The Technical Side

Sources of Error

By Chris Cothrun, Service Technician, Ingenuity, Inc,

For the past two years we have been providing tips on keeping your survey equipment as accurate as possible. In this issue we will review some of that information as well as add some more possibilities for error. We will divide the errors into three categories: systematic instrument error, personal error, and random errors from natural causes.

Systematic instrument errors have gotten the most attention in our previous articles, because they can, for the most part, be eliminated by adjusting the instrument or by using procedures that eliminate the error. One source of error is mis-adjusted level vials. Most advanced instruments have single or dual axis compensators that correct the major errors that result from the vials being out of adjustment. This can be checked by centring the bubble in the vial and then rotating the instrument 180 degrees. If the bubble is still not centred, use an adjusting pin to move it halfway back to centre, and repeat the whole checking process again. Another source of error is the telescope reticle. This error can be checked for and eliminated by using the mean of a direct and reverse angle reading. There are several errors that occur as a result of the various components of the instrument not being mechanically adjusted. These include the trunion axis (telescope axis) not being perpendicular to the vertical axis or centre of the instrument, the optical axis not coinciding with the line of sight, out of centre circles, and imperfect graduations.

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These errors are eliminated either by direct and reverse angle measurements or multiple observations using different parts of the circle.

Personal errors occur from both the mistakes made in the field and the limitations of the human eye in making observations. I can't help much with the mistakes part (except tell you to get a good night's sleep and wait until after work to start happy hour), but I can give a few suggestions on the other. Think about the mistakes the eye can make when setting up and observing angles. You first set the instrument over a point using the optical plummet or a plumb bob. You next level the instrument using the level vials. Then you make at least two angle measurements sighting to some sort of target through a telescope. If using a theodolite you then observe an angle reading through the circle reading optics. Each of these processes is subject to errors due to the human eye. Aside from actual reading mistakes, parallax causes most of this error. Parallax occurs when the image of the reticle is not in the same focal plane as the image of the target. When the eye is moved, there is a noticeable displacement of the reticle on the target, Even if your reticle and target look sharp they may not be on the same focal plane. To adjust the reticle, move your head up and down while looking at the target and adjust the reticle until there is no apparent movement of the reticle against the target. Let's look at the effects of the errors and parallax on each of the processes mentioned earlier.

You start off by setting the instrument over a point, preferably with an optical plummet. Many optical plummets have a set focus at an average instrument height. If your instrument is set higher or lower, the point will not be in focus. Even if you can focus the optical plummet, there are a couple of optical plummet designs that seem to have a large focus range but exhibit parallax over most of the range. Then there is the eyepiece or reticle focus. Again, the reticle image can seem sharp but if you move your head slightly you are off the point. So what kind of error do we get from this? It would be the same as if you had not set up exactly over the point. This positional error results in a larger angular error at shorter distances. Distance errors as a result of mis-positioning are dependent on the direction to the target but are usually quite small.

Next you are going to level your instrument. Actually, I know you have to go back and forth between levelling the gun and setting it over the point but we'll consider the levelling part next. Many of the plate vials have an accuracy of 30" per 2mm. I would estimate that these vials can be set easily to one-fifth of this, giving us about 6" error. With most instruments having at least a single axis compensator, this doesn't affect the vertical angle. However, there is still the effect on the horizontal angle, which we discussed in our last article on compensators. Furthermore, there is a small error in position over the point if the instrument is not perfectly level.

One of your largest sources of sighting errors is from parallax. Again, making sure the images (reticle and target) are sharp is not enough; you have to bob your head while looking at your target and check for any movement. The focal length of your eye changes during the course of the day so you have to check for changes often. Now you sight your backsight, take an angle reading, and then sight the foresight and take another angle reading. Hopefully, you flop the telescope and repeat the process and average the an-

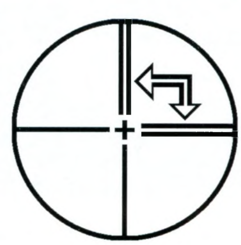

Figure 1

gles. There are two big sources of error: not sighting the point correctly and reading the angles wrong. For the best accuracy in sighting the point, I would recommend using some sort of target instead of the centre of the prism. Range poles or the little 'candy cane' sighting poles are often used. There are also targets for prisms. If you are trying to be as accurate as possible, you should be using a target. You will obtain rely even better results if you centre the target using the bifilar side of your reticle instead of the single wire. (Figure 1)

