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U.S. DEPARTMENT OF COMMERCE
Frederick H. Mueller, Secretary
COAST AND GEODETIC SURVEY
H. Arnold Karo, Director

Gravity Measurement Operations in the Field

LIEUTENANT COMMANDER HAL P. DEMUTH

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Technical Bulletin Series

This series of Technical Bulletins was inaugurated to present to the personnel of the Coast and Geodetic Survey and to others the results of research and development in the various fields of the Bureau's activities. Since many of the bulletins deal with new practices and new techniques, the views expressed are those of the authors and do not necessarily represent final Bureau policy.

Technical Bulletin No. 9 contains a brief description of gravity measurement field operations with emphasis on those items which have not been covered by various published manuals. Included are meter calibration, small and large dial measurements, base loop connections, elevation determination by altimeter, and transportation and care of the meter.

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Gravity Measurement Operations in the Field

LIEUTENANT COMMANDER HAL P. DEMUTH

U.S. Coast and Geodetic Survey

THE present policy of the Coast and Geodetic Survey is to establish gravity meter stations on an area basis throughout various sections of the United States. This long-range project calls for stations to be established on an average of one every 6 miles, corresponding to the 6-mile level spacing adopted as a national objective.

To establish a complete gravity measurement at a point, the elevation and latitude of that point must be known; the elevation to the nearest foot and the latitude to the nearest 0.1 minute. In order that the elevation be accurate, bench marks are used as gravity stations whenever possible, the marks used being those of any reliable organization. In general, Coast and Geodetic Survey or Geological Survey marks are preferred, as the data are readily available, and the general plan of establishing these marks corresponds to the spacing of the gravity stations. In addition to bench marks of these organizations, the Army Engineers, Mississippi River Commission, and various municipalities provide stations of known elevation.

Whenever a basic gravity area survey is planned and the area expected to be covered is chosen, the States included in this area are requested to furnish copies of their County Highway Maps. These maps have been found adequate for plotting the gravity stations, and to provide the necessary identifying features for describing them. The available vertical control is plotted on each county map, so that the location of the gravity stations can be chosen to take advantage of the existing bench marks. The proposed gravity stations are selected, utilizing all possible bench marks, and following the 6-mile spacing plan. These stations are then numbered for more convenient indexing. The station numbering system is based on the IBM "Numerical Code for States, Counties, and Cities of the United States." A station is identified by an eight-digit number. The first two digits signify the state, the next three the county, and the last three the serial number within the county. When a bench mark is used as a gravity station, both its name and the gravity station number should be plotted on the county map.

SMALL DIAL MEASUREMENTS

Since the Worden Gravity Meter is in use at the present time in the Coast and Geodetic Survey, the observed data are the differences in gravity between any two given points, and not the actual gravity values. A base station must be established in the locality of an area gravity survey, in order that the differences in gravity value between this base station and the selected area stations may be observed. The index prepared for the field parties indicates which base station is to be used, and an approximate difference is noted for each selected area station and the chosen base station. This information is provided to assist the field parties in determining where to set the small dial of the meter for each day's work. This base station is selected in some spot near the area so that the predicted difference in gravity value between this base and each gravity station site is small enough to be observed by the Worden meter used. This predicted difference in gravity value is based on two factors, the elevation and latitude of the base station, and the corresponding elevation and latitude of each gravity station site. As a first assumption, a standard rule of thumb is used, which is based on the theory that an increase in gravity difference of 1 milligal is to be expected for each 1 minute increase in latitude, and an increase of 1 milligal is expected for each decrease in elevation of 10 feet. As an example, if Station A is in latitude 45° 50', and at an elevation of 1,220 feet; and Station B (the base station) is in latitude 45° 31', and at an elevation of 1,400 feet, the following computation will provide an approximate value for the difference in gravity from B to A:

	Station A	Station B	Difference
Latitude	45°50'	45°31'	+19'
Elevation ... feet	1,220	1,400	-180
Gravity change:			
Latitude ... milligals	.....	.....	+19
Elevation ... do	.....	.....	+18
Total ... do	.....	.....	+37

This type of computation provides the field party with the data as to the expected net change in gravity in order to set the meter. In this case, the setting should be near the low side of the small dial range, in order that an increase of 37 milligals can be measured from the base station.

