10-Foot Portable Subtense Bar

D. E. WINSOR, Design Engineer, U.S. Bureau of Public Roads, Region 9, Denver

The subtense bar has long been accepted theoretically as a base for triangulation. When used with precise survey instruments, very accurate results can be otained. In recognition of the potential of this device, Europeans have designed and used subtense bars for many years. Their subtense bars, at least those used commercially in this country, are limited to a 2-meter length.

It was reasoned that computations would be simplified and the range of operations would be proportionately increased if the bar length could be increased to 10 ft. To retain its value for field use, 10 ft was arbitrarily selected as the optimum for portability and wind resistance. A working model has answered all the requirements of portability and accuracy.

To hold the cost to a minimum, the basic parts of the instrument were constructed from obsolete surveying instruments. A graduated centering rod was incorporated so t˙.e exact height of instrument could be easily determined. Although the primary purpose of the subtense bar is for horizontal traverse, it was reasoned that it would also be valuable for trigonometric leveling.

This subtense bar has been in almost constant use since it was developed in 1956, and the results have been highly satisfactory. It has been used on two 16-mile conventional ground surveys and in the prosecution of 100 linear miles of ground control work for mapping by photogrammetric methods. In establishment of preliminary traverse for highway location, the use of the bar in every instance has proved more accurate than the best chaining obtained from the field crews. The most encouraging development, however, is the elimination of gross errors which invariably develop in conventional chained traverse. The unexpected use in establishing supplemental vertical control for photogrammetry has even exceeded the original wishful thinking. The ease and accuracy with which these vertical controls can be established in rough terrain have saved many man-hours. The instrument has been accepted as standard equipment for the ground control crew, along with the theodolite, self-leveling level, etc.

● **THE SUBTENSE** bar has long been accepted theoretically as a base for short range triangulation. When used with precise instruments, very accurate results can be obtained. This principle of distance measurement consists of the precise measurement of the angle subtended by a bar or chord of known length. The bar is set up directly above the end point of the distance to be measured and in horizontal position.

Then: D = Distance
b = bar length
Δ = subtend angle

$$D = \frac{b}{2} \times \text{ctg} \frac{\Delta}{2}$$

In recognition of the potential of this device, Europeans have designed and used subtense bars for several years. Their subtense bars, at least those available commercially in this country, are only 2 meters long. It was reasoned that computations would be simplified and the range of operations would be proportionally increased if the bar length could be increased to 10 ft. To retain its value for field use, 10 ft was arbitrarily selected as the optimum for portability and wind resistance. Predicated

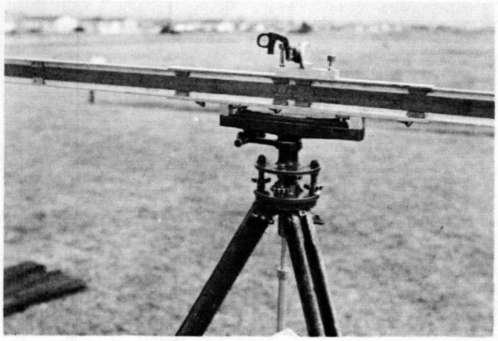

Figure 1. 10-ft subtense bar; leveling and sighting arrangement.

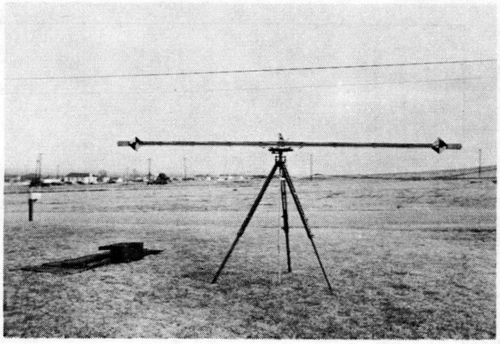

Figure 2. Bar in operating position.

by the acute need for a device to facilitate the making of precise surveys over rugged topography, the idea was translated into a working model. This model was constructed in May 1956, and has satisfactorily answered all the requirements of portability and accuracy.

To hold its cost to a minimum, the basic parts of the instrument were constructed from obsolete surveying instruments. A graduated centering rod was incorporated so that the exact height of instrument (H.I.) could easily be determined. Although the primary purpose of the subtense bar is for horizontal traverse, it was reasoned that it would also be valuable for leveling by trigometric methods. This subtense bar has been in almost constant use since it was developed in 1956, and the results have been highly satisfactory.

