Instructions for Construction of a Lehman Seismometer

By

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Foreword and Purpose: The Lehman Seismometer was first constructed by James D. Lehman of James Madison University in Harrisonburg, Virginia as an inexpensive and highly accurate means of monitoring movements within the earth. The machine can be easily built for under $500, and thus, is an accessible piece of equipment for students and others interested in seismic studies. The objectives in building a Lehman Seismometer were to document the construction process in a coherent, well-photographed manual for future reference by others, and to construct such a seismograph that would be functional for student use in understanding earthquakes, including teleseismic events. This task was undertaken for partial fulfillment of the Geology, B.S. degree at the University of Northern Iowa, and the final product is the pictorial guide, “Instructions for Constructing a Lehman Seismometer”, which is found on the following pages.

Materials and Equipment Needed: One needs to first acquire the proper building materials, most of which can be obtained from a local hardware or department store. If building at a university, many of the supplies can be purchased through the university's electronic workshop or industrial technology center.

Materials:

1. **Aluminum base plate**: Dimensions: 3/8" x 12" x 18". This piece will serve as a mounting plate upon which most of the components of the seismograph will be attached. Cost: about ***$40.00 (figure 1).***
2. **Three adjustable feet**: Dimensions: 15/64-20. Feet will allow for easy leveling of base plate. Cost: about ***$3.00 (figure 2).***
3. **Two elbow joints, Two T-joints and Two mounting plates**: Dimensions: all must threaded to ½" standard pipe thread. Joints and mounting plates connect upright pipe pieces. Cost: about ***$12.00 (figures 3,4 and 5).***
4. **Two nipples**: Dimensions: must accept ½" components. These nipples will be the connecting piece between the T-joint and the mounting plate. Cost: about ***$1.80 (figure 6).***
5. **Pipes**: Dimensions: two ½" diameter 6" long pipes and two ½" diameter 16 ½" long pipes, all threaded at both ends. Once connected, the pipes will serve as the main apparatus of the seismograph, being an upright support for the boom. Cost: about ***$4.50 (figures 7 and 8).***
6. **Pivot bolt**: Dimensions: ¼-20 hardened steel bolt, 1 ½" long, with accompanying nut. Boom will pivot against this bolt, which will be inserted into the lower crosspiece. Cost: about ***$0.50.***
7. **Screws:** Dimensions: two 11/64 ½" long for boom stops, six 19/64 1" long for mounting plates. Six 19/64 ½" nuts are also needed. Screws will secure pieces to base plate. Cost: about ***$1.00.***
8. **Boom**: Dimensions: steel boom ½" in diameter, about 36" in length. The boom and its magnet will sway relative to the coil during a seismic event, creating a current. Cost: about ***$3.00 (figure 9).***
9. **Boom stops**: Dimensions: two, 3 ½" long rigid, elongate stopping materials (wooden or non-magnetic metal strips) to be attached to base plate. Will prevent over-swaying of boom. Cost: about ***$2.00 (figure10).***
10. **Suspension Cable**: Dimensions: seven strand, stainless steel, 0.0185 inches, about 36" long. Cable connects boom to upright apparatus. Cost: about ***$2.50***
11. **Turnbuckle**: Dimensions: eye and eye type, zinc plated, 3/16" by 5 ½". Turnbuckle connects cable pieces, and allows for easy adjustment of cable length. Cost: about ***$1.00 (figure 11).***
12. **Cable bolt**: Dimensions: ¼-20 hardened steel bolt, 1 ½" long with accompanying nut. Once cut, the bolt will hold the upper portion of the cable secure, as the bolt is attached through the upper crosspiece. Cost: about ***$0.50.***
13. **Coil of Copper Wire**: Dimensions: as ordered through Allied Electronics, part no. 214-3588. Copper wire moves relative to magnet on boom and a current is induced. Cost: about ***$25.00 (figure 12).***
14. **Coil mount**: Cost: about ***$1.50 (see under "Construction Process: Preparing the Copper Wire" and figure 36).***

15. **Coil form**: Dimensions: two, 3" diameter Plexiglas plates, one 1" long, ½" diameter piece of wooden dowel, screws of appropriate size. This coil form will be the spool for the copper wire, which will fit neatly within the magnet. Cost: about ***$1.00 (figure 13).***

16. **Magnet:** Dimensions: with opening about 1" wide and 5/8" deep can be obtained from Edmund Scientific, part no. U41,949. The magnet will interact with the coil of copper wire, inducing a current. Cost: about ***$55.00 (figure 14).***

17. **Magnet mounting bolt**: Dimensions: one 6/32 brass bolt, 1 ½" long with washer. Brass bolt secures magnet to boom without disrupting magnetic field. Cost: about ***$1.00***.

18. **Lead weight**: Dimensions: enough lead material for a weight of about 5 pounds. The weight will serve as mass for the boom. Cost: about ***$6.00 (figure 15).***

19. **Weight form:** Dimensions: variable and not critical. Cylindrical weight works well. The form can be an old coffee can, etc. The form is used for containing the melted lead. Cost: about ***$1.00***

20. **Wooden Dowel**: Dimensions: 6" long and 3/4" in diameter. Dowel will be attached to dampening card at one end, and to boom at the other. Cost: about ***$1.75 (figure 16).***

21. **Dampening card**: Dimensions: about 3 ½" by 3 1/2" square Plexiglas. Will be attached to dowel with screw, and will rest in the dampening fluid. Cost: about ***$1.00***

22. **Dampening screw:** Dimensions: variable. One 6/32 ¾" long screw should suffice. Screw will secure card to dowel. Cost: about ***$0.50***.

23. **Dampening oil**: Dimensions: varying viscosities will dampen to desired effects. Cost: about ***$2.00.***

24. **Oil container**: Dimensions: variable, depends on size of dampening card. Small tin container should allow dampening card and fluid to rest inside perimeter. Cost: about ***$1.00.***

25. **String Spirit Levels:** Dimensions: two levels, each about 1" to 2" long. Used to level base plate. Cost: about ***$3.00 (figure 17).***

Equipment:

Drill press ***(figure 18)*** and hand drill with associated drill bits, including sizes 17/64, 19/64, 11/64, 9/64, 7/64, 16/64, vise, center punch ***(figure 19)*** base stand and rod, ruler, file and sandpaper, grinding wheel ***(figure20)***, forceps, die and tap ***(figure 21)*** with accompanying sizes of ½-20 die, 15/64-24 tap, 7/32 tap, muffle furnace and/or welding torch, plumb bob, "Superglue" or other adhesive, Philips and flathead screwdrivers.