When the party begins a day's work, the meter is set at the selected base station, the setting based on an expected difference between the base station and the area stations as outlined above. The meter is then taken to each of the selected sites, and read at those points, with the time,

the meter reading, and the elevation of the meter above or below the bench mark being recorded. At the close of the day, the meter is returned to the base station and is read. This provides a value for any mechanical "drift" in the meter over the period of the day, and each of the observed gravity differences can then be adjusted to eliminate any drift. It is assumed that this drift is linear with respect to time, and it is prorated and applied to each station gravity difference.

In some sections of the country where area gravity surveys are desired, there is a dearth of vertical control, and no known elevations are available at sites where gravity stations must be observed in order to preserve the selected 6-mile spacing. In this case an elevation must be determined for these gravity stations. This is done by using two altimeters, and measuring a difference in elevation between a known elevation and the desired gravity station sites. Accurate surveying altimeters are used for these measurements as they can be read directly to the nearest 10 feet and interpolated to the nearest foot. One altimeter is placed on the point of known elevation, the other altimeter carried to the sites where elevations are desired. At intervals of 5 minutes, the base (or known elevation) altimeter is read, this reading being recorded along with the time and temperature at the base. The field (or gravity station) altimeter is read and this reading, the time, and the temperature are recorded. The field altimeter is then returned to the elevation base, where it is again read and compared with the base altimeter. The atmospheric drift as a result of changes in barometric pressure can then be eliminated from the resultant elevation difference, as can the apparent change in elevation resulting from temperature changes. The gravity reading at these stations is obtained in the same manner as is the gravity reading at a station having a bench mark for elevation. Altimeter stations are usually selected at spots that are easily described for future location, such as a crossroads (that can be identified on the county maps used), a schoolhouse, or a country store.

Included in this discussion is a sample Gravity Meter Observation sheet (fig. 1), with the entries filled in for a series of gravity measurements, both for bench mark and altimeter stations. Also included are sample altimeter records (fig. 2) and a calculation sheet for the determination of elevations of the altimeter stations (fig. 3), with the equation provided to obtain the temperature correction.

EQUIPMENT USED

The Coast and Geodetic Survey now employs the Worden Gravity Meter for the determination of gravity differences. For the complete description and instructions on the use of this meter, the reader is referred to the manual published by the manufacturer.

In addition to the meter itself, the manufacturer supplies accessories which are essential to efficient operation. These accessories include a short tripod, a longer tripod (24-inch legs), a truck tripod, truck mounting harness, carrying case, and shipping can.

One of the most important factors in the use of the Worden meter is the calibration. This factor cannot be stressed too strongly, and an accurate determination must be made of the small dial constant, K_{sd}. This value converts the observed meter dial divisions to actual gravity differences. Since it is impossible to assume that any such value will remain constant during the entire lifetime of the meter, periodic redeterminations are vital. If a meter was used to determine differences in gravity for an area survey, and no firm value was known for the calibration of the meter, the entire survey might be in error on the order of several milligals.

It has been the policy of the Coast and Geodetic Survey to redetermine the small dial constant for each meter in use at least once a year. This is done by using either of two methods. The first method is to use the meter under test to measure the gravity differences along a line of stations for which very accurate gravity values have been determined. By comparing the observed gravity values with the known gravity values, a meter constant, K_{sd}, can be determined. The second method is to take the meter under test on an actual gravity survey with a second meter which has a firm calibration figure. In a short period of time, between 50 and 75 gravity stations can be surveyed with the standard meter, and for each of these stations, a value of gravity can be determined. These values of gravity can then be compared with the values as measured by the meter under test, and this meter calibration can be determined. Both methods have been used, with successful determinations of the small dial constant in each case. The Coast and Geodetic Survey has two major calibration lines for the first of these methods. One of these lines is at Sperryville, Va., near Washington, D. C. The second line is called the Mid-Continent Gravity Calibration Base, extending from Brownsville, Tex., to Winnipeg, Canada, and includes approximately 50 stations. The value of gravity at each of these stations is known with a high degree of accuracy.

It has been found by experience that the most efficient organization of a gravity survey party for the Coast and Geodetic Survey includes two men and one light truck for each gravity meter used. In addition, they need two altimeters, and an assortment of hand levels, tapes, etc. to aid

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(6-23-59)

U.S. DEPARTMENT OF COMMERCE
COAST AND GEODETIC SURVEY

Area Survey
GRAVITY METER OBSERVATIONS

PAGE _____

LOCATION: South Dakota, Minn. DATE: 4/12/56

CHIEF OF PARTY: H.P.D. METER: No. 20

OBSERVER: E.F.L.

