors are identical in the short period band (Ref 3). The CMG-3T has similar mechanical and electronic components to CMG-3NSN units which have been tested at Albuquerque Seismological Laboratory, USGS.

SENSOR FREQUENCY RESPONSE

The CMG-3T seismometer is delivered with comprehensive documentation which includes the 'Operator's Guide' and complete calibration document. Each CMG-3T sensor measured frequency response is provided as normalized amplitude and phase plots. The frequency plots are given as the long period and short period sections of the seismic spectrum.



POLES AND ZERO TABLE

WORKS ORDER NUMBER: 0436

SENSOR SERIAL NO: T3356 and T3357

POLES (HZ)	ZEROS HZ
$-5.891 * 10^{[illegible]} \pm 5.89 * 10^{[illegible]}$	0
-31.5 ± 33	0
-145	

Normalising Factor: $A = 3.01 * 10^{[illegible]}$
Sensor Sensitivity: See Calibration Sheet

NOTE: The above poles and zeros apply to the vertical and horizontal sensors and are given in units of Hz. To convert to Radian/sec multiply each pole or zero with 2π. The normalising factor A should also be recalculated.

As well as the measured frequency response, poles and zeros of the sensor transfer function are provided as a single transfer function.

WHY A SINGLE TRANSFER FUNCTION?

It is required that a modern broadband seismometer covers the complete seismic spectrum. Under no circumstances should the theoretical response of the sensor be described by dividing the response into separate bands as this methodology will simply turn the clocks back to the days when more than one seismometer (long period and short period) had to be used to cover the seismic spectrum.

LINEARITY

The very wide dynamic range and the high linearity level of the CMG-3 sensor makes linearity measurement of the sensor system a challenging task. The linearity measurement of the CMG-3 sensor was carried out during the USGS NSN network sensor evaluation and the sensors exhibited distortion ratios of - 111 dB for the vertical and - 107 dB for the horizontal sensor. The linearity measurement method is given in Ref 3.

REFERENCES

Ref 1 USHER, M.J., BURCH, R.F. and GURALP, C.M., "Wide-band Feedback Seismometers", 1979. Physics of the Earth and Planetary Interiors, 18: 38-50.

Ref 2 GURALP, C.M., "The Design of a Three-component Borehole Seismometer", 1980. Ph.D. Thesis, Univ of Reading.

Ref 3 Albuquerque Seismological Laboratory, NSN test data (unpublished).

Ref 4 USGS Report, "USGS Technical Summary". 25 January, 1990.

CMG-3T SEISMOMETER SYSTEM SPECIFICATION

Outputs and Response

Full scale outputs:	± 20 Vdc differential velocity (2*750 V/m/s for 100 sec sensor) ± 10 Vdc mass position (3000 $V/m/s^2$ for 100 sec sensor)
Standard Response:	Flat velocity 0.01 to 50 Hz
Optional USNSN Response:	Flat accel. 0.005 to 0.033 Hz; flat velocity 0.033 to 50 Hz
Optional Extended Broadband:	Flat velocity 0.0027 to 50 Hz
Other OPTIONAL Responses:	0.0083 to 50 Hz 0.0333 to 50 Hz

Controls

Calibration:	The calibration signal can be connected to each axis separately. Calibration enable lines are provided for each axis. Cal enable lines (active low) < 1mAmp.
Calibration Resistor	51K Ohmn
Mass centering:	Microprocessor controlled. Automatic centering with remote Control.
Mass lock/unlock:	Microprocessor controlled with limit switches. Automatic mass lock/unlock with remote control.

Physical

Lowest spurious resonance:	140 Hz vertical
Temp. before recentre needed:	± 12 deg. C
Mass re-centering range:	± 2.5 deg from horizontal
Operating temperature range:	- 10 to + 75 deg C
Base plate and top cap:	Stainless steel
Pressure jacket material:	Stainless steel
Power/signal connector:	Milspec connector on top cap, KPT 02E-16-26P. Stainless, 1500 psi connector available.
Pressure relief valve:	On top cap
Carrying handle:	On top cap
Case diameter:	168 mm (6.61 in)
Case height with handle:	350 mm (13.75 in)
Weight:	31.4 lb (14.2 Kg)

Power

Standard power supply:	+ 12 Vdc, with internal DC/DC converter(Isolated) (Can operate over 10 to 36 Volts.)
Current at standard (12 V) output:	+ 75 mA
Additional cal relay current:	< 1 mA
Additional current when re-centering:	+ 300 mA (See Operator's Guide.)