

# Evaluation of The Model 4 Geodimeter

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•IN THE FALL of 1957 the Photogrammetry Section at the Headquarters office of the California Division of Highways acquired a Model 3 Geodimeter for the purpose of measuring distances in making basic control surveys. The range and accuracy of the Model 3 made it possible to make survey ties directly to U. S. Coast and Geodetic Survey triangulation stations by traverse surveying procedures. In this manner the California State plane coordinate system could be established in the immediate vicinity of a highway mapping project without encountering costly and time-consuming conventional survey problems because of the remoteness of the triangulation stations or the ruggedness of the topography.

The Geodimeter has demonstrated its reliability and value for complementing precise surveying equipment. The development of the Model 4 Geodimeter which combines dependability, high accuracy at short ranges, and portability has made the instrument an invaluable tool, not only for basic control surveying but also for accomplishing all types of surveys.

## DEVELOPMENT OF THE GEODIMETER

The initial model of the Geodimeter was developed to attain extreme accuracy in measuring distances of from 5 to 40 miles. The Model 1 instrument was introduced in early 1953, and was superseded by a refined version, the Model 2, in 1955. With the Model 2 Geodimeter, measurements can be made as accurately as by the highest precision in tape measuring of distances. Many users of the Model 2 requested development of a more portable unit which would be useful in making surveys not requiring utmost accuracy. Subsequent refinements of design, at the expense of range and accuracy, resulted in production of the Model 3 Geodimeter. This model is designed to measure distances in the 1- to 20-mi range, with a possible error of  $\pm 0.40$  feet.

The Model 4 Geodimeter was designed primarily to meet requirements for an instrument of high accuracy in measuring distance of from 1,000 feet to 4 miles. In clear air, distances up to 12 miles have been measured. For distances of 400 to 1,000 feet the accuracy of measurement is 1 part in 10,000 or smaller difference, and the proportional accuracy increases as the measured distance increases in length. The maximum error for a single observation at any distance is  $\pm 0.04$  feet, plus 5 millionths of the distance.

### Operating Principles

The basic principle of all models of the Geodimeter system of distance measurement is the indirect determination of time required for a pulsed light beam to travel between two stations.

A modulated beam of light is emitted from the Geodimeter at one end to a passive reflector placed at the other end of the line of sight. The reflector returns the light pulses back to the instrument where a phase comparison is made between the projected and reflected light pulses.

The precision of the Geodimeter relies on the fact that the velocity of light and the frequencies of the crystal oscillators are very accurately known and that they remain almost constant.

Changes in atmospheric temperature and barometric pressure produce a small known variation in the velocity of light. Temperature and pressure data are recorded for each observed line and resultant corrections are applied to the computed distance.

Variations in frequency constants are caused by ambient temperature. To maintain fixed frequencies, the crystals are enclosed in an electronic oven where a nearly constant temperature is maintained.

The reflector device is a 2-in. diameter solid glass prism mounted in a metal case. To afford the greatest flexibility and economy in operation, each prism is mounted in individual shockproof casings which can be placed in housings which will hold 1, 3, or 7 prisms. The housings will mount on any Wild theodolite tripod and with a special bracket a maximum of 21 prisms may be utilized. The prisms are easily portable and can be left unattended. The Geodimeter light will be reflected back to the instrument even though the axis of the prism is offset in its pointing by as much as 20°. Plastic reflectors, similar to those used on highway guide posts, may be used instead of prisms in measurement of distances up to 0.4 miles. It is possible, therefore, to select the most suitable reflector combination for the distance being measured.

### Effect of Atmospheric Conditions

The largest source of error in Geodimeter measurement is caused by errors made in the determination of meteorological conditions. An error of 1 C in temperature or 3 mm of mercury in atmospheric pressure will cause a one part per million error in the measured distance. The influence of humidity is negligible within the accuracy limits and is not given consideration in the computations. For all practical purposes, the mean of the temperature and pressure data recorded at the Geodimeter and reflector stations is sufficient. In precise surveys requiring differences as small as one part in one million or smaller, additional data regarding temperature, atmospheric pressure, etc., must be obtained along the line of sight to minimize the effects due to variations in temperature and air pressure.