STATION	G. C. TIME	INST. NO. WP 17035 Alti-meter	INST. NO. 20 SMALL DIAL	Δh *	TEMP. °F	DESCRIPTION OF STATION
40 099 001	1440		1601	0.0		BM SHERMAN 1935, Sioux Falls Base
22 063 007	1740	2255		0.0	50	BM W 12, 1931, Line 92
22 063 013	1755	2240	4921	+0.2	51	NE cor. Sec. 5, T 103 N, R 36 W, at center of crossroads.
22 063 007	1805	2260		0.0	48	BM W 12, 1931
22 105 001	1910	2389	4148	0.0		BM G 145, RESET 1936, Line 91
22 105 014	1920	2323	4228	0.0	52	NW cor. Sec. 25, T 102 N, R 39 W, at center of crossroads.
22 105 001	1935	2395		0.0	50	BM G 145, RESET 1936
22 105 003	2000	2418	3773	+0.2	53	NE cor. Sec. 24, T 101 N, R 39 W, at center of crossroads.
22 105 002	2010	2360	3696	+0.2	54	NE cor. Sec. 23, T 101 N, R 39 W, 25 ft. NE of center of paved road, in center of gravel road.
22 105 003	2020	2420		0.0	53	Prev. described
22 105 001	2035	2409		0.0	53	BM G 145, RESET 1936
40 099 001	2255		1599	0.0		BM SHERMAN 1935, Sioux Falls Base

*RECORD THE ELEVATION OF GRAVITY METER FOOTPLATES ABOVE (+) OR BELOW(−) STATION, TO NEAREST 0.1 FOOT.

USCOMM-OC 27480-P

FIG. 1.—Area Survey Observation Record.

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U.S. DEPARTMENT OF COMMERCE
COAST AND GEODETIC SURVEY

GRAVITY METER OBSERVATIONS

PAGE_____

LOCATION: South Dakota, Minn. DATE: 4/12/56

CHIEF OF PARTY: H.P.D. METER: Base Altimeter No. WP 17031

OBSERVER: L.R.B.

Altimeter Base STATION	G. C. TIME	INST. NO. WP 17031 Alti-meter	INST. NO. SMALL DIAL	Δh *	TEMP. °F	DESCRIPTION OF STATION
22 063 007	1740	2252		0.0	50	BM W 12, 1931, elev. 1476.0 ft.
	1745	2253			50	Line 92
	1750	2253			51	
	1755	2253			48	
	1800	2257			49	
	1805	2257			48	
22 105 001	1910	2383		0.0	49	BM G 145 RESET 1936, elev.
	1920	2385			48	1592.8 ft. Line 91
	1925	2387			49	
	1930	2389			50	
	1935	2390			50	
	1950	2392			50	
	1955	2392			52	
	2000	2397			54	
	2005	2400			52	
	2010	2400			54	
	2015	2399			54	
	2020	2400			54	
	2025	2401			53	
	2030	2401			53	
	2035	2402			53	

*RECORD THE ELEVATION OF GRAVITY METER FOOTPLATES ABOVE (+) OR BELOW(−) STATION, TO NEAREST 0.1 FOOT

USCOMM-DC 27460-P

FIG. 2.—Altimeter Base Record.

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U. S. COAST AND GEODETIC SURVEY
FORM 824
FEBRUARY 1951

ALTIMETER LEVELING

LOCALITY: S. Dak., Minn.
CHIEF OF PARTY: H.P.D.

4/12/56

BASE ALTIMETER NO. WP 17031				FIELD ALTIMETER NO. WP 17035			CORRECTED READING (FORWARD)	ELEVATION DIFFERENCE (FORWARD)	CORRECTED READING (BACKWARD)	ELEVATION DIFFERENCE (BACKWARD)	MEAN ELEVATION DIFFERENCE	MEAN TEMP.	TEMP CORR'N *	CORRECTED ELEVATION DIFFERENCE	BASE ELEVATION	FIELD ELEVATION	MEAN FIELD ELEVATION	STATION
LOCATION	TIME	TEMP	READING	LOCATION	TEMP	READING												
BM W 12,	1740	50	2252	22 063 007	50	2255	2255								1476.0			
1931, elev.	1755	48	2253	22 063 013	51	2240	2239	-16	2244	-16	-16.0	49.5	0.0	-16.0		1460.0	1460	22 063 013
1476.0 ft.	1805	48	2257	22 063 007	48	2260			2260									
Line 92																		
(22 063 007)																		
BM G 145	1910	49	2383	22 105 001	49	2389	2389								1592.8			
RESET 1936,	1920	48	2385	22 105 014	52	2323	2321	-68	2328	-67	-67.5	50.0	0.0	-67.5		1525.3	1525	22 105 014
elev. 1592.8	1935	50	2390	22 105 001	50	2395	2395		2395									
ft. Line 91	2000	54	2397	22 105 003	53	2418	2411	+16	2423	+14	+15.0	53.5	+0.1	+15.1		1607.9	1607	22 105 003
(22 105 001)	2010	54	2400	22 105 002	54	2360	2350	-45	2362	-47	-46.0	54.0	-0.4	-46.4		1546.4	1546	22 105 002
	2020	54	2400	22 105 003	53	2420	2410	+15	2422	+13	+14.0	53.5	+0.1	+14.1		1606.9		
	2035	53	2402	22 105 001	53	2409			2409									

