

Making springs for the Inyo FBV seismometer

The Inyo and successor Force-Balance Vertical seismometer designs use an astatic leaf spring similar to the original STS-1, but made from 17-7 stainless steel alloy.

Making springs for the Inyo from the raw material requires a few steps:

Starting with a piece of 0.012" stock, try to determine the direction of the material grain, which will be parallel to the direction in which it was rolled. It may be difficult to see and magnification may be helpful. The slight grain pattern on the surface will be elongated in the rolling direction and the springs should be cut parallel to that direction, though I believe that after hardening it may not matter as much. *In fact, Dave tells me that all Inyo springs he has made to date have been cut the other way to avoid possible lengthwise curvature from having been stored on a roll.*

Although as supplied from the manufacturer the material is relatively hard (Condition C) it is also rather thin, and so can be successfully cut with a sharp sheet-metal shear. Take care to clamp or otherwise restrain the piece you are cutting from in order to avoid getting a tapered spring. The Inyo design uses a spring which is 16mm (0.63") wide. Something less than 6.6" length will be required, but it might be wise to leave the spring longer, only cutting it to final length after initial testing is completed.

After cutting the spring, its side edges should be carefully smoothed and slightly rounded to reduce any micro-cracking that may have occurred during shearing. 400 or 600 grit wet/dry paper would seem to be a good choice for the final polishing.

17-7 stainless is a precipitation hardening (PH) material, which means that it is quite easy to harden, exhibiting an approximately 50% increase in yield strength after baking. Before hardening it will bend a little before breaking but after, it will just snap, much like glass. The hardening process suggested by the manufacturer takes it from Condition C to Condition CH 900, the strongest/hardest state for the material. The lot test on the roll of 0.012" material obtained by Dave Nelson suggests that after hardening it will achieve a yield strength close to 300,000 psi. Thus, when stressed to 200,000 psi, as it may be in the Inyo, it will still be somewhat below its yield stress.

Before hardening the spring should be cleaned with a mild abrasive cleaner, rinsed with warm water and dried. This will help prevent the possible formation of surface scale during hardening. After cleaning the spring should not be handled with bare hands in order to avoid fingerprints.

The manufacturer specifies a hardening cycle of 1 hour at $900^{\circ}\text{F} \pm 10^{\circ}\text{F}$. The temperature should be monitored closely to avoid any temperature overshoots, as the material will get permanently softer if the temperature goes too high. Too low and it won't get quite as hard as it could. Timing is not important so long as it bakes long enough. We suspect that it is best to simply leave the spring in the oven, letting it cool before taking it out. The surface of the spring will exhibit a light brown staining after hardening. This might be avoided by wrapping the spring tightly with 0.002" stainless foil before heating in order to protect it from the air. So far, it hasn't been felt necessary to do this, but it could be tried if the staining was a concern.

After assembling the instrument and finding what spring length is needed to obtain the desired free period, you can cut it to its final length. A good method would be to simply score the spring and snap it, much as you would cut glass.