Figure 1: Aluminum base plate

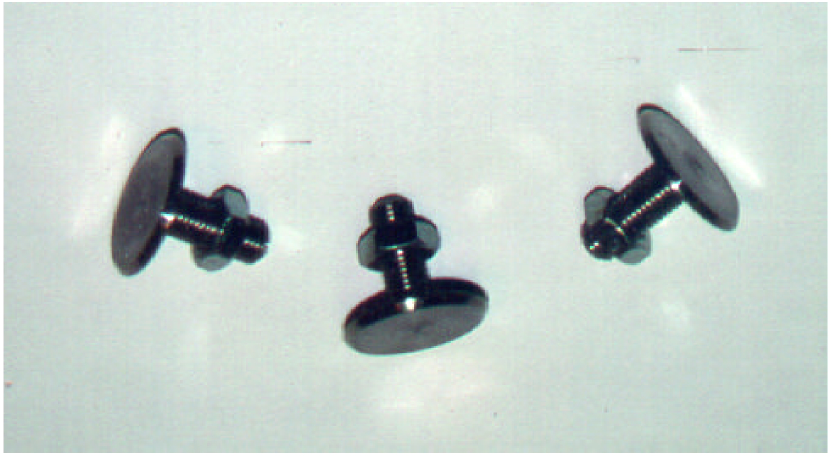

Figure 2: Three leveling feet

Figure 3: ½" diameter u-joint

Figure 4: ½" diameter t-joint

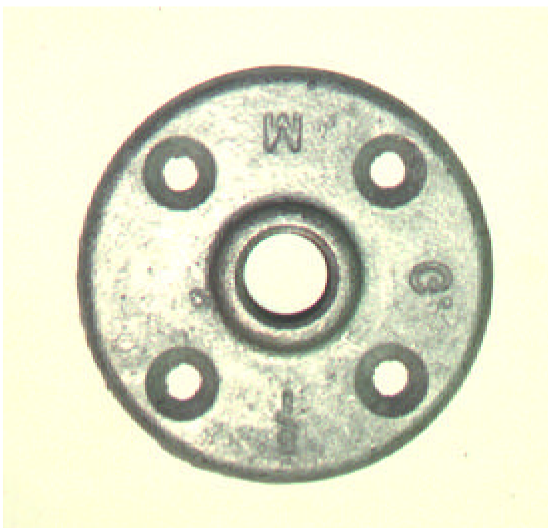

Figure 5: ½" diameter mounting plate

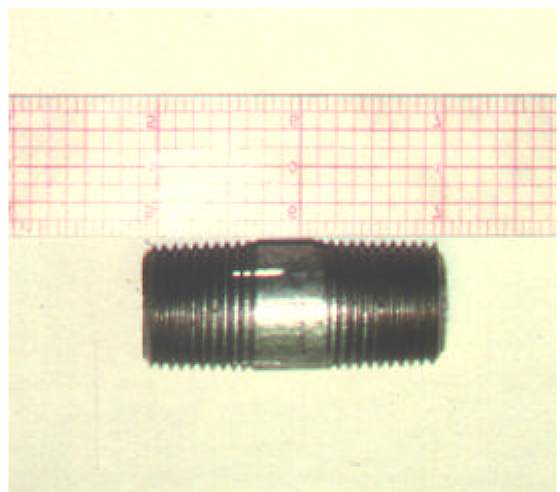

Figure 6: ½" diameter nipple

Figure 7: 16 ½" pipe, threaded at both ends

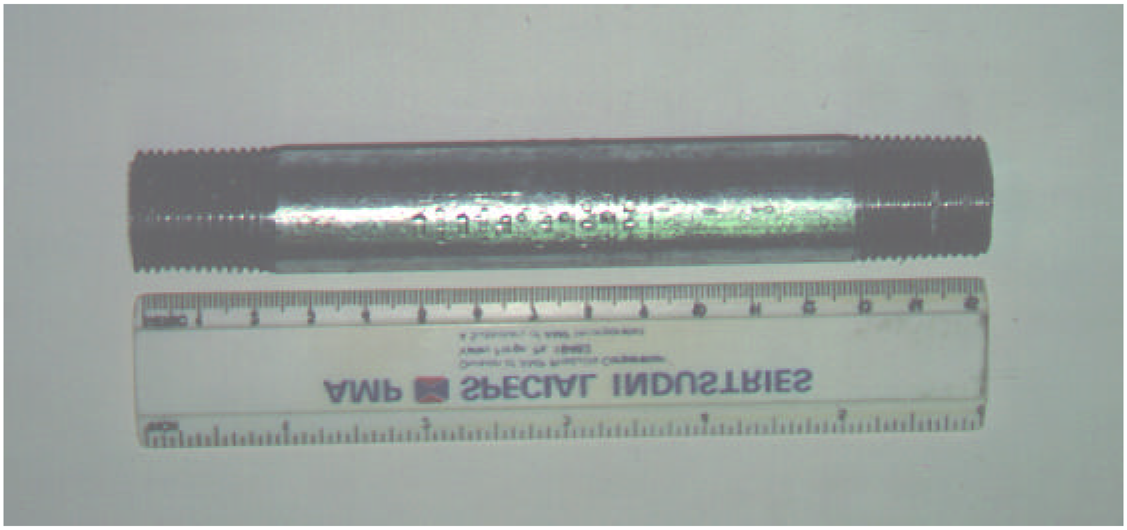

Figure 8: 6" pipe, threaded at both ends

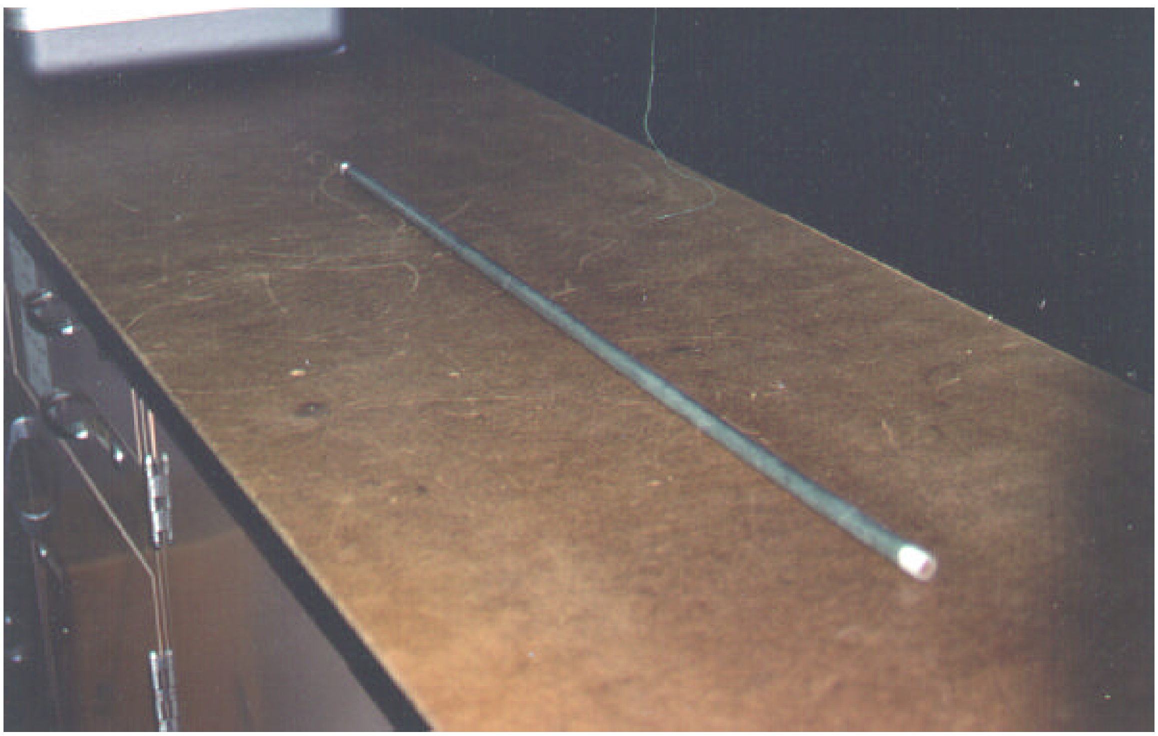

Figure 9: 36" long steel boom

Figure 10: Boom stops

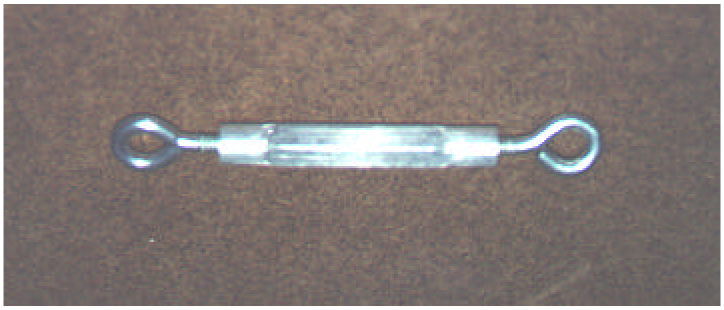

Figure 11: Eye and eye turnbuckle

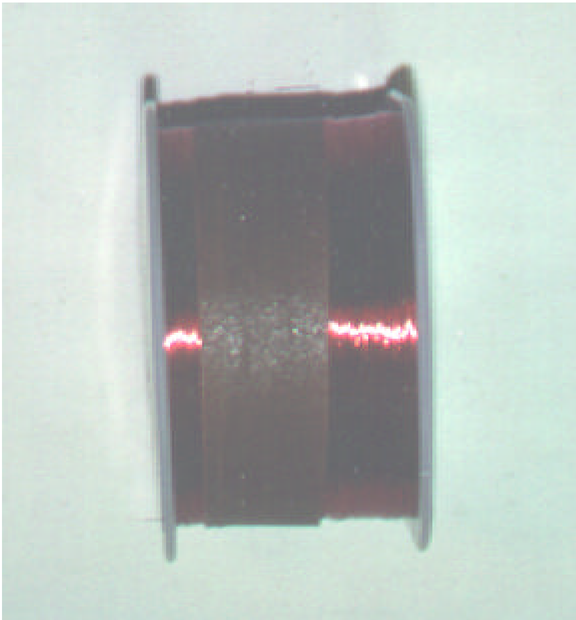

Figure 12: Coil of copper wire

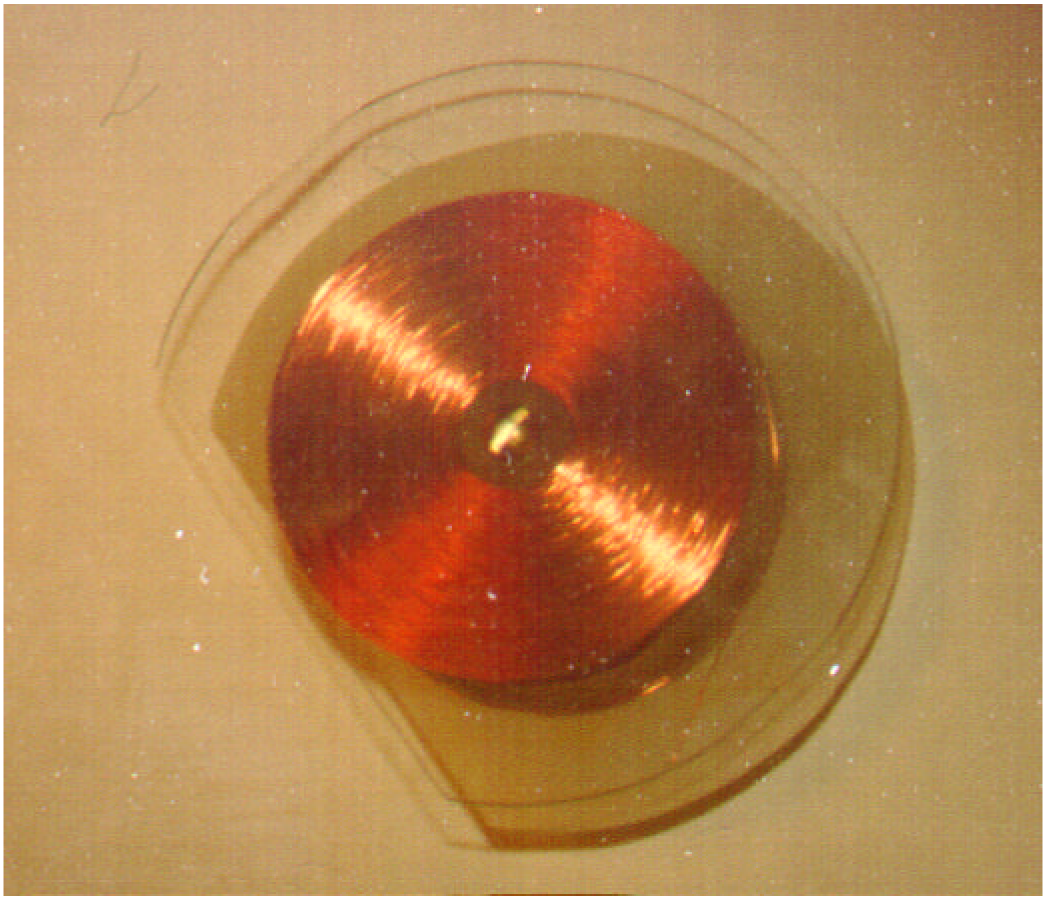

Figure 13: Coil form

Figure 14: Magnet

Figure 15: Lead weight

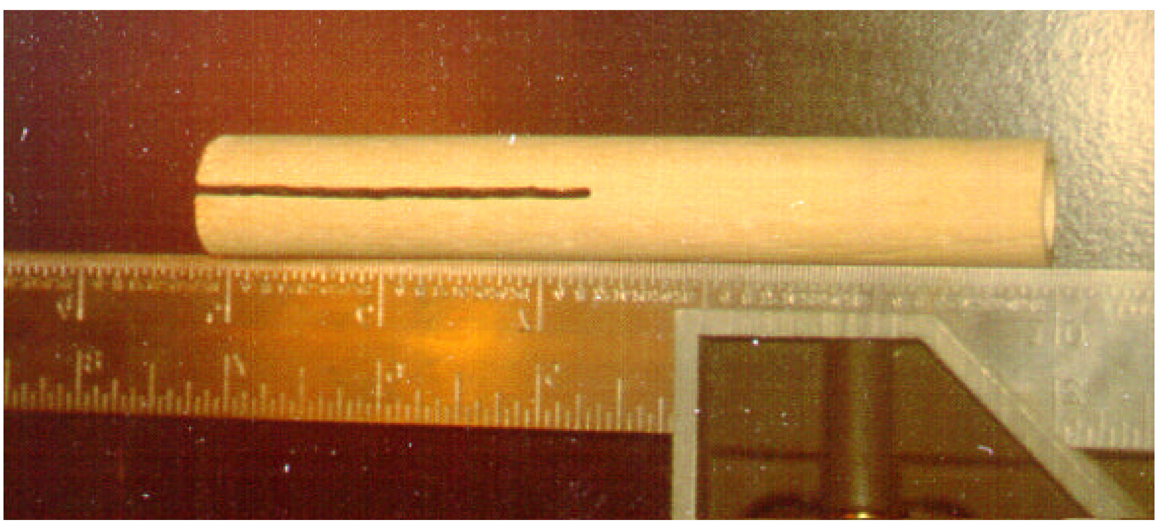

Figure 16: Wooden dowel

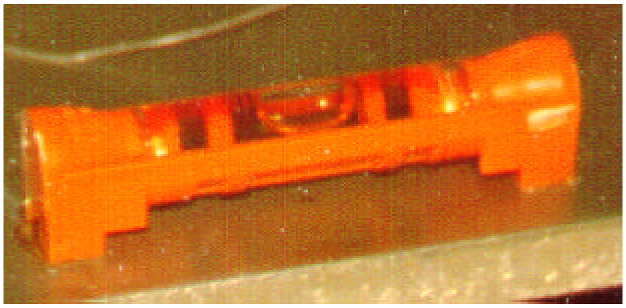

Figure 17: String spirit level

Figure 18: Drill press