The range of the Model 4 varies with the state of atmospheric conditions. The instrument will measure a distance correctly as long as a sufficient signal is returned from the reflector. If the return signal is weak or not discernible, the instrument will merely stop operating. It is impossible to give specific range limits in measurement of distances under adverse weather conditions, such as in snow, rain, fog, mist, or haze. The maximum range will be determined by the density of the adverse factor and the number of reflecting prisms available. As an example, a distance of 11.2 miles was measured using nine prisms. On the following night a remeasurement was done under apparently similar atmospheric conditions, but 28 prisms were necessary. The following data are an indication of ranges in distance which can be measured under varying visibility conditions: fog: 100 to 2,000 feet; rain: 1,000 feet to 3 miles; heavy haze: 1,000 to 5,000 feet; medium haze: 1 to 3 miles; light haze: 3 to 7 miles; and clear air: 7 to 12 miles.

Under most atmospheric conditions, the normal time required to make a measurement is from 5 to 15 minutes. In extreme cases the time required to make a measurement may be 15 to 30 minutes.

### THE MODEL 4 GEODIMETER

Three Model 4 instruments have been produced by the manufacturer which are essentially identical in basic design and operation. These units are designated as Models 4A, 4B, and 4D. After introduction of Model 4A, the manufacturer requested field evaluations of the instrument and many suggested changes and improvements were incorporated into the later models. Most of the refinements found in the latest models can be adapted to older Model 4's quite readily.

The important change between the 4A and 4B was the installation in the latter of an improved heating unit for the crystal oven. To maintain the rated accuracy of the instrument for measuring long distances, it is necessary to control the temperature of the crystals within a small range, which confines the modulating frequencies to their specified values at all times.

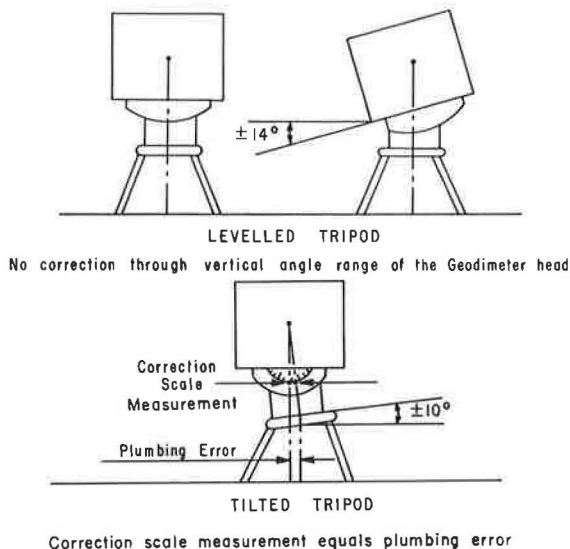


Figure 1.

Additional changes found in the 4B are subsequently mentioned. A tuning condenser was added to the Kerr-cell circuit which permits this circuit to be maintained at optimum level at all times and results in increased speed and stability of the null system. A system of three different aperture stops was developed for the receiver optics which allows either wide or narrow angle light acceptance from the area of the reflector. This has been an invaluable aid when operating in daylight or in areas which are highly illuminated at night.

