Making springs for the FBV seismometers

The Inyo and successor Force-Balance Vertical seismometer designs have an astatic spring as originally used in the STS-1, but made from 17-7 PH stainless steel alloy.

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

Starting with the appropriate thickness of 17-7 PH, condition CH stainless, 0.012" thick for the Inyo, 0.006" for the Yuma and 0.004" for the Napa, 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 much. [In fact, Dave tells me that to date he has cut most springs the other way.]

Although as supplied from the manufacturer the material is relatively hard (Condition CH) it is also rather thin, and so can be cut with a sharp sheet-metal shear. Take care to clamp or otherwise restrain the piece you are cutting in order to avoid getting a tapered spring. The Inyo design uses a spring which is 16mm (0.63") wide, and something less than 6.5" length will be required, but it might be wise to leave the spring longer, only cutting it to final length after the initial setup is completed. The Yuma spring is 1.25" wide and the Napa is 1".

After cutting, the side edges of the spring 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.

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, more like glass. The hardening process suggested by the manufacturer takes it from Condition CH to Condition CH 900, the strongest/hardest state for the material. The lot test on the 0.012" material obtained by Dave Nelson suggests that after hardening it will achieve a yield strength slightly over 300,000 psi (2068 MPa). Thus, when stressed to 200,000 psi, as it may be in the Inyo, it is still somewhat below its yield stress.

The manufacturer specifies a hardening cycle of 1 hour at 900°F ± 10°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 and let it cool before taking it out. Before baking the spring surface should be well cleaned:

> Thorough cleaning of parts and assemblies prior to heat treatment improves appearance and is necessary for the development of uniform properties. Removal of oils and lubricants with solvents also assures that the steel will not be carburized from this source. Carburized 17-7 PH Stainless Steel will not respond properly to heat treatment.

Cleaning may be accomplished by the following two step procedure:

1. Vapor degrease or solvent clean. This step removes oil, grease and drawing lubricants.

2. Mechanical scrubbing with mild abrasive cleaners, Oakite 33 or similar proprietary cleaners to remove dirt or other insoluble materials. All traces of cleaners should be removed by rinsing thoroughly with warm water. A light, tightly adherent, uniform-appearing oxide after heat treatment is evidence of proper cleaning.

After hardening, the surface of the spring will exhibit a light brown staining, which 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 brown stain was a concern.

After assembling the instrument and finding what length the spring needs to be 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. When possible, leave a little excess length to allow for future adjustment.