Build a Seismograph, Part 2

Watch for earthquakes and nuclear tests around the world. This month: the mechanical construction.

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The mechanical construction of the seismometer is straightforward, and requires no precision engineering. Most of the materials can be obtained as scrap and recycled as befits an earth sciences project. The one critical operating parameter is friction, so the sensing beam must pivot on a smooth surface like a small ball bearing. I used the flywheel spindle of a defunct cassette player because it had a hardened and ground spherical bearing surface. This sits in a conical counterbore on a quarter inch bolt head screwed into the back post. A ballpoint pen end will work just as well.

Size of the instrument is a matter of choice. I built a rather large unit because I had room for it. In urban areas, an instrument with a longer period than 6 seconds will tune out most of the traffic vibration, and the size can be cut by increasing the mass and keeping the beam angle to a minimum. This means better quality mechanical engineering.

I used a 48 inch long pendulum beam of 20mm square section aluminum tube. The beam must be light and rigid, because it will be loaded with extra weight to tune it. (Fig. 1).

The base is a 60 inch length of 5 inch by 3 inch timber. At the pivot end it is screwed onto a transverse 24-inch piece of 1.5 inch square steel box section fitted with 3/8 inch levelling screws. A piece of angle with a single levelling screw is fitted to the sensing end.

The pendulum beam hangs from a 36 inch vertical iron post coach bolted to the wooden base and thus kept insulated from the earth. The unit should work just as well if the post is fixed to a SOLID ground floor or the beam is hung from a basement wall. Ordinary cavity walls are not rigid enough, and may prove too sensitive to people, traffic and temperature changes.

At the top of the post is an adjustable screw eyebolt vertically above the beam pivot support bolt (see photo).

The beam is suspended by a thin stranded alloy wire (not soft copper), adjusted to hold it parallel to the base and some 5 inches above it. The suspension point is 15 inches from the outermost end of the beam to allow space for weights and reduce the side thrust on the pivot.

Protection

The moving beam should be protected from draughts with a light removable cover, which can be made of polystyrene water tank insulation sheet, hardboard or chipboard, and the unit should be set up on a solid ground floor away from people and vehicles.

It is mechanically set up first. The oscillation period depends on the angle the beam makes with the horizontal and its effective mass. To give an accurate seismic response, mechanical damping must be added. Liquid damping is simplest using an adjustable aluminum vane (100 X 50mm) under the beam which dips into a container of paraffin or light oil, or even water if there is no risk of freezing.

If the instrument is installed in an outbuilding with wide temperature swings, paraffin will give the most constant damping, but will need a larger vane than oil.

Loading

The beam is loaded with up to 5kg of extra weight near the end. I used short lengths of scrap iron pipe slipped on to the beam.

When the beam is loaded, the pivot end of the instrument is jacked up about 10mm to turn it into a sensitive long period pendulum. This is a matter of trial and error. The important thing is to establish a stable mechanical zero and period greater than 7 seconds.

Once a period of 7-10 seconds is achieved, the damping is set by adding liquid to the vane bath — a small plastic food container is ideal for this — until the pendulum comes to rest after one and a half to two swings.

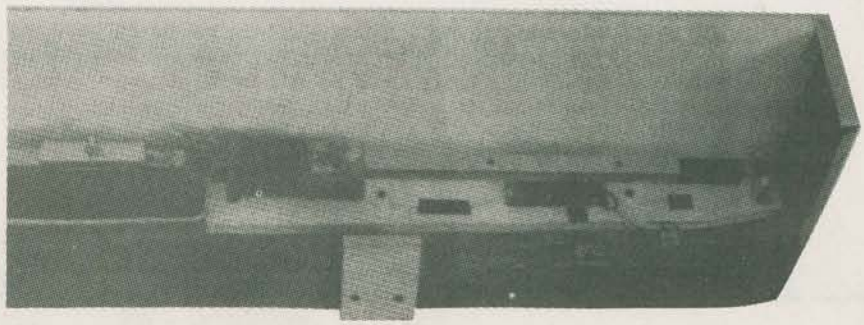
Sensing

The sensing coils and electronics are now fitted. Care should be taken to arrange a non-metallic mount for the sensing coils — I used a plastic pipe clip for the static coil and a piece of square section insulating plastic bar clearance drilled for the moving coil, and pressed into the end of the sensing beam. The coil must be a LOOSE fit in the hole, to avoid damaging the windings; it can be secured with wax or similar.

The lead from the moving coil needs to be very flexible and is fed inside the beam to a hole close to the pivot. A loop is then taped to the support column, and the lead taken to the detector board pins. The detector board is mounted on the wooden base.