The model 4A was designed with removable side and top panels which provide easy access to the instrument for repair and adjustment in the field. The housing for the model 4B is in one unit which attaches to the base of the instrument frame. If field repairs are necessary, the whole electro-optical system is exposed to the elements. One-piece construction of the housing, however, made the determination of plumbing eccentricities simple. The Geodimeter head is attached to a Wild surveying instrument tripod and allows the instrument to be pointed through a vertical range of  $\pm 14^\circ$  if the tripod head is level. If the tripod head is not level, errors are introduced in the distance measurements, because the plumb-bob is suspended from the tripod and not the horizontal axis of the instrument. A plumb correction device has been adapted to the Geodimeter head to permit direct measuring of the plumbing error caused by tilt in the tripod head (Fig. 1). Also, a small hole has been drilled on the sides of the instrument housing at the horizontal axis of the Geodimeter. A pin is inserted into each hole and a bar plummet is suspended from the pins which will indicate the plumbing plane of the Geodimeter. This instrument "plumb-bob" is used when the tilt of the tripod head exceeds the range of the plumb correction device or when the Geodimeter is offset from the survey station marker.

The Model 4D is known as the daylight Geodimeter and is basically the same as its predecessors. The exciter lamp is a mercury gas lamp which is thirty times brighter than the incandescent lamps used in Models 4A and 4B. A discussion of this instrument is found in another portion of this article.

### GEODIMETER FIELD EXPERIENCE

The maximum productivity and economy in Geodimeter surveying can be achieved only through efficient planning and reconnaissance work in the field.

For maximum productivity, the most efficient use of the Geodimeter is achieved utilizing two survey parties. One party operates the Geodimeter exclusively. The



other party uses theodolites to measure required horizontal and vertical angles. Experience has shown that a combined angle-measuring and distance-measuring party is not satisfactory. Combined operations are desirable only in those instances where occupying a station is so hazardous or time consuming that a joint effort is advantageous from the standpoint of economy and safety.

The Model 4 Geodimeter is best suited to surveying by measuring distances in a traverse. To make the accuracy of angle measurements compatible with the accuracy of distance measurements, it is advisable to measure the angles by use of a theodolite with a measurement increment of one second of arc. Radiating several lines of measurement from one station marker must be planned with utmost care, inasmuch as the ultimate surveyed positioning of survey control points may depend more on angle measurements between lines of sight than on the distance measurements between points. Also, the measured position of radiated points is difficult to verify because a closure is not made without further surveying.

The fundamental requirement for measuring a distance by use of a Geodimeter is a clear line of sight between points of measurement, the same as is required for measuring angles with a theodolite. It is especially important that a thorough reconnaissance be made to verify feasibility of the office-made plan for the control survey and to modify it as necessary, to select access routes to station markers chosen, and to mark the stations adequately so a minimum of time will be utilized in finding the station markers in the dark. The largest time-consuming factor in making control surveys by use of a Geodimeter is the time required to move from one survey station marker to another. The instrument moving time depends on the ease with which station markers can be located and occupied. It is therefore evident that the production of a Geodimeter survey party is directly proportional to the effort expended in the daytime planning and preparation for accomplishing the control of the surveying.

Personnel requirements are extremely flexible, depending mainly on the type of survey, its extent, and the nature of the topography. The basic party for Geodimeter surveying may consist of two men, the instrument operator and a reflector attendant. For making traverse-type surveys, the party usually required consists of the instrument operator, an assistant, and two reflector attendants.

### Methods of Measuring

Methods and procedures in using the Geodimeter to measure distances vary in relation to the degree of precision desired on any given survey project. The basic procedure consists in making a series of 24 measurements (Fig. 2). Four measurements are made to the reflector (Ref.) and four are made on the internal base line of the Geodimeter (Cal) in each frequency. The effect of the internal measurement is to determine the zero point in each frequency and to eliminate any errors should electronic drift occur in the instrument.

The switching through the four phases will eliminate errors due to asymmetry of the Kerr-cell RF voltage and the phototube bias voltage. The connections to the switch are arranged so a  $180^\circ$  RF phase change will occur when switching from phase 2 to phase 3. The bias voltage changes between positions 1 and 2 and between positions 3 and 4. The manufacturer suggests a tolerance of 3 to 4 divisions between the sum of the measurement values of phases 2 and 3 and phases 1 and 4. To maintain consistent accuracies, however, it is recommended the measurement tolerance be limited to 1 division. If the stated tolerances are exceeded, the four measurements should be repeated. This procedure enables the instrument operator to establish the validity of each set of measurements and eliminates all errors in measurement observations.