Mistakes in reading the angles also occur. With electronic total stations and data collection so popular, many of these are eliminated, but there are a couple of things you should be aware of if you are using an optical reading theodolite. You can have the same problems with parallax because the angle reading system is combining three or more separate images (the micrometer and both sides of the circle) onto the same focal plane. All of these images should be in sharp focus and without parallax or the instrument may need optical adjustment. If you don't focus exactly onto this plane, you can move your eye and see the circle readings change.

I also mentioned errors from natural causes. I can't help you much with these except to make you aware of them. These are the errors from wind, temperature changes, changes in atmospheric conditions, and ground or tripod settlement. High accuracy surveys require some extra effort to reduce these effects. This includes shading the instrument with an umbrella, using a concrete pillar instead of a tripod, and even making observations at night when atmospheric conditions tend to stabilize. Be aware of them so you can change your procedures if necessary.

If you want to know more, the book *Surveying Theory and Practice* by Davis and Foote contains some excellent information. As always, I welcome your comments, agreements, and disagreements. Send any correspondence to The Technical Side, 1562 Linda Way, Sparks, NV 89431 or fax it to (702) 359-6993.

Environmental Conditions and the EDM

By Martin Crook

Many distance measurement problems encountered when using electro-optical EDMs can be directly related to atmospheric conditions and other interference that can affect the accuracy, repeatability, and proper operation of distance meters. First, a little background on the operation of these units.

Equipment

Most electro-optical distance meters measure distance by using a series of different frequencies (or signals) imposed on a nearly visible carrier wave. These waves are transmitted to a retro prism, which reflects the signal back to the instrument. As each frequency is received, it is compared to an internal standard to determine a phase offset. These several values are used to calculate a distance. In this discussion, we will assume that the EDM is functioning properly and measuring distances accurately. The retro prism must be clear of dirt, fogging, and fractures, and be pointed squarely at the distance meter in order to achieve good results. Most prisms can be removed from their canister and cleaned, but some are sealed into the canister, or "can." Sometimes dirt and/or moisture on the back side of a prism are not very obvious, but they can greatly impair the reflective ability of the glass. Fractures or chips not only cut down the amount of available reflective surface but can also cause the signal to scatter or change direction. The result is a weakened return signal or possibly a false distance. Prism pointing errors can cause small distance errors (less than .05 ft) and a loss of signal return.

Conditions

Any condition that interferes with your ability to see clearly will also impair the EDM in measuring a distance. An EDM signal is not very strong and will dissipate or lose collimation at a great distance. If fog, moisture, heat waves, dust, smoke, snow or any other particles are in the line of sight, the EDM signal can be affected by being blocked or deflected. These types of conditions may require the use of additional prisms to return enough signal to complete the measurement, a different occupation, or even rescheduling. Shooting across a body of water or a boggy area can cause problems due to excessive moisture in the air. Deflected signals can increase a distance measurement by making the path longer. Generally, heat waves deflect or refract a signal path vertically, but if the wind is blowing, a horizontal deflection can also occur. If your vision is influenced by a condition, the EDM will also be affected. Diffraction can cause an EDM signal to completely miss the prism. A rise or a knoll in the line of sight between an instrument and a prism can cause the EDM signal to bend as it passes near the top of the rise. This phenomenon occurs in both directions, going to the prism and coming back to the EDM. This bending can cause the signal to completely miss the prism or EDM, even when the target appears to be in plain sight of the operator. Diffraction also causes intermittent signal return or erratic measurements when a branch, pole, or the edge of a building, is in the line of sight but does not block the beam transmission.

High-voltage power lines can affect such EDM internal components as inductors, coils, capacitors and digital circuits, including the microprocessor. The charge or field that occurs when using EDMs near high voltage not only affects measurement accuracy, but can damage precision internal components. Fortunately, this is a rare occurrence. Taking measurements parallel to high-voltage power lines has produced some interest-