Figure 19: Center punch

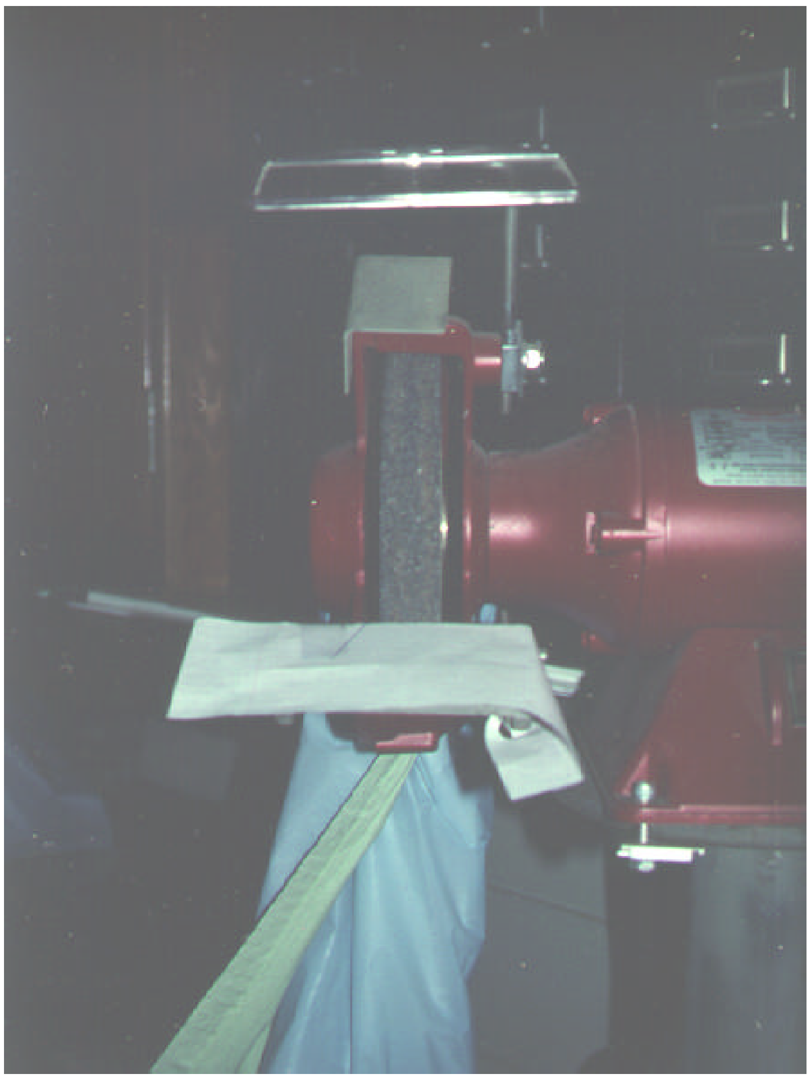

Figure 20: Grinding wheel

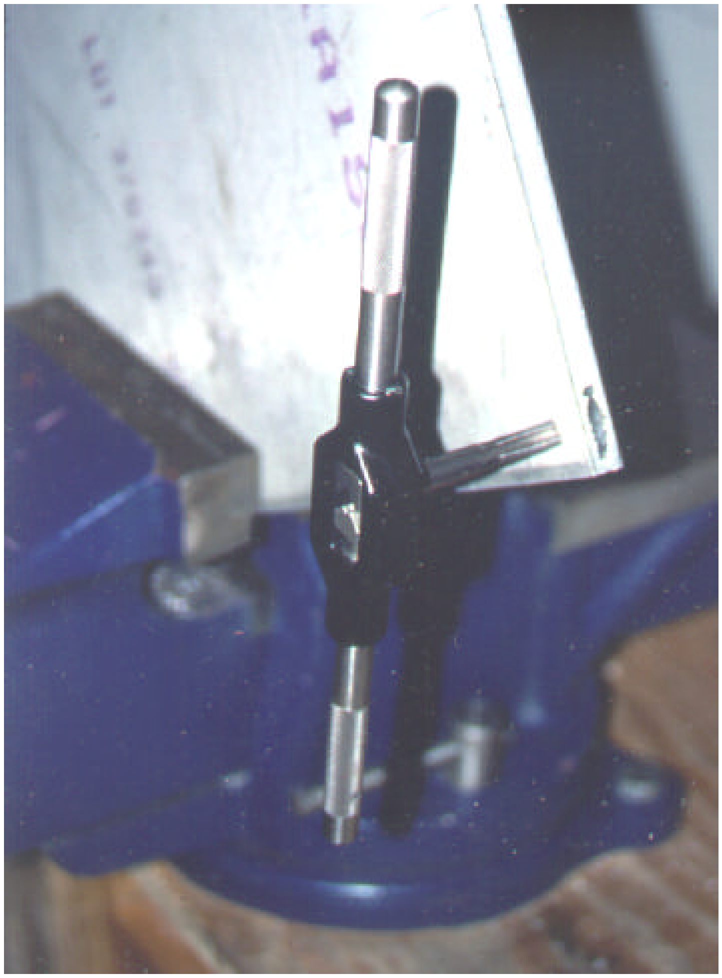

Figure 21: Tap

<u>The Construction Process:</u>

***<u>Assemblage of Upright Apparatus</u>*: The construction process begins by assembling the upright apparatus.**

1. Screw each ½" nipple into a mounting plate.
2. The two T-joints are added to the individual nipple/mounting plate combinations ***(see figure 22).*** It is important to screw in the components loosely at first, because the pieces on opposite sides will not rotate in similar directions.
3. The 16 ½" pipes are now added. Once both upright pieces are screwed in, they are connected by means of the 6" pipes and the elbow joints. Each elbow joint should be screwed loosely onto a 16 ½" pipe.
4. The 6" pipes are now added as connectors between the elbow joints and t-joints on each upright support ***(see figure 23)***.

Figure 22

Figure 23