The speed, sensitivity and null action of different Geodimeters will vary. The novice operator of a Geodimeter therefore should complete all 24 measurements for each distance until he is thoroughly familiar with the characteristics of his particular instrument. When the operation of the instrument is mastered and consistent measurement results are obtained, the following procedures may be followed: For extreme accuracy, measure all phases in each frequency and repeat the complete sequence of measurements at least 3 times. For the normal accuracy, which far exceeds require-

GEODIMETER OBSERVATIONS  
N A S M 4

Calibration No. 5 Serial 56  
 Date 10-1-63 Observer RAD Approx. Dist. 3.0 KM  
 District HQ Co. SAC Rte. — Sec. — W.O. —  
 Geod. Stat. A Refl. Stat. B  
 Type Refl. 1-3PRISM Null GOOD Visibility GOOD

P H	F-1 Ref	F-1 Cal	F-2 Cal	F-2 Ref	F-3 Ref	F-3 Cal
1	+ 92.0	+ 40.0	+ 43.0	+ 218.0	- 104.0	+ 45.0
2	- 91.0	- 40.0	- 42.5	- 216.5	+ 104.0	- 45.0
3	+ 89.0	+ 41.0	+ 44.0	+ 216.5	- 104.0	+ 50.0
4	+ 88.0	- 41.0	- 43.0	- 214.0	+ 104.0	- 50.0
2+3	180.0	81.0	86.5	433.0	208.0	95.0
1+4	180.0	81.0	86.0	432.0	208.0	95.0
Sum	360.0	162.0	172.5	865.0	416.0	190.0
M	R <sub>1</sub> 90.0	C <sub>1</sub> 40.5	C <sub>2</sub> 43.1	R <sub>2</sub> 216.3	R <sub>3</sub> 104.0	C <sub>3</sub> 47.5

	Geod.	Refl.	Sum	Mean	P/PM	Sum P/PM
Temp	20°C	24°C	44°C	22°C		
Pres	50'	750'	300'	150'		

-G+ No OFFSETS +R-

Theodolite	At	R
D:	88-22-30	
R:	271-37-42	
Sum	359-59-72	+12
Mean	(4) 01-37-36	

HI - Geod. 4.9 FT  
 HI - Refl. 5.1 FT  
 Remarks \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

STATE OF CALIFORNIA, DIVISION OF HIGHWAYS

Figure 2. Geodimeter observations, California Division of Highways.

ments for highway surveys, measure all phases on the reflector and measure phases 2 and 3 only on the internal light path. Because there is no atmospheric disturbance on the internal light path, the null action is highly stable. For surveys where nominal accuracies are acceptable, measure only phases 2 and 3 throughout the distance-measuring sequence. The latter procedure is recommended only for experienced instrument operators, because there is no check possible on the validity of measurements to the reflector unless all data are used in the field to compute the distance between station markers.

The most difficult measurements to make with a Geodimeter are those made under turbulent atmospheric conditions. These conditions are usually found when a cool night has been preceded by a hot day and the line of sight is over irrigated agricultural land or through successive temperature inversion layers. The null action becomes erratic because of changes occurring in the atmosphere, and tolerance in the set of measurements made to the reflector is difficult to achieve. Under these circumstances the measuring procedure should be modified so phases 2 and 3 are measured first and then phases 1 and 4.

Additional sensitivity and stability of the instrument may be achieved under marginal atmospheric or range conditions by increasing the input voltage approximately 10 percent.