After assembly, the instrument may take a few days to settle down, but thanks to the generous clearances in the pick off system, no great precision is needed, and deviation from zero can be corrected by the jacking screws.

The beam and support pillar should be bonded to the negative rail of the electronics. If the instrument is to be used at some distance from the monitor point, it must only be earthed there — any earth



General arrangement of the beam, sensing coils, damping vane and detector board. Part of the draft protection can be seen.

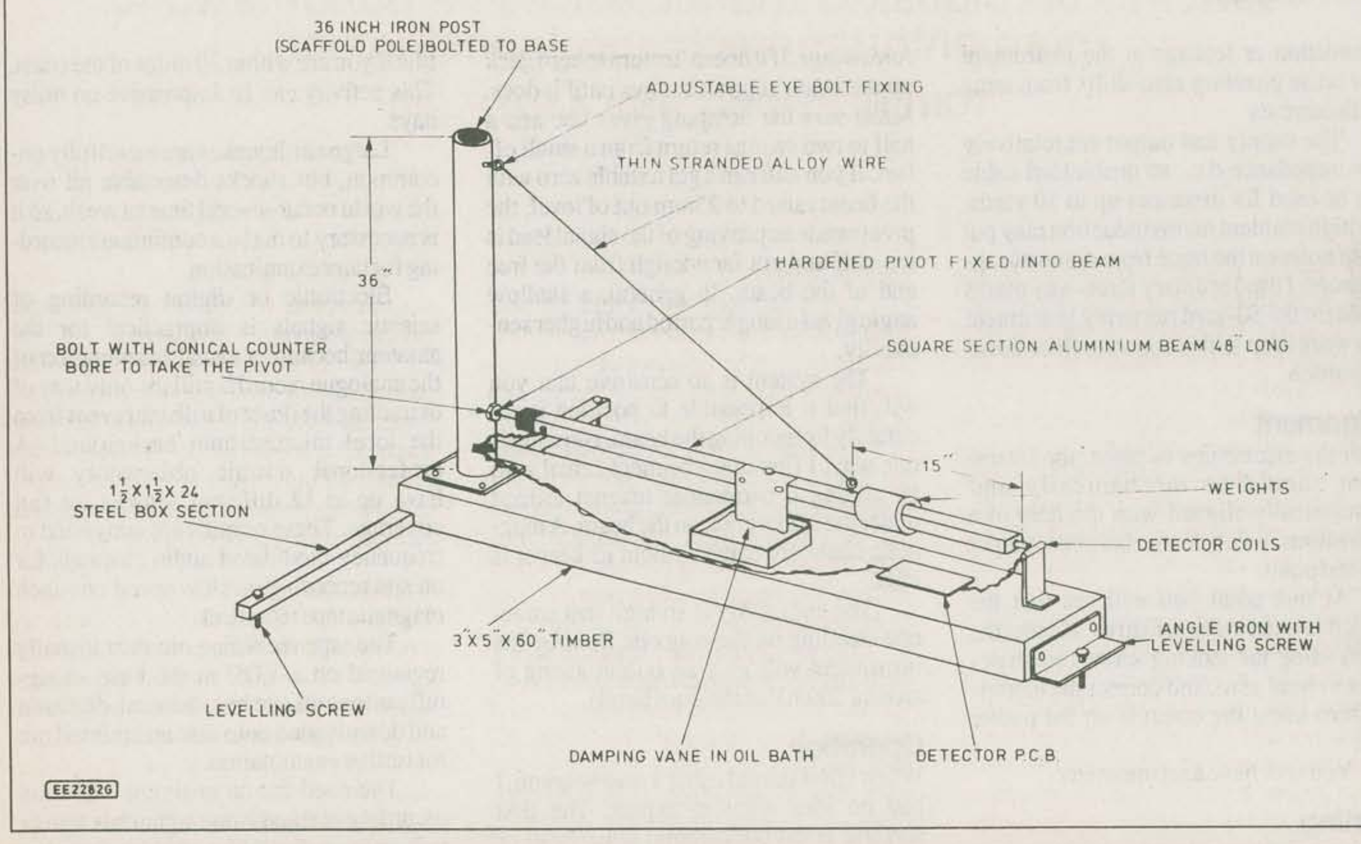
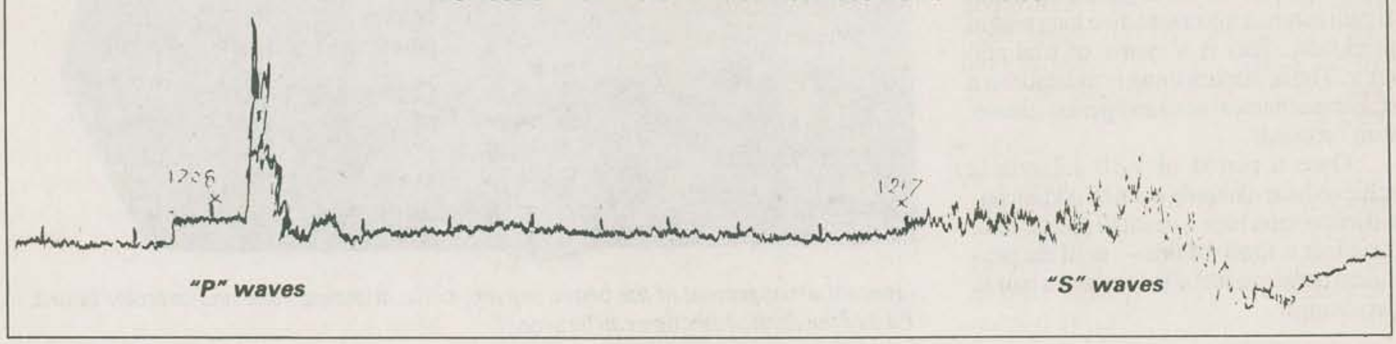