<u>Preparation of the base plate</u>: Once the upright apparatus is complete, holes are drilled in the base plate for the three adjustable feet and for the attachment of the upright support.

5. It is best to place the upright support on the base plate, about ½" in from the end and relatively centered between the sides ***(see figure 24)***. The locations for drilling holes to secure the upright apparatus are marked with a center punch. To measure for the adjustable feet: mark two holes on the back edge (edge closest to upright apparatus), about ½" from each back corner and then ½" in and midway across on the front edge ***(see figure 24)***.
6. After marking, drill a hole completely through the plate with the appropriate drill bit sizes: 17/64" for adjustable feet and 19/64" for mounting plates.
7. Now drill holes in the base plate for attachment of the boom stops. Boom stops can be constructed in any number of ways; ***see picture 10*** for an example of a boom stop device. These stops can be attached with screws of various sizes. Drill the holes with the appropriate bit size for the screws that are to be used. The holes for attachment should be drilled on both sides of the boom, and equidistant on each side. Measuring for these holes simply requires the boom to be laid in its approximate rest position, and then marking holes on the base plate on each side.

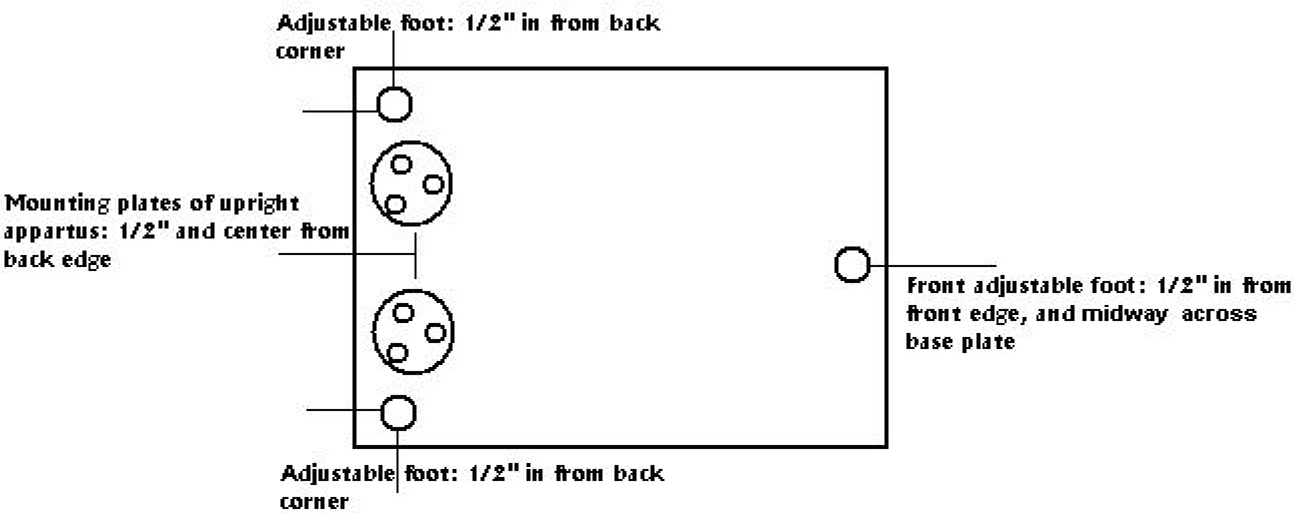

Figure 24: Location of drill holes

8. After drilling the base plate, holes for the leveling feet must be tapped. These holes are threaded with a 15/64"-24 tap ***(see figure 25)***. Holes for the mounting plates and boom stops do not need to be tapped, as these screws can be secured with nuts. Once drilling and tapping holes for the leveling feet on the base plate is complete, the upright apparatus can be attached. Spot welding the jointed areas on the upright support is not essential, but it does increase the apparatus's stability.