At the reflector station the only error which can be introduced is in plumbing the tripod head. If the tripod head is leveled by eye or by the use of a bulls-eye level the expected error in the distance from this source will be in the order of ± 5 mm. This

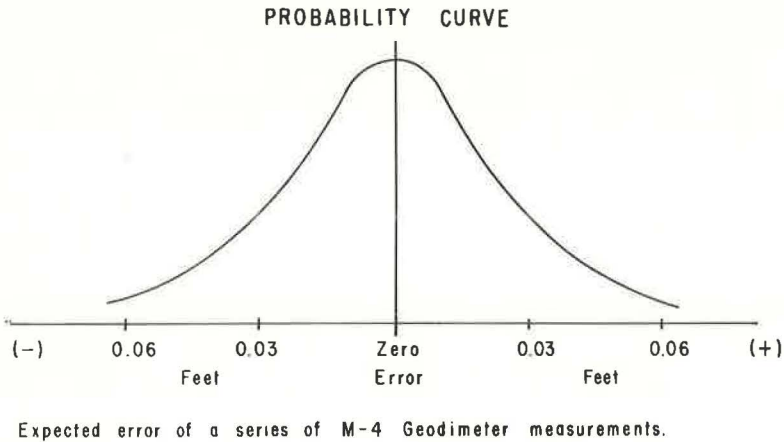


Figure 3. Probability curve.

error can be eliminated by using an adaptor which allows the reflector to be attached to the Wild traverse target optical leveling base.

#### Instrument Errors

Previously published data have indicated that the instrumental error of the Model 4 Geodimeter will closely approximate a probability curve as shown in Figure 3. The validity of this curve has been substantiated by numerous experiments. Because this error tends to be purely accidental, it is expected to cancel out through a series of courses. Experiments were conducted on test courses which were traverse segments approximately 4,800 feet long, divided into increments of 800 feet to 1,600 feet. After the individual segments were measured by increment, the full segment was measured in a single observation. The closing errors varied between 0.01 and 0.03 of a foot for three segments, and 0.06 of a foot error occurred in a fourth segment.

The type of error previously noted can result in closures of one part in one million or smaller difference for surveys which close upon themselves. It is evident, however, the individual courses in the survey do not contain the same degree of precision.

#### Vertical Angles

Inasmuch as the Geodimeter measures slope distances, the accuracy of the resultant horizontal distances will depend on the care with which the vertical angles are measured.

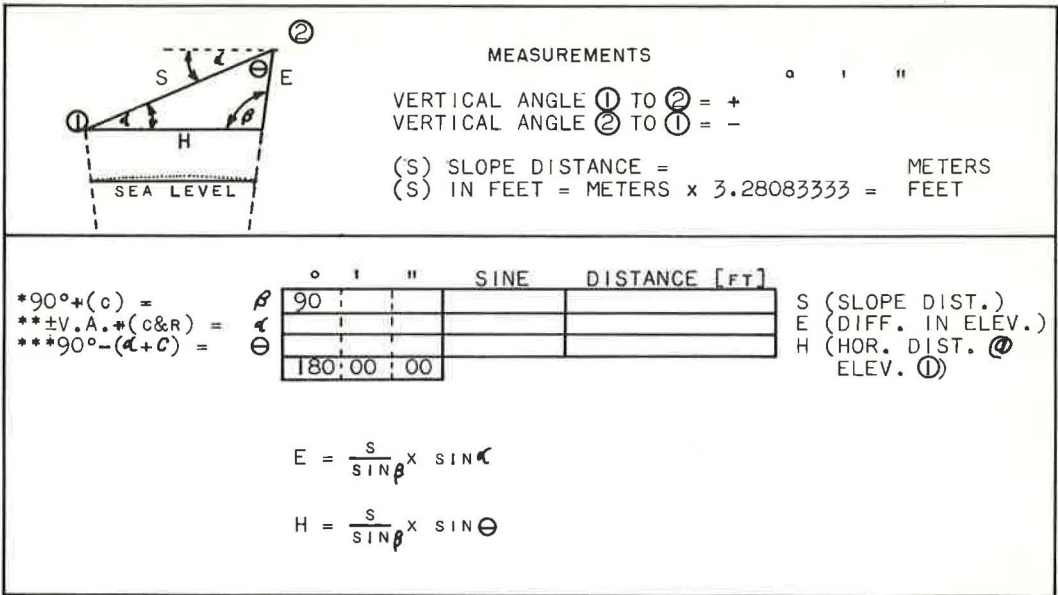
Over relatively flat topography, where the vertical angle does not exceed a few degrees, the theodolite is set up near the Geodimeter at the same instrument height. The mean of one direct and one reverse vertical angle measurement will provide the necessary accuracy. Where topography slopes are steep, extreme care must be taken in measuring the vertical angle. The theodolite must be set up over the Geodimeter plumb point and instrument height differences must be taken into consideration in the computations.

