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TRAVELLING MICROSCOPE CALIBRATION

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I have been working on calibrating the travelling microscope system for inspecting the E614 wire planes. I have compared the microscope readout with a Russian glass comb (used for stringing) and a Bishop Graphics precision glass ruler.

The travelling microscope consists of two cameras mounted on a linear rail system. One camera points down vertically and the other points down at a 45° angle to the same focal point. The images appear on television screens and are lined up with a graticule on the screen. The cameras are moved along the rail and their position is read out using a digital linear encoder. The x direction position is measured directly by the vertical camera. Distance in the vertical direction is the difference between the position measured with the two cameras.

I observed two types of error in the travelling microscope. The first is a linear error of 0.1µm/mm. The second is a nonlinear error of ±10µm in the x direction and ±20µm in the vertical direction. The nonlinearities are shown in Figure 1. Measurements are reproducible to a σ of ±2µm. Since the results with the Russian glass comb and the Bishop Graphics ruler are consistent with each other I assume that all the error is in the travelling microscope. Since the digital linear encoder is specified to be accurate to ±5µm over all I believe that the errors I am seeing are a direct result of the accuarcy of the mechanical components of the microscope system, in particular the rail bed, the bearing and the rail. Figure 1 also shows the vertical motion of the camera carriage measured with a dial gauge. Although not perfect, there is some correlation between the vertical motion and the nonlinearities.

There are two approaches that can be taken to deal with these errors. The first is to map them and correct for them in software. The second is to build the system with more mechanical precision to either reduce or eliminate the need for software correction. In the software approach we can pick up a fiducial on the encoder scale and measure absolute values of position relative to the fiducial, then correct for the nonlinearities in software. In the mechanical approach we rebuild the system using more precise components. The present system as built only used standard machine shop machining tolerances (typically 50µm or so), ordinary steel for the base, standard grade rail and a standard grade bearing block. I have consulted with several machine shop experts here and have learned that we should be able to do much better. First we should order tooling steel plate for the rail bed. It is a more stable material. With this material it should be possible to get the rail bed ground flat to a precision of ±5µm or better in flatness. It is also possible to order ultra precision rail which should reduce the running parallelism from about 20µm to 2µm. In addition we can specify a greater preload in the bearing block which should reduce play in the motion. I believe that these changes would result in greatly improved linearity and will be more reliable than software corrections.

I estimate that it will cost about $2000 to purchase an ultra precision rail and bearing block and about $2000 to machine and grind a more precise railbed.

This would give us one precision inspection tool. Originally the idea was to build two travelling microscopes so we could use one on each end of the wire plane for inspection and for wire replacement. My recommendation is that we build just one improved microscope and see how it works. We can inspect the planes by turning them 180° and using the same machine to inspect both ends. It would not be possible to replace wires on the inspection table with this approach. Instead we could put the plane back on the stringing table and survey a replacement wire back in using a stereo microscope on a floor stand. This approach would save on equipment cost at the expense of interfereing with production speed. If it was felt that it slowed down production too much we could then build another precision system to inspect both ends and replace wires on the inspection table.