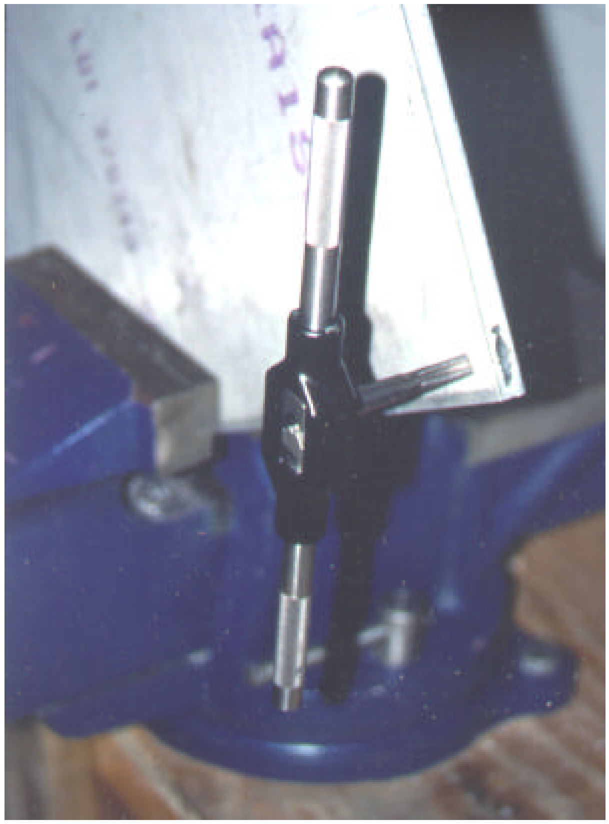

Figure 25: Tapping

Preparation of the boom: ***The next step in constructing a Lehman Seismometer is preparation of the boom***.

9. First cut the steel rod to a length of about 35 ½”; the length is not critical and is entirely dependent on the dimensions of the base plate.
10. One end of the boom will need to be threaded about six to seven inches using a ½-20 die. It is important to use a good oil lubricant in this process and small rotations (about ¼ turn each time).
11. After threading, a knife-edge should be made on the end opposite the threaded region. A knife-edge can be made by the use of a grinding wheel, rotating the boom exactly 180 degrees on each approach. It is easiest to use a magic marker during this process; making one dot on each side of the rod helps in rotating the boom correctly for a perfect knife-edge. When approaching the grinding wheel, it is also important to use the same angle of attack. Do not raise or lower the level of the boom relative to the grinding wheel once the process is started. After the knife-edge looks approximately symmetrical, it can be inspected for accuracy. It is desirable to have the knife-edge appear linear in appearance in cross section ***(see figure 26).*** If the knife-edge appears triangular, or thicker at one end than the other, it can be easily corrected. One correction method requires a whole new angle of attack. This will simply bring the start of the knife-edge further down the rod, and can easily be done on the grinding wheel. Another method can be done with the use of a hand file. Unequal pressure should be directed towards the thicker portion of the knife-edge. Once corrections are made, the knife-edge should be hand filed on both sides to reduce feathers or imperfections ***(see figure 27).*** The knife-edge should, in theory, be perfectly symmetrical about the axis of the boom ***(see figure 28).***