Computations for reducing a slope distance to a horizontal distance by exact methods are a cumbersome time-consuming procedure. A method (Fig. 4) developed by the California Division of Highways is a rapid and accurate solution. The equations used are close approximations which will yield results exceeding first-order accuracies. This is beyond the accuracy of the instruments involved in measuring the basic data.

#### Horizontal Angles

The Geodimeter is capable of measuring distances through any type of obstruction allowing passage of even a fraction of the light beam to and from the reflector. Included





\*(c) IS CORRECTION FOR CURVATURE. (c) =  $+4.93'' \times \frac{S}{1000}$  , ADDED TO 90° TO FIND β

\*\* (C&R) IS CORRECTION FOR CURVATURE & REFRACTION  
 (C&R) =  $+4.25'' \times \frac{S}{1000}$  , ADDED ALGEBRAICALLY TO MEASURED V.A. TO FIND α  
 IF RECIPROCAL V.A.'S ARE MEASURED, THE MEAN VALUE = α DIRECTLY

\*\*\* IN THE CASE OF V.A. MEASUREMENT AT ONLY ONE END OF LINE, Θ = 180° - (α+β)  
 IN THE CASE OF RECIPROCAL MEASUREMENTS, Θ = 90° - (α+c)

Figure 4. Reduction of slope distance to plane coordinate grid distance.

among these obstructions would be trees, brush, foliage, and power poles. Accuracy of the Geodimeter measurement will not be impaired by these terrain and ground cover features but horizontal angles may be unduly influenced by horizontal refraction which would result in loss of angular accuracy.

Calibration and Frequency Checks

Recalibration of the Geodimeter delay line is necessitated by changes which develop in the electronic circuitry of the instrument. The process of calibration is used to determine changes occurring in the relationship between wave length fractions as seen on the Geodimeter delay dial and the actual distance measurement these fractions represent with respect to a precisely measured base line. A calibration shift will cause a spread between the computed distances obtained for each frequency regardless of the length of line measured.

There are two methods by which a delay line shift can be ascertained. In the field, the instrument operator is able to make a rough check of the calibration by examining both the low and high ends of the delay dial while on the internal light path. The difference of the calibrated values of the delay line measurements will give the wave length of the frequency being checked, provided the calibration is still valid. In the office, the presence of a delay line shift is identified by a spread in the computed distance in the three frequencies beyond the normal range of 0-3 cm in one measurement out of ten or more.

The effect of changes in the frequencies of the crystals is not noticeable in field operations and may not be noticeable in computations. The effect of frequency drift is manifested only in measurement of long distances where a 30-cycle change in the frequency would cause approximately a 1 part per million error in the distance measurement. The expected change in frequency is in the range of  $\pm 50$  cycles within a 3-month period. If a sufficient change occurs in one frequency only, the effect would be discernible in the computations. If more than one frequency was affected, however, it is possible for the errors to either increase or cancel each other.

The time interval between calibrations and frequency checks is a variable dependent on the stability of each instrument and the accuracies required in the distances measured. As an experiment, a Model 4A Geodimeter which was out of calibration was used to measure some 30 distances. The instrument was then recalibrated and the distances were measured again and recomputed. The average deviation between the results was 1.2 cm and a maximum deviation of 3 cm occurred in only two measurements. To maintain reasonable accuracies, the Model 4 Geodimeter should have a recalibration and a frequency check every six months. To provide for maximum instrument accuracy, a calibration and frequency check should be made every two months.

