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SANDIA SYSTEMATIC DECLASSIFICATION REVIEW
DOWNGRADING OF DECLASSIFICATION STAMP

CLASSIFICATION CHANGED TO U AUTHORITY R. B. Craney
Emelda Selph 4/12/97
PERSON VERIFYING MARKING & DATE Carmela D. Gallias 4/15/97
RECORD ID 97SN1295
DATED: 4/15/97

SANDIA SYSTEMATIC DECLASSIFICATION REVIEW	
1. Review Date <u>4-14-97</u>	2. Classification (Circle Numbers)
Authority <u>ADU</u>	1. Classification retained <u>U</u>
Name <u>vs boyer</u>	2. Classification changed to <u>U</u>
Review Date <u>4/15/97</u>	3. Downgrade of classification information
Authority <u>ADU</u>	4. Consistent with <u>U</u>
Name <u>R. B. Craney</u>	5. Comments <u>OK for Comment</u>

[REDACTED]

SC-TM-64-56-16

GRAVITY MEASUREMENTS AT
SPECIAL WEAPONS STANDARDS LABORATORIES

E. B. Massengill

ABSTRACT

This memorandum gives results of a gravity survey made by the United States Coast and Geodetic Survey for Sandia Corporation. Direct measurements of the acceleration of gravity, needed for adjustment of mercury barometric standards, were made at fifty-one Special Weapons standards laboratories. Theoretical and measured values of the gravitational accelerations are tabulated, together with corresponding local gravitational anomalies and barometric errors which the survey revealed.

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MAY 22 1987

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Case No. 609.00

GENERAL M & R CONTROL NO. & 61496
September 21, 1956

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-3-

GRAVITY MEASUREMENTS AT
SPECIAL WEAPONS STANDARDS LABORATORIES

Sandia Corporation is responsible for standardization of measurements within the Special Weapons Systems (Special Weapons Regulation No. 132-1, AFSWP, 17 June 1953). The primary pressure reference for Special Weapons instruments is a pair of mercury barometers standardized by the National Bureau of Standards in Washington and located at Sandia Corporation in Albuquerque. Other mercury barometers, which serve as regional standards for manufacturers and for military and Sandia Corporation personnel, customarily are standardized by primary transfer standards -- likewise mercury barometers -- which are calibrated at the primary reference laboratory in Albuquerque and then shipped to secondary standards laboratories. Secondary reference barometers are used to calibrate such instruments as telemetering pressure transducers, baroswitch testers or portable standards used by the military to calibrate baroswitch testers, barographs, radiosondes, and meteorological barometers.

The primary standard at Albuquerque and the secondary standards referred to it must be adjusted for differences in the weight of mercury due to differences in the earth's gravitational force from one location to another. The mass of a cubic centimeter of mercury may have different weights at different geographic locations. A mercury column of a given height, standardized at Albuquerque, balances a greater atmospheric pressure at Baltimore, where mercury is heavier, and a smaller atmospheric pressure at Eniwetok, where mercury is lighter, than at Albuquerque.

Though standards used in the past have all been adjusted for these regional differences, some uncertainty has existed as to the precise values of the force of gravity in the various standards laboratories. It is well known that gravity is less at Eniwetok than at Baltimore because Eniwetok -- on the earth's equatorial bulge -- is farther from the earth's gravitational center and experiences a larger centrifugal effect than Baltimore which is farther north. Similarly, it is known that gravity is less at the altitude of Albuquerque than at that of a coastal city like Casablanca, which, although it is at the same latitude as Albuquerque, is closer to the earth's center. Barometric corrections for Special Weapons instruments have been calculated by formula for the effects of latitude and altitude. In the past they have not, however, allowed for variations in the density of the earth, which can cause significant local differences.

In addition to these differences due to latitude and elevation, gravity is influenced by the density of the earth. The earth is more dense under the ocean deeps than it is under high mountain ranges. This difference could be expected to cause the actual force of gravity to be higher than the calculated value in an ocean region like the Pacific Proving Ground, and lower than the calculated value in the Rocky Mountain area at Albuquerque.