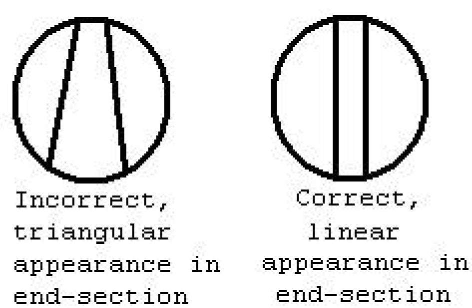

Figure 26: End section of knife-edge

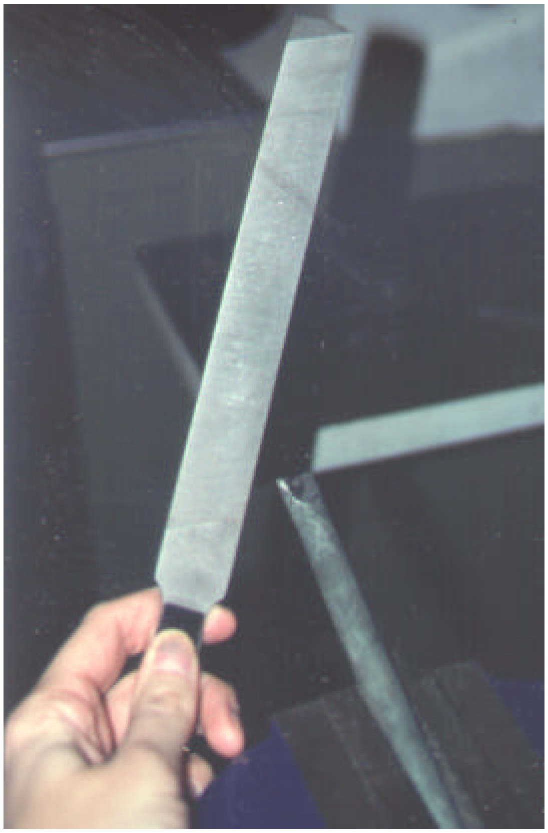

Figure 27: Filing of knife-edge

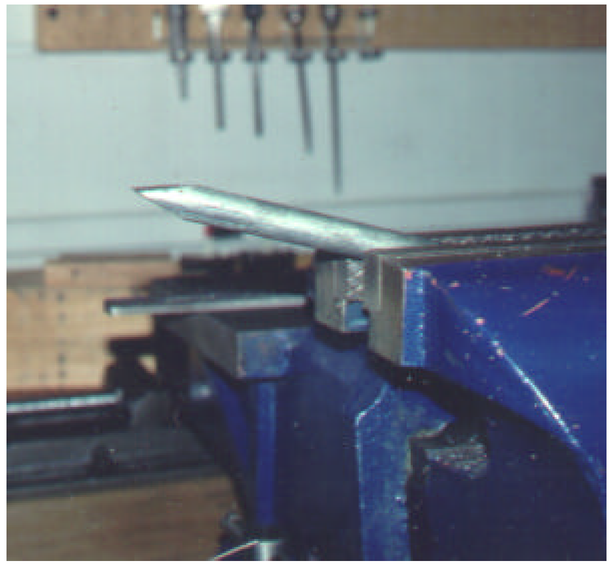

Figure 28: A perfect knife-edge

10. Once the knife-edge has been created, the boom can be drilled for acceptance of the magnet and cable wire. Drill a hole ½” in from the threaded region of the boom with a 7/64” drill bit.
11. Drill a hole for the magnet with a 9/64” drill bit, 1” from the cable hole.
12. After drilling, the magnet can be attached with a 6/32”, 1 ½” long brass bolt and a nut.

***Drilling of the Crosspieces*: In order for the boom to be attached to the upright apparatus, one needs to next drill the upper and lower crosspieces.**

13. The first location is ½ way across the upper crosspiece. Mark with center punch. To measure for the equivalent location on the lower crosspiece, one should first level the base plate, then use a plumb bob to mark the spot on the lower crosspiece that lies below the upper crosspiece drill spot. Mark with center punch.
14. The lower crosspiece can then be drilled on the drill press (***see figure 29***).
15. The upper crosspiece will need to be drilled with a hand drill, as it requires a hole to be drilled at an angle. The best method for accuracy requires two people; one person should firmly hold the base plate/apparatus combination on the floor, while the second person stands above and drills at an angle. It is easiest to place a ruler or yardstick against the upright apparatus, resting from the upper crosspiece to a point on or near the base plate where the cable “would” attach to the mounted boom. This makes for better sighting while drilling.

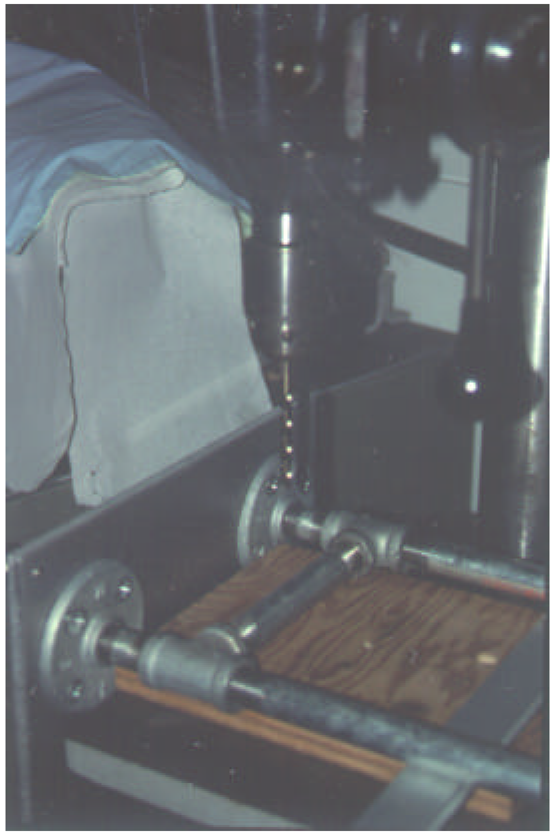

Figure 29: Drilling of lower crosspiece

<u>Bolt Preparation</u>*: *Once the holes have been drilled on the crosspieces, the bolts that are to be inserted can be readied.

18. The head of the bolt for the bottom crosspiece, a ½-20 hardened steel bolt, 1 ½" long, should be filed flat. This will be the pivot bolt upon which the knife-edge of the boom will swivel. It is important for the head of the bolt to be as flat as possible.
19. The bolt for the upper crosspiece will hold the cable, and it needs to be sawed about 1/3 of the way through to ensure the cable is held secure ***(see figure 30)***.

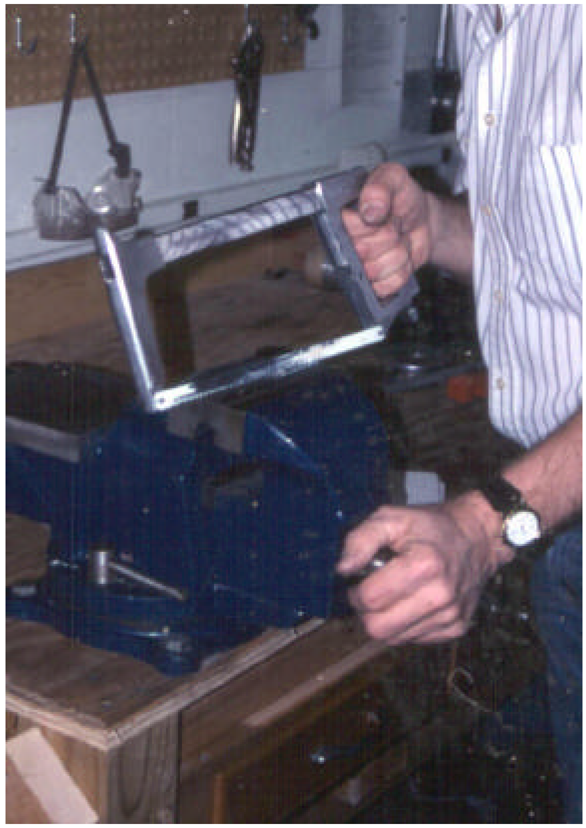

Figure 30: Sawing of bolt for upper crosspiece

<u>Creation of the Lead Weight</u>: The next procedure in constructing a Lehman seismometer is creating a lead weight*. *The easiest way to melt a lead brick is by use of a muffle furnace. If one has access to such equipment, it is highly advisable to do so. If not, a lead brick can be melted to the appropriate shape and weight (5 pounds and of any symmetrical form- a cylinder works nicely). A good setup is depicted in figure 31.

20. The arrangement consists of a lead brick that has been drilled, and then clamped to a rod/base stand device. Underneath the brick is a tin mold, into which the drippings of the lead brick will fall. One should put a ceramic plate underneath the drippings tin to prevent melting onto the stand, etc. The brick can be melted by one of two methods; acetylene tanks can be purchased at any local hardware store ***(see figure 32)*** and welding torches can be accessed at university and/or local industrial workshops. Either method works well as long as the brick is heated slowly and evenly at one end. The procedure should be done with all appropriate safety equipment (goggles, gloves, etc.) and it should be done in a well-ventilated area. A fume hood works nicely ***(see figure 33)***, as long as the air circulation rate is not high enough to inhibit the melting of the brick.