### Repairs and Maintenance

The major unknown factor at the time the first Model 4 Geodimeter was acquired was the frequency and cost of repairs which would be necessary. The advantages gained by using the instrument could have been nullified by excessive lost time due to mechanical or electronic malfunctioning. The Geodimeter has proved to be a remarkably trouble-free device.

The repair histories of ten instruments used by the California Division of Highways and two privately owned instruments have been maintained. Five of the instruments have been in use for approximately 80 percent of each work year since their acquisition and the remaining units are in use approximately 65 percent of the time. The heavy usage of these Geodimeters and the limited repairs needed under these conditions substantiates the dependability of the instrument.

The cost of repairs has been a nominal item. Under the terms of purchase, the major difficulties arising during the first year of operation are covered by the manufacturer's warranty. There has been no difficulty with the manufacturer or the West Coast distributor concerning warranty adjustment. The total cost of major repairs for 26 instrument years of operation has been approximately \$1,600 or an average of \$62 per year for each instrument. Additional costs will be incurred during routine maintenance, which include replacement of the exciter lamp and inoperative tubes and periodic calibration of the delay dial and frequency check of the crystals. Consideration must also be given to the probable replacement of the Kerr-cell and switching devices after two or three years of use.

If the cost of repair and maintenance is projected on the basis of 5 years of nearly continuous operation, it is reasonable to assume these costs will total about \$500 annually.

### Daylight Operation

Replacement of the conventional 5W projection lamp in the Model 4B with a 100-w mercury lamp has increased the night range of the instrument and given it added daylight capabilities.

The mercury lamp housing has been adapted to fit existing lamp adjustment devices, and the original condenser lens system has been modified. A lamp ignition system and a blower fan, which protect electronic components from the heat generated by the mercury lamp, is mounted on top of the Geodimeter. The additional power needed for the lamp is provided by a special power unit which is incorporated into a single housing with the standard power pack. Operation procedures in use of the converted instrument are identical to the standard Model 4B.

The California Division of Highways has seven Geodimeters utilizing the mercury lamp adaption. Preliminary data indicate maximum daylight range, using nine prisms,



will vary from between 1 and 2.5 miles during summer months. Difficulties are encountered when the distances to be measured are along lines over pavement or highly reflective ground, as found in the California desert areas, when the air temperature exceeds 80 F. Distances exceeding 2 miles over grassy range land have been measured with ease in temperatures exceeding 100 F. Under winter conditions, it is anticipated measurements during daylight hours will be made as readily as those at night.

The advantages of the Model 4D Geodimeter are (a) use of the instrument day or night to take advantage of weather or topographic factors, (b) increased range of measurement at night, and (c) simple convertibility back to 4B Geodimeter operation if desired. The only disadvantage of the Model 4D Geodimeter is the slight decrease in portability of the unit due to the added weight of the power pack.

Because daylight will tend to absorb a portion of the Geodimeter light beam, it is necessary to use glass wedges on the prisms to provide adequate signal deflection when measuring short distances so the light is reflected to the receiver optics. Under varying atmospheric conditions the use of wedges has been advantageous for measuring distances as long as approximately 4,000 feet. Beyond this distance, the deviation effect of the wedges becomes excessive and no useful light will be reflected. The choice of wedges is a function of both distance and atmospheric conditions so the combination of wedges needed may vary for measurement of distances of identical magnitude.

An interesting aspect of the model 4D Geodimeter is the fact the instrument can be converted back to model 4B operation with ease. From an operational standpoint there are two conditions which make this feature an important asset: first, if a mercury lamp malfunction should occur and a replacement lamp were not available; and second, if long packs were to be made into areas where the size and weight of the Geodimeter and power supply were critical.