* C_t = (0.002)(Mean elev. diff.)(50° − Mean temp.)

Note: If mean temperature is greater than 50°, sign of C_t is same as sign of mean elevation difference; if mean temperature is less than 50°, sign of C_t is opposite the sign of mean elevation difference.

FIG. 3.—Altimeter Computations.

in locating bench marks from the descriptions. These auxiliary hand tools will also assist in describing altimeter stations that might be observed.

BASE LOOP CONNECTIONS

The basis for any area gravity survey is the one or more gravity stations within the area for which the actual value of gravity is known. Another very important use for the base net stations is the connecting of scattered locations to the Mid-Continent Gravity Calibration Base. Since this calibration line is a series of stations for which the values of gravity are known to a great degree of accuracy, an accurate measurement of the gravity difference between these stations and other locations will provide an accurate value of gravity for each of these other locations.

In order to obtain the actual values of gravity for these base stations, precise measurements are made of the difference in gravity between these stations and the nearest station whose gravity value is known. A series of measurements of this difference is made in an order conducive to an accurate determination. Let Station A be a station that is to be connected by base loop measurements to another station, designated Station B, for which the value of gravity is known. The Coast Survey has adopted a plan using two gravity meters to determine this gravity base loop. Essentially this method is to measure the gravity difference using each meter, and then to average the gravity differences obtained. The meters are set at Station B, using an estimated value of the gravity difference expected to be encountered. The meters are then read and the readings and the time recorded at each of the stations in the sequence B-A-B-A, with as little time as possible elapsing between stations, in order to reduce the effect of meter drift. Extreme care must be taken with these measurements, caution should be exercised to prevent any undue jarring of the meters, and enough time allowed at each station for the meter to settle down after first leveling the foot screws. The elevations must be the same for all meter readings at a given station, or a note must be made of any difference. Figure 4 is a sample Gravity Meter Observation sheet containing an entire base loop measurement. Figure 5 shows the computations necessary to determine a field value of the actual gravity at the new station. This type of measurement is referred to as a small dial loop, as only the small dial of the meter is used. Large, or geodetic, dial measurements are discussed below.

In some cases it will be found necessary to determine base loop stations in areas where the difference in gravity between the origin of the base net and the first station on the list is greater than the small dial range of the meter. In this case an extra station (or stations) is observed near the middle of the gravity span and is looped in, following the same procedure as would be used to connect any two base stations. The extra station is usually designated as a "Reset" station, and in many cases it is not selected with the thought of establishing it as a permanent station. This is done extensively in making small dial connections over large distances using air travel. In this type of operation, various reset stations are usually picked near the terminal buildings of the airports visited along the route of the flight.

Base stations are usually selected by the field parties to fulfill certain functions. Their main function in the area survey is to provide a base for setting the meter daily on the routine area measurement and establishment of area stations. These stations must be in an accessible location, have a known elevation, and their permanence is important for future reference and reobservation. As a rule, Coast and Geodetic Survey marks are located in municipal buildings, public parks, schools, or business buildings.

In establishing base stations, or in any other work where high accuracy is required, care should be taken at all times to insure that both meters are functioning properly. Experience has shown that individual gravity differences as measured by two meters should agree within about 0.1 milligal. In analyzing a chain of such stations involving a large total gravity difference, it may be advisable to hold constant the scale factor of one of the meters and to compute a provisional scale factor for the other meter that will provide the best overall agreement between the two. If, under these conditions, the individual gravity values do not agree within a tolerance of 0.2 milligal, the observations should be repeated. Frequent failure to satisfy this requirement is a strong indication of faulty meter performance.