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-4-

Appreciable differences can occur within a few hundred feet of lateral distance and, for adjustment of a given instrument, a direct measurement of gravity must be made in or very near to the laboratory where the instrument is housed.

Though the errors due to density are less serious than those due to latitude and altitude, the fact that they were unknown hitherto has led to uncertainty concerning the uniformity of the Special Weapons regional standards. It was felt that even a small bias accumulated from one instrument to another could cause rejection of good arming and fuzing baroswitches and acceptance of poor ones at the borderline of the tolerances given to manufacturers of weapon components, as shown in the figure.

To eliminate this possibility, Sandia Corporation arranged for the AEC, late in 1954, to have a team of experts from the United States Coast and Geodetic Survey Q-cleared to make a gravity survey of all Special Weapons standards laboratories. During the winter and spring of 1955, this team measured the force of gravity in all the laboratories in the United States. At one location isolated by snow, a chain of measurements around the laboratory was substituted for a measurement at the isolated area. In the fall of 1955, similar measurements were made inside all the overseas standards laboratories.

Gravity meters operating on the principle of the spring balance with a precision of one part in ten million were used for the measurements. The results presented in the table below, include reference values of the force of gravity measured at non-Special-Weapons locations together with those desired for correction of the Special Weapons standards.

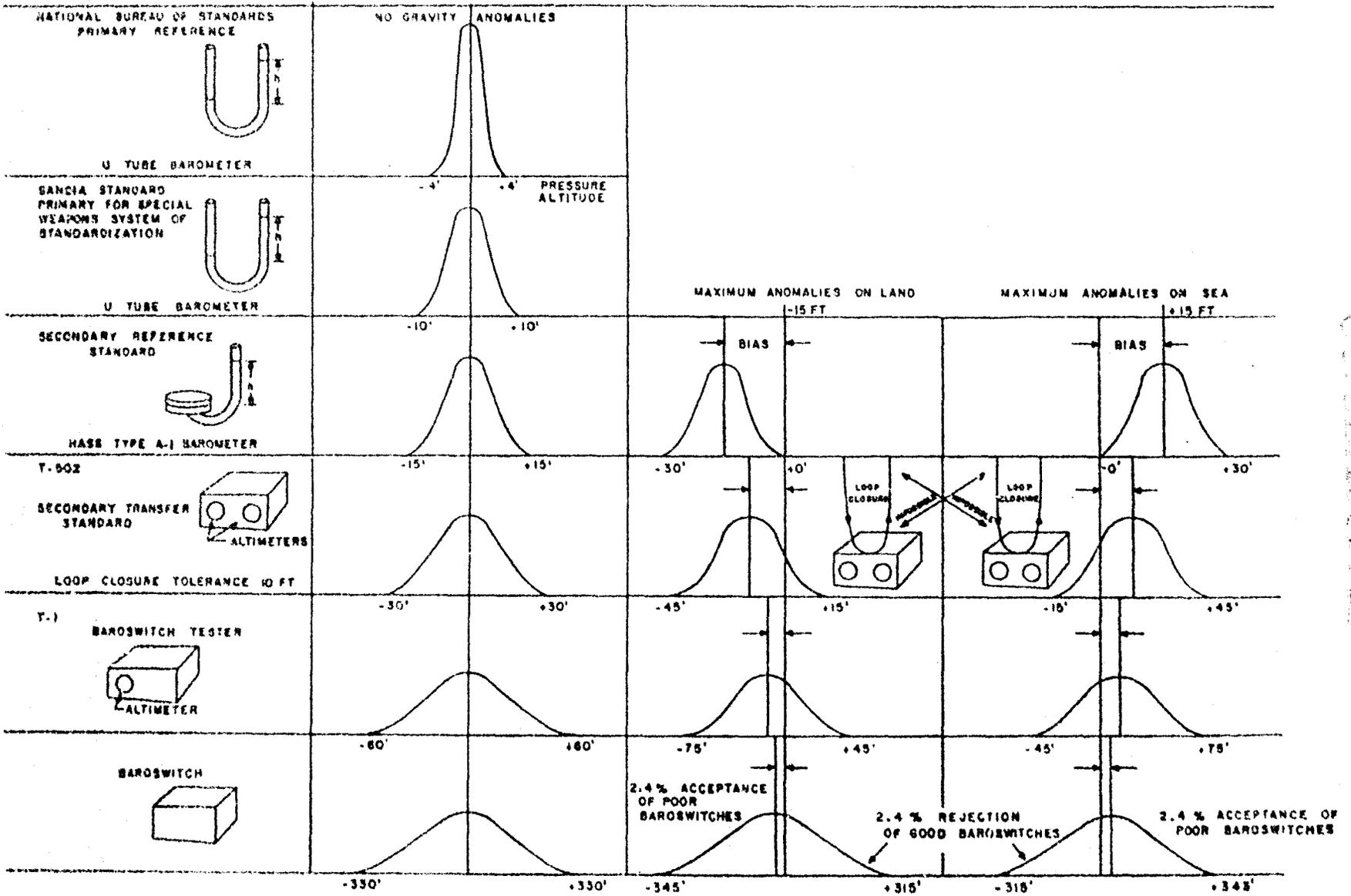
Starting April 10, 1956, the adjustment of all pressure standards throughout the Special Weapons System has been based on the measurements by the Coast and Geodetic Survey. The primary reference originally was adjusted to a value of the gravitational force determined some years ago at a distance from the present Sandia Laboratory. The new value found by the Coast and Geodetic Survey differs from the earlier measurement by the equivalent of a half-foot of pressure altitude, and will be used with the new primary reference.