Depending on atmospheric conditions and the experience of the Geodimeter operator, the time required for making a daylight distance measurement will vary between 5 and 30 minutes.

#### Repeatability of the Model 4 Geodimeter

The expected accuracy of repeated Geodimeter measurements of a distance will be on the order of  $\pm 12$  mm. The repeatability of Instrument No. 164 is given in Table 1. The distances were measured by two different operators at various times of the day. The weather pattern was changing from clear skies to rain, and the temperature varied between 11.5 C and 14 C.

Using the same instrument two separate distances were measured day and night by two different operators (Table 2). The distances given in Table 2 are conversions of slope measurements to horizontal distances. The spread in the measurements from Wruble to Whalen No. 2 was attributable in part to a discrepancy in the vertical angles as measured during the day and during the night.

Numerous experiments have been made repeating with the Model 4D Geodimeter the measurements originally

TABLE 1  
DAYLIGHT REPEATABILITY TEST  
(April 10, 1963)

Station	Distance (m)	Variation from Mean (m)
Test to No. 1	618,900	+0.003
	618,898	+0.001
	618,894	-0.003
	618,897 <sup>a</sup>	
Test to No. 2	864,677	+0.003
	864,679	+0.005
	864,667	-0.007
	864,673	-0.001
	864,674 <sup>a</sup>	
Test to No. 3	548,143	-0.007
	548,156	+0.006
	548,150 <sup>a</sup>	

<sup>a</sup>Mean.

TABLE 2  
DAY-NIGHT REPEATABILITY TEST  
(April 10, 1963)

Station	Time	Distance (m)	Variation from Mean (m)
Wruble to Whalen No. 2	Day	1211,275	-0.007
	Night	1211,290	+0.008
	Mean	1211,282	-
Wruble to Stump	Day	3890,336	-0.001
	Night	3890,338	+0.001
	Mean	3890,337	-

made at night by use of Model 4A and Model 4B Geodimeters. Comparison of day and distances measured during day-light hours by use of the Model 4D with the distances originally measured during nighttime hours is similar to the results given in Tables 1 and 2.

#### Advantages of the Geodimeter

The primary advantage of the Model 4 Geodimeter lies in the fact that results achieved are positive. The validity of raw measurement data is established by the instrument operator in the field while the measurements are being made. The computations are also self-checking and any incorrect solutions are, in almost every case, caused by blunders made in reducing the field notes and transcribing measurement data to computation forms. Experienced computers can resolve virtually every possible field or office error. As an illustration, only one distance has been remeasured in more than 8,000 Geodimeter measurements made by two California Division of Highways' Geodimeter parties.

Another significant benefit from using the Model 4 Geodimeter is when making control surveys in urban areas. With its great flexibility it is possible to measure from street to street or through residential areas without having to enter private property, as is necessary in ordinary measurement of distances by taping procedures. In short, elimination of taping effects the greatest savings in time and money.

Reports submitted by the various California Highway Districts and private users indicate use of the Model 4 Geodimeter results in a minimum monetary savings of 40 percent by comparison with conventional field methods of control surveying. The average amount of time saved, 60 percent, is not included in this figure, as some surveys would never have been accomplished without use of the instrument because of the nature of the topography, ground cover, and sparse distribution of U. S. C. and G. S. triangulation stations.

#### CONCLUSIONS

The results obtained from 26 instrument years of Model 4 Geodimeter use have proved the reliability and dependability of this instrument as a distance-measuring device. Accuracies greater than those required for highway survey purposes are achieved by normal operational procedures in measuring either short or long distances. In addition, use of the instrument effects substantial savings in the cost and time of accomplishing control surveys.

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2. Katibah, G. P., and Radmanovich, D., "Meet the Geodimeter." California Highways and Public Works (May-June 1962).
3. Radmanovich, D., "Geodimeter Operators Training Course Manual." California Division of Highways (1961).