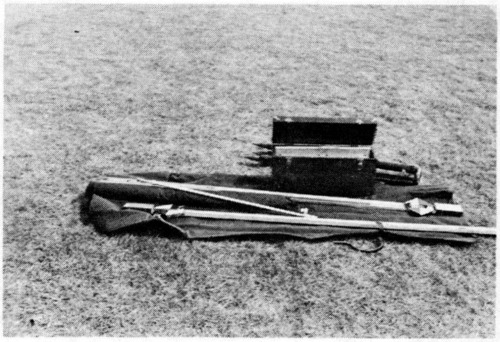

Figure 3. Bar undisturbed.

Measurements are affected by two types of errors, accidental and systematic. Accidental errors are the result of errors in reading the subtend angle. These errors are substantially eliminated by repetition of angle measurements. The bar is so constructed as to eliminate most of the systematic errors. To accomplish this, invar strips anchored at the center of the bar are held to correct distance under spring tension. Targets mounted on channels through which the invar floats have micrometric adjustment for exact setting. This device tends to eliminate any incorrect length of the base stemming from normal atmosphere fluctuation. The sensitive level bubble and accurate pointing device insure a horizontal bar perpendicular to the line measured. The vertical projection of the ground point to the elevation of the targets is accomplished by the use of a graduated centering rod equidistant from the two targets.

When side hill measurements are taken, unequal lateral refraction on the two targets may occur causing unfavorable results. This is difficult to eliminate because the observer does not know when the targets are affected. On this type of terrain, it is good practice to measure distances both forward and backward. The mean may be assumed to be more correct. Using a universal theodolite, which measures angles to the nearest second of arc, and limiting the range of measurements to 850 ft, third order accuracy in horizontal measurements has been achieved. In all instances, the traverse closures were more accurate than that attained by chaining in the plumb-bob and hand-level methods which are used in most highway survey work. Greater distances were accurately measured when atmosphere conditions were favorable. Some difficulty was encountered in pointing the instrument correctly to the targets