21. After the weight has cooled in the form, it can be removed and drilled. A ½" hole should be drilled through the weight: it is not necessary to thread this hole as the soft lead of the weight will thread itself against the threaded region of the steel boom.

Figure 31: Setup for melting of lead brick

Figure 32: Acetylene tanks

Figure 33: Torching setup inside fumehood

<u>Preparing the Copper Wire</u>: One of the last procedures is the preparation of the wire coil. It is highly unlikely that one can acquire the coil of wire on an appropriate-sized spool. A spool is needed that will allow the maximum closeness between the coil of copper wire and the magnet on the boom; it is desirable to have the wire move as far inside the magnet as possible.

22. A homemade spool can be built out of two Plexiglas (or fiberglass) plates, a wooden dowel cut to the appropriate width (just wide enough to fit inside the opening of the magnet, around ¾”) and a brass bolt and nut ***(see figure 34)***. Two holes should be drilled through one plate for threading of the wire to monitoring devices. This new coil spool can be applied to the setup in ***figure 35***.
23. The homemade spool is attached to a hand drill that is secured by a vise. The manufacturer’s wire is held between two clamps on a rod/base stand apparatus.
24. The copper wire is then threaded from the store-bought spool to the homemade spool. The hand drill can then be used to wind the copper wire onto the new spool. The wire should be wound evenly from one plate to the other, minimizing lumps in the layering. An even thickness is desired.
25. The finished product can be enhanced by cutting straight one side of the spool ***(see figure 13)***. This will increase the copper wire/magnet interaction. The copper wire should be attached to a coil mount, which can be hand made from various materials ***(see figure 36)***. Typically, this will consist of a bar or metal

piece (non-magnetic) that is attached to a sturdy base. The bar must allow the attached copper wire to be of equal height with the magnet when the magnet is on the raised boom.

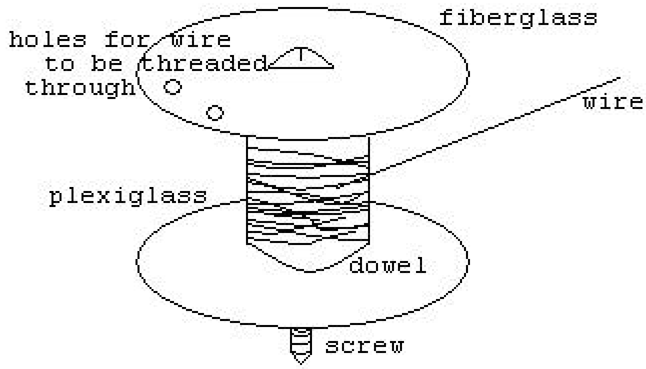

Figure 34: Coil form construction

Figure 35: Setup for winding copper wire

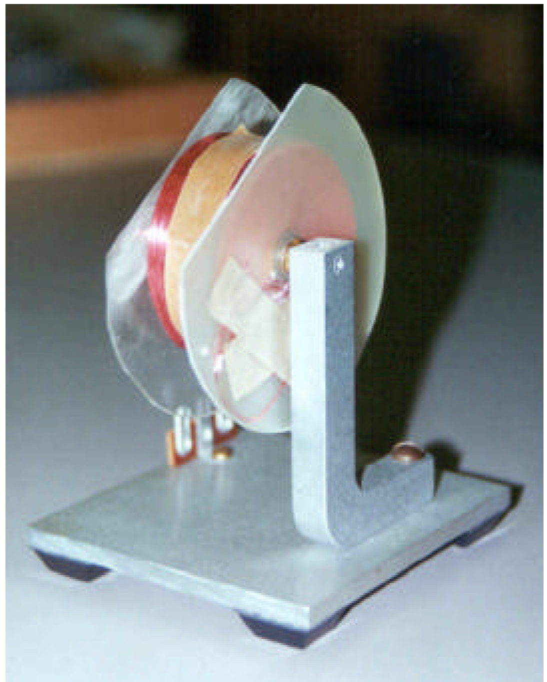

Figure 36: Coil mount

Addition of Dampening Devices**: Lastly, a dampening device needs to be made for the end of the boom**.

26. Cut a wooden dowel (3/4” diameter) to about 6”.
27. Saw one end about ½ way through ***(see figure 16)***, and drill the other end to accept the ½” diameter of the steel boom.
28. Attach a dampening card at the sawed end; this can be held in place with screws and/or adhesive. Once the boom is mounted, rest the card in any type of contained dampening fluid; oil works well.

Final Procedures:

The machine is now built, and is ready to be set in place. The boom can be threaded with the connecting cable, and the connecting cable pieces should be held with an eye and eye turnbuckle. It is best not to tie the cables to the turnbuckle, as this can lead to kinking and eventual breakage. The cable ends can be threaded through the eyes of the turnbuckle and clamped with a screw, washer and nut combination ***(see figure 37)***. After the cable is connected, the boom should be gently placed up against the pivot bolt, and adjusted with the turnbuckle to the appropriate height above the base plate. The boom should be relatively horizontal, or at most, tilted slightly down. The boom should not be tilted up, as this will upset the period of the sway.

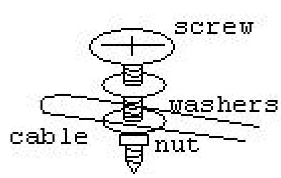

Figure 37: Clamp for cable ends

The base plate will also need to be adjusted by means of the leveling feet to a position that it is parallel with the boom and surface that it rests on. Two string levels should be added to the base plate to aid in adjustments. String levels should be placed in perpendicular directions and should also be flush with the surface of the plate ***(see figure17)***. Adding adhesive around the feet of the string levels, rather than underneath, will ensure a flat contact between the levels and the plate.

The construction of a Lehman Seismometer is now complete, and the seismograph is ready to detect earthquakes. The output wires from the coil of copper wire should be attached to an amplifier to magnify the induced signal. The amplifier can then be connected to a monitoring or recording device, like an oscilloscope or a computer. More information on detecting and analyzing earthquakes is available from the Public Seismic Network homepage at: http://www.home.earthlink.net/~dcdarby

Acknowledgments:

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