In gravity area surveys, special provisions are made to visit all pendulum gravity stations in the area, and to connect these pendulum stations to the current base net for that area. The current base loop gravity value is then compared with the published value of gravity at the pendulum site, and in this manner any large errors or discrepancies in the current work can be detected.

LARGE DIAL MEASUREMENTS

Whenever gravity differences are to be measured in localities where small dial measurements are not desired, or where small dial measurements cannot be made (as over large water areas where reset stations are not available), then the geodetic (large) dial measurement is used. The reader is again referred to the *Worden Gravity Meter Manual* for the use and general description of the geodetic dial. Specific details are covered in this discussion which cannot be found in that

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U.S. DEPARTMENT OF COMMERCE
COAST AND GEODETIC SURVEY

Base Loop Measurement

GRAVITY METER OBSERVATIONS

PAGE _____

LOCATION: South Dakota

DATE: 5/9/56

CHIEF OF PARTY: H.P.D.

METER: No. 114, No. 20

OBSERVER: M.G.C.

STATION	G. C. TIME	INST. NO. 114 Small Dial	INST. NO. 20 SMALL DIAL	Δh *	TEMP. °F	DESCRIPTION OF STATION
40 077 007	1515	0991	1039	0.0	49	ARLINGTON BASE
40 005 002	1625	3915	3820	0.0	50	HURON, 1950 (grav. mark)
40 077 007	1800	0985	1045	0.0	51	ARLINGTON BASE
40 005 002	1910	3920	3827	0.0	52	HURON, 1950 (grav. mark)
40 077 007	2030	1000	1053	0.0	52	ARLINGTON BASE

*RECORD THE ELEVATION OF GRAVITY METER FOOTPLATES ABOVE (+) OR BELOW(−) STATION, TO NEAREST 0.1 FOOT.

USCOMM-DC 27460-P

FIG. 4.—Base Loop Measurement.

STOCK NO. 38

Small Dial Base Loop Computation

ARLINGTON – HURON

Meter	Station	G.C.T.	Δ Time	S.D. Reading	Δ S.D.	Corr. Δ S.D.	Mean Δ S.D.	Δ Grav. mgals	Mean Δ Grav. mgals
114	ARL.	1515		0991					
	HURON	1625	1.2	3915	2924	2927			
	ARL.	1800	2.8	0985					
							2928	32.64	
	ARL.	1800		0985					
	HURON	1910	1.2	3920	2935	2928			
	ARL.	2030	2.5	1000					
									32.56
20	ARL.	1515		1039					
	HURON	1625	1.2	3820	2781	2778			
	ARL.	1800	2.8	1045					
							2778	32.48	
	ARL.	1800		1045					
	HURON	1910	1.2	3827	2782	2778			
	ARL.	2030	2.5	1053					

Gravity: ARLINGTON BASE 980.42195
Mean Δ g +0.03256
HURON BASE 980.45451 gals

Note: To obtain the mean Δ gravity, the mean Δ S.D. values were multiplied by the small dial constants for the respective meters:

No. 114 K_{sd} = 0.011147 mgal/div.

No. 20 K_{sd} = 0.011693 " "

FIG. 5.—Base Loop Computation.

manual. The manual warns that the geodetic dial must be used with extreme care, as large errors can occur if these precautions are not taken. In order to eliminate any such error, the Coast and Geodetic Survey has adopted a specific, uniform method of observation with the geodetic dial. An outline of this method is given below, followed by an example of an actual observation (fig. 6) and the field computation of the observed gravity difference. Office reductions usually involve a more elaborate treatment of geodetic dial calibration data.

The meter is balanced at the first station using the large dial, with the small dial set at approximately midscale. The large dial reading is noted, and the nearest integral reading is used as a basis for a series of five observations to follow. The final value is based on the mean of five successive settings of the meter, with two integral large dial readings above the center value and two below this value, the meter being balanced by the small dial for each of these readings. These readings should be obtained in either ascending or descending order, and are followed by five more readings, using the reverse order of the large dial readings on the second set.

For each set of five readings, the differences obtained in the small dial values are then computed, that is, the individual values for the small dial differences per large dial division are obtained. The overall mean value for all readings at a station gives the number of small dial divisions per large dial division. This completes the observations taken at the first station. The entire procedure is repeated at the second station.

To obtain the actual value of the gravity difference between the two stations, a sample computation is provided which outlines this method.

$$LD_b - LD_a = \Delta LD$$

$$\frac{A_1 + A_2 + A_3 + A_4}{4} = A_m$$

$$(A_m)(\Delta LD) = \Delta SD_1$$

$$SD_b - SD_a = \Delta SD_2$$

$$\Delta SD_1 + \Delta SD_2 = \Delta SD_t$$

$$(\Delta SD_t)(K_{sd}) = \text{Gravity difference}$$

Following the steps outlined above and figure 6:

$$\Delta LD = 433 - 438 = -5$$

$$A_m = \frac{623.2 + 624.0 + 623.5 + 622.5}{4} = 623.3$$

$$(A_m)(\Delta LD) = -3116$$

$$SD_b - SD_a = 4739 - 4656 = +83$$

$$\Delta SD_t = -3116 + 83 = -3033$$

$$\Delta \text{ Gravity} = (K_{sd})(\Delta SD_t) = -(0.011147)(3033) = -33.81 \text{ milligals}$$

TRANSPORTATION AND CARE OF METER

One of the features of the base loop measurement that warrants discussion is the type of travel that may be necessary, and the proper method of transporting the meter during such travel. The Coast and Geodetic Survey has experienced nearly every method of travel in such work. One of the methods that has proven very successful is travel by air, both in small dial and large dial measurements. In such travel the meter can be damaged, or at least the results of the measurements can be rendered useless, if the meter is subjected to rough treatment. This can be circumvented by having the meter operator keep the meter at all times, and not allow it to be checked or stored by the airlines personnel. This might cause some slight inconvenience to the traveler, as in most flights the meter would have to be stowed at his feet. This does not present any great discomfort, and will protect the meter from undue jolts as the result of any sudden changes in altitude from air pockets or rough air currents. Truck travel (where the meter is fastened to the bed of the truck by the prescribed truck harness) is probably the least harmful method of travel to the meter, if the driver takes care to reduce speed in areas of rough roads, and to avoid sudden stops or changes in direction. If an automobile is used, as in the case of a rented car, the meter can be placed on the floor, between the front seat and the dashboard. It will ride quite smoothly providing no sudden stops or turns are made, so that the meter does not jar against the dash.

The Worden meter is temperature compensated, that is, for a certain range of its scale the effects of outside temperatures are corrected. If this meter is subjected to large and rapid changes of temperature, however, the effects are readily apparent in the results. Cases have been noted where the meter was stored in an air conditioned office, and was taken outside the next morning. The outside temperature was 20° higher than the temperature of the air conditioned room, and this rapid change in temperature sent the meter into "thermal shock," which resulted in its being out of commission for 48 hours. During this period the beam vibrated so rapidly that a reading or balancing was impossible. Cases have been noted where the reverse temperature change would result in the same effect upon the meter. If the meter is taken back into the original temperature after only a short time (just long enough to take a reading), then no ill effects will be noted in the results. In truck travel in cold weather where the truck heater keeps the interior of the truck and the meter at approximately 45°, and where the outside temperature is much below this figure, the best readings are obtained by making all of the meter observations on the truck tripod.

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(6-23-59)

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COAST AND GEODETIC SURVEY

Large Dial Measurement

GRAVITY METER OBSERVATIONS

PAGE_____

LOCATION: South Dakota DATE: 10/11/54

CHIEF OF PARTY: H. D. N. METER: No. 114

OBSERVER: C. W. T.

STATION	G. C. TIME	INST. NO. Large Dial	INST. NO. SMALL DIAL	Δh *	TEMP. ~~°C~~ Δ S.D.	DESCRIPTION OF STATION
ABERDEEN	2117	440	3410	0.0		
1950	18	439	4035		625	
	19	438	4659		624	$LD_a = 438$
	20	437	5276		617	Mean $SD_a = 4656$
	21	436	5903		627	
					623.25 = Mean diff. = A_1	
	2124	436	5901			
	25	437	5275		626	
	26	438	4659		616	
	27	439	4032		627	
	28	440	3405		627	
					624.00 = A_2	
REDFIELD	2231	435	3493	0.0		
1950	32	434	4119		626	
	33	433	4741		622	$LD_b = 433$
	34	432	5359		618	Mean $SD_b = 4739$
	35	431	5987		628	
					623.50 = A_3	
	2238	431	5984			
	39	432	5358		626	
	40	433	4737		621	
	41	434	4115		622	
	42	435	3494		621	
					622.50 = A_4	

*RECORD THE ELEVATION OF GRAVITY METER FOOTPLATES ABOVE (+) OR BELOW(−) STATION, TO NEAREST 0.1 FOOT.

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FIG. 6.—Large Dial Measurement.

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