The new system of barometric corrections not only improves the accuracy of individual instruments and the uniformity of standardization within the Special Weapons laboratories; it also provides the added convenience of "interchangeability", whereby a portable standard, calibrated by any one of the secondary standards, may be used in the field to check a baroswitch tester, and may then be referred to any other secondary standard at a later time to be sure that its calibration has not changed. In the past this procedure was not feasible. A portable standard which gave different readings when referred to different mercury standards might do so because its calibration had drifted, but on the other hand the reason

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EFFECT OF GRAVITY ANOMALIES ON PRESSURE REFERENCE STANDARDS



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-6-

might be a discrepancy in the weights of mercury between the two secondary standards; the recheck had to be made by the original instrument. Corrections made possible by direct measurements of gravity now bring the entire system of Special Weapons pressure measurements closer to the ideal, where readings by one secondary standard are identical with those by another, within the tolerances assigned to the instruments.

Since the determinations of gravity were carried out to six or seven figures, they can be expected to prove generally useful in the Special Weapons laboratories for some time to come. Potential nonbarometric uses include corrections needed in precise weighing, the improvement of ballistic tables, and determinations of moments of inertia by pendulums.

E. B. MASSENGILL - 1651

Case No. 609.00
September 21, 1956

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GRAVITY MEASUREMENTS AT SPECIAL WEAPONS STANDARDS LABORATORIES 1955

Harley D. Nygren, Lieut., USC&GS, Observer

Meters 20 and 114

Probable error < \pm 0.001 gal

Gravity Datum: COMMERCE BASE, $g = 980.1185$ gals (Potsdam System).

	Gravity Calculated gals	Gravity Observed gals	Location	Anomaly gals	Error mm Hg	Error Pressure-Altitude ft
1	979.20	979.230	ABLE (3428) On table, 34 inches above floor. Pressure Calibration Room, S Bldg.	+ .03	- .02	+1
2	979.16	979.148	Alamogordo NM (3420) HOLLOMAN AIR DEVELOPMENT CENTER. On table, 3.0 ft above floor. Lab 1, Bldg 823, West Area. (Bell Aircraft Corp).	- .01	+ .01	0
3		979.123	Alamogordo NM Reference Station P-767.			
4	979.16	979.106	Alamogordo NM (3466) WHITE SANDS PROVING GROUND. On table, 3.0 ft above floor, 1.2 ft above barometer stand. Bldg 1690, Photo Lab.	- .05	+ .04	-1

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	Gravity Calculated gals	Gravity Observed gals	Location	Anomaly gals	Error mm Hg	Error Pressure-Altitude ft
5		979.224	<u>Albuquerque NM</u> Reference Station P-764.			
6	979.24	979.2216	<u>Albuquerque NM (3426)</u> SANDIA CORPORATION. On the concrete slab in the Primary Reference Laboratory, Rm 119, Bldg 860, Sandia Base. About 32 inches above the floor.	-.02	+.02	-1
7	979.24	979.221	<u>Albuquerque NM (3427)</u> SANDIA BASE. On table, 35 inches above floor, calibration room, Bldg 640, Military Tech Area. SSWP.	-.02	+.02	-1
8		979.292	<u>Austin Tex</u> Reference Station P-10.			
9	979.31	979.293	<u>BAKER (3452)</u> On the table, 34 inches above the floor, Calibration Room (Pressure Standard), S Bldg.	-.02	+.02	-1
10		980.114	<u>Baltimore Md</u> Reference Station P-23A.			

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	Gravity Calculated gals	Gravity Observed gals	Location	Anomaly gals	Error mm Hg	Error Pressure- Altitude ft
11		980.712	Bimidji Minn Reference Station P-1098.			
12	930.78	980.812	Bimidji Minn RED LAKE BOMBING RANGE. (Values interpolated from measurements in neighboring area.)	+ .02	- .02	+1
13	980.79	980.819	Bimidji Minn RED LAKE BOMBING RANGE. (Values interpolated from measurements in neighboring area.)	+ .03	- .02	+1
14		979.667	Boulder Dam Nev Reference Station P-1028.			
15		980.273	Boxelder SD Reference Station P-357.			
16		980.9007	Brettigny France (28) BRETTIGNY AIRPORT. Tower Bldg, Rm 133. Floor about 15 ft above field elevation.			
17		980.363	Buffalo NY Reference Station P-319.			
18		981.2686	Cambridge England (21) CAMBRIDGE UNIVERSITY. Pendulum House floor.			

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	Gravity Calculated gals	Gravity Observed gals	Location	Anomaly gals	Error mm Hg	Error Pressure- Altitude ft
19	979.18	979.248	Cape Canaveral Fla (3454) AIR FORCE MISSILE TEST CENTER. On barometer stand, 2.4 ft above floor. F & F Laboratory, Bldg 1428.	+ .07	- .05	+2
20		979.6429	Casablanca French Morocco (34) CAZES AIRPORT. In Customs waiting room for incoming passengers.			
21	979.60	979.5896	Casablanca French Morocco (32) Casablanca Station No. 1. On stand.	- .01	+ .01	0
22	979.60	979.5871	Casablanca French Morocco (33) Casablanca Station No. 2. On stand.	- .01	+ .01	0
23	979.60	979.5893	Casablanca French Morocco (31) Temporary Station.	- .01	+ .01	0
24	979.81	979.809	CHARLIE (3488) Top of concrete barometer stand, 3.0 ft above floor. Pressure Measurement Area, Electrical Bay, S Structure.	.00	.00	0
25	979.62	979.588	Culver City Calif (3450) TECHNICAL DEVELOPMENT CO. On table, 34 inches above floor. Test Lab.	- .03	+ .02	-1
26	979.46	979.528	DOG (3476) On surface of the slab, barometer stand, 2.7 ft above floor. Standards Laboratory, S Bldg.	+ .07	- .05	+2

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	Gravity Calculated gals	Gravity Observed gals	Location	Anomaly gals	Error mm Hg	Error Pressure- Altitude ft
27	980.72	980.740	<u>EASY (3436)</u> On top of slab, 2.3 ft above floor. Calibration Room, Plant 1, Bay 2.	+ 02	-.02	+1
28	980.21	980.274	<u>Elmhurst NY (3474A)</u> <u>KOLLSMAN INSTRUMENT CO.</u> On surface of floor. Test Equipment Section, Bldg F. *	+ .06	-.05	+2
29	980.21	980.278	<u>Elmhurst NY (3474B)</u> <u>KOLLSMAN INSTRUMENT CO.</