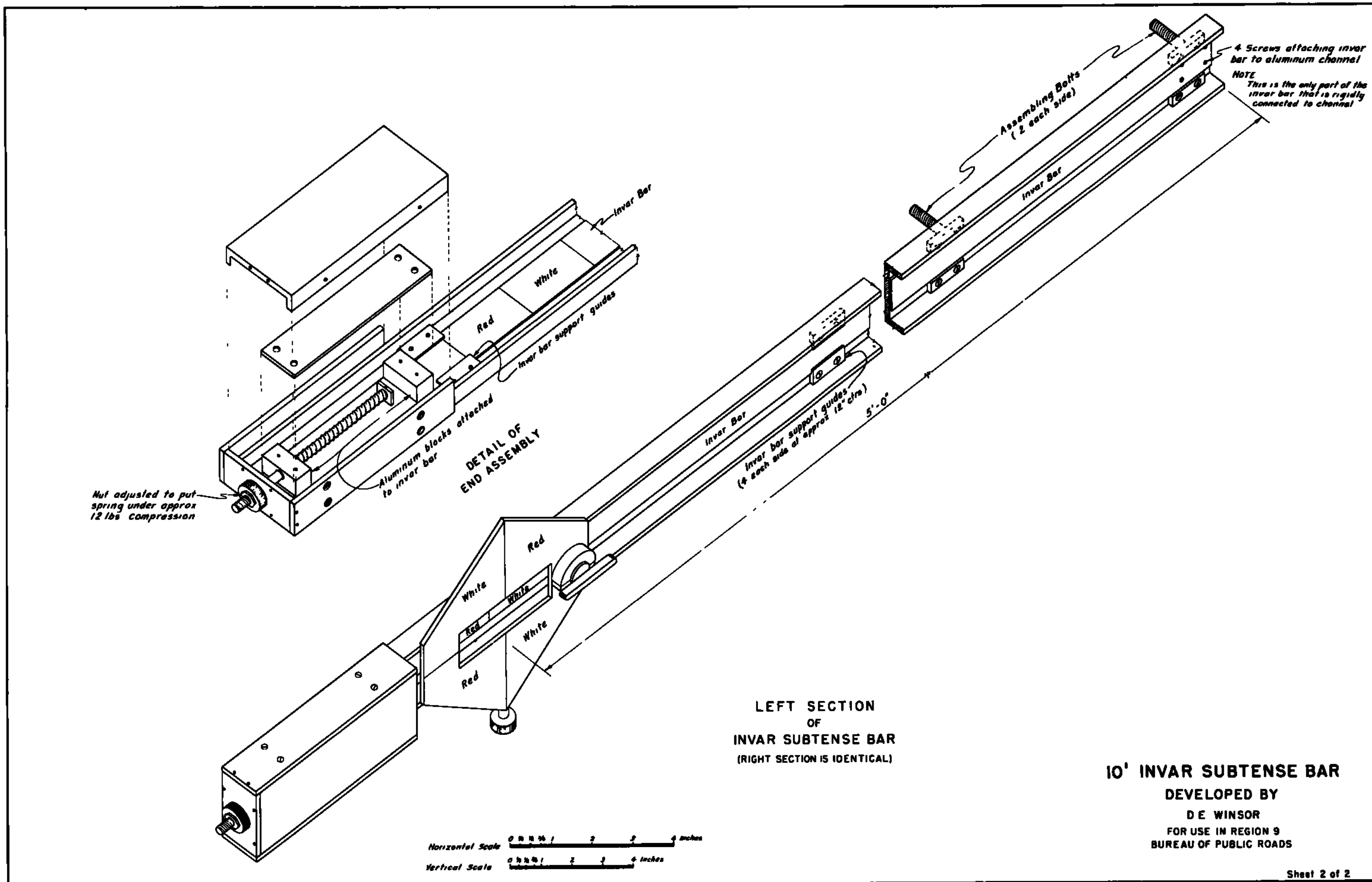

Figure 4. 10-ft invar subtense bar.

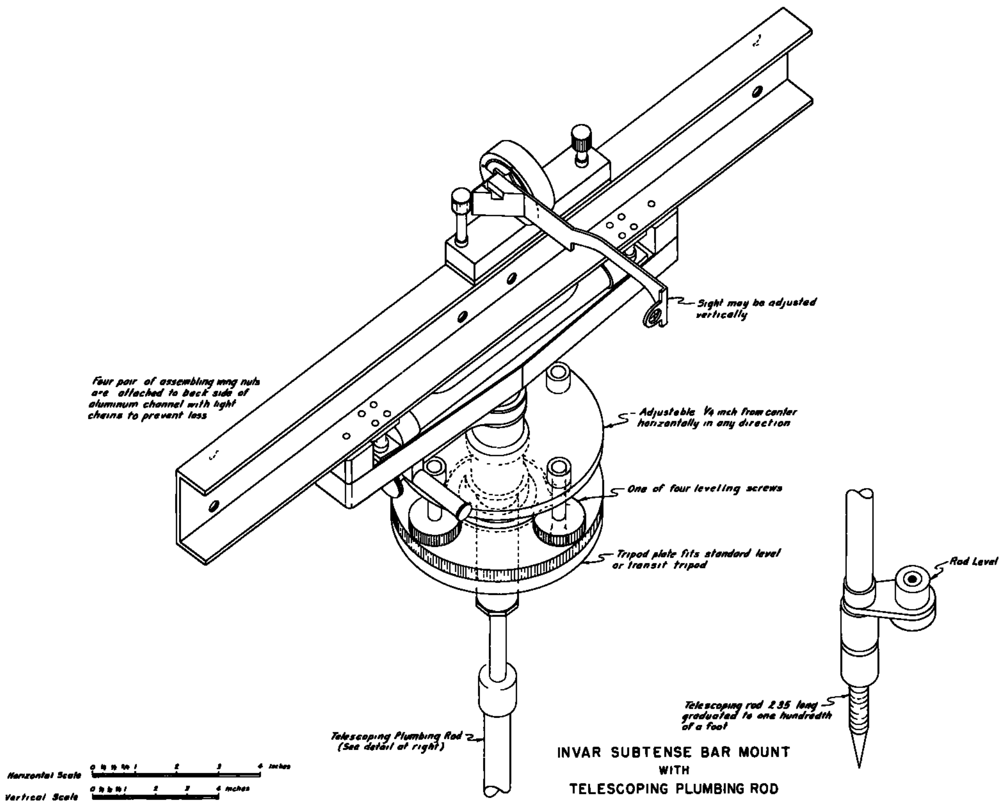

Figure 5. 10-ft invar subtense bar.

on the long courses. This may be helped by a re-design of the targets. Accurate trigonometric elevations can be achieved by limiting horizontal distance measurements to 1,000 ft and vertical angles of 15 deg maximum where practical.

In establishing vertical control throughout rugged topography for photogrammetric purposes, the subtense bar is an ideal tool. Using the leap frog method, or that normally employed in geometric leveling by rod and spirit level, only the H. I. of the subtense bar need be recorded. Level circuits of required accuracy for vertical control can be completed in one-fourth the time required by spirit level methods of running geometric levels. In summing up, the 10 ft subtense bar, when used where the topography is rugged, rough, and mountainous, is a time and labor saving device. Giving due consideration to the influence of errors, this instrument can provide a very adequate means for accurate measurement of horizontal distances and vertical elevations. It is a precision device and must be complemented with a precise angle-measuring instrument and a conscientious survey party.