Fig. 1. Construction of the Seismograph.

RECORDINGS MADE WITH THE SEISMOGRAPH

"Antipodean" surface waves recorded on 22.10.88.

The Russian 150 kiloton nuclear test recorded on 14.9.88.



The Armenian earthquake in 1988. This recording shows a typical aftershock — the Seismograph was not recording when the main shock took place.

connection or leakage at the instrument can cause puzzling zero shifts from stray earth currents.

The supply and output are relatively low impedance d.c., so unshielded cable can be used for distances up to 50 yards, but high ambient mains induction may put extra noise on the trace from domestic appliances. I used ordinary three-way mains cable for the 50-yard run to my instrument in a workshop with a concrete floor down the garden.

Alignment

With the electronics in place, the instrument should be mechanically and electronically aligned with the help of a plus/minus 1 volt meter between output and test point.

At this point you will see that the device is extremely sensitive. Centre the beam using the jacking screws to an accurate visual zero, and correct the electrical zero using the controls on the power unit.

You now have a seismometer

Testing

Test for stable zero by blowing the beam gently to one side; it should settle after a few swings. If it doesn't return to zero, jack up the beam support screws until it does. Make sure the damping gives one and a half to two swings return from a small offset. If you still can't get a stable zero with the beam raised to 25mm out of level, the pivot needs improving or the signal lead is too stiff and not far enough from the free end of the beam. In general, a shallow angle gives a longer period and higher sensitivity.

The system is so sensitive that you will find it impossible to position it accurately by touching the beam. Blowing is one way. I fine tune the mechanical zero by sliding a permanent magnet around under the iron weight on the beam. A magnetic cupboard catch without its keeper is ideal.

The sensitivity is so high that someone standing on the concrete floor by the instrument will give an output swing of around 300mV as the floor bends.

Operation

When I first started using a seismograph, I had no idea what to expect. The first surprise is the background noise level or microseisms caused by low pressure weather systems, traffic, trains and tidal tilts if you are within 30 miles of the coast. This activity can be impressive on noisy days.

Large earthquakes are mercifully uncommon, but shocks detectable all over the world occur several times a week, so it is necessary to make a continuous recording for later examination.

Electronic or digital recording of seismic signals is impractical for the amateur because a visual examination of the analogue record is still the only way of extracting the onset of a distant event from the local microseismic background. A professional seismic observatory will have up to 12 different sensors for full coverage. These outputs are converted to frequency modulated audio channels for on site recording on slow speed one-inch magnetic tape recorders.

The tape recording are then visually reviewed on a VDU at the base so significant events can be bracketed, digitized and downloaded onto disc and printed out for further examination.

The need for an analogue real time recording of the seismic signal has a great influence on the choice of chart recorder. For adequate detail, a minimum speed of 15mm per minute is required. This translates to about one metre per hour — so paper economy is important.

Recorder

The traditional mechanical seismograph used a large drum covered with paper or smoked glass. The drum was arranged to move axially about 6mm per revolution to give a very long spiral trace for each recording. These days, a spiral trace electronic seismograph recorder can be built using standard electronic servo components and mechanical ingenuity. But this is perhaps beyond the scope of many readers.

For those who don't want to build a recorder, paper economy can be obtained on linear trace machines, by constructing a hand winder to rewind the chartroll and running multiple parallel traces. Most types of chart recorder — especially old ones can be adapted for use with this project.

It is possible to convert machines from expensive sprocket drive paper to narrower or cut down plain paper rolls (Telex, Fax, calculator or till), by improvising a rubber pinch wheel between the middle of one of the guide bars and the chart roll to drive the paper by friction. Precision rubber rollers can be made from ordinary black rubber grommets pressed onto a piece of brass or plastic tube and ground to fit the clearance between guide bars and chart drive roll. The roller is ground to size by fitting it on a screwdriver or suitable bearing and holding it at an angle against a bench grindstone wheel so it spins rapidly as the rubber is evenly ground away. Wear gloves and eye protection

Accurate timing is important for seismographic observation, so timing marks should be added on the trace either by hand later or by means of a generator. The simplest timing mark generator is a mains synchronous motor operating a microswitch every minute. If a changeover microswitch is used, a small capacitor can be charge to a few volts d.c. through a resistor and discharged to make a pip on the trace every minute. Some recorders have internal timing mark generators, and these can be triggered by a timer.

It is essential that the marker is superimposed on the trace, not on the side of the chart if spiral or multiple track recordings are made. New synchronous 1 r.p.m. motors are expensive, so an attractive option is the defrost cycle controller from a defunct microwave oven. These are usually small cased synchronous timers with a 30 second on and 30 second off mains switched output which can be used to pulse a relay to generate isolated low voltage timing marks. If hour marks can also be added, they can be distinguished by switching a small d.c. offset on to the trace for a few seconds or lifting the pen to leave a short gap if the recorder has a remote pen lift facility.

Recorder Supplies

There are a number of possible sources for used chart recorders of various types. These were often used in industrial boiler houses (thermocouple recorders) and of course in school or collage labs or as electrocardiographs in hospitals etc. (although the paper speed on the latter would need to be reduced).

Various circular paper type recorders could also be used to give a reasonable recording for the Seismograph. It should not be too difficult for most readers to unearth a suitable instrument in an electrical junk shop or through local industry or educational establishments, etc. Most of the original users have now changed to different methods of recording and very often chart recorders are no longer needed; while many of them look distinctly old fashioned they are usually excellent examples of precision engineering and are rarely worn out or broken.

Observing

Earthquakes are truly natural random events, and cannot be predicted, so the only way to catch a big one is to keep the equipment running continuously. This means logging the start and finish of each trace carefully so that the arrival time of any event can be determined accurately from the minute markers.

EArthquakes are caused by stress induced fracture and movement of the earth's crust and the semi-liquid mantle under it, and can occur a depths down to 500km, although most occur in the upper 50km of the solid crust.

The energy released is transmitted radially from the fracture, and has most effect on the surface immediately above. A shallow earthquake will create a comparatively small area of devastation whereas a powerful deep event will lay waste large areas.

The earth appears to comprise a heavy molten nickel-iron core about 5000km in diameter, overlaid with a lower density viscous and semi-solid mantle which supports and floats the solid surface crust and continental plates.

The speed of propagation of an earthquake wave varies with density. The liquid care of the earth does not transmit earthquake waves at all, so waves from an event in the eastern hemisphere reach us via the mantle and crust, passing around the core.

The different densities of the crust and upper mantle modify the speed of the waves. The deepest waves skirting the core travel at 8km/second. These waves that are ducted in the interface between the crust and mantle make 5km/second, and the surface waves make 4km/second.

An analysis of the difference in arrival times and character of the waves from a specific event will give a clue to the location of the epicenter, and when three or more synchronized recordings are compared, the exact location may calculated.

Computerizing

Mention was earlier made of the difficulty of computerizing seismographic records. The biggest problem is distinguishing the characteristic small early signals of a distant event from the local microseismic background.

It is largely a question of frequency. Most microseismic waves are of 3 to 6 second period, whereas the first waves from an event less that 5000 miles away are of 0.5 to 2 second period, arriving through the mantle at 8km/second. They are known as P (primary) waves and represent the actual sharp impulse accompanying the energy release at the epicenter. There are no P waves from events sufficiently distant for direct propagation to be blocked by the core.

Next to arrive are the first S (secondary) waves. These travel at 5km/second in the discontinuity between the mantle and crust, and have world wide range. Last to arrive are the slow and dramatic surface waves, with periods from 8 seconds upwards, travelling at 4km/second.

Earthquakes from the activity zones around the Mediterranean and into Russia will show all three wave types and the signal from a large event should stand out clearly enough to allow a rough calculation of its probable distance from the differences in arrival times, before it gets on the news. The signals are normally direct primary waves with no secondary or persistent surface wavetrains for such minor events.

The instrument is also sensitive enough for nuclear test watching. The recording shown was made from a well-publicized 150-kiloton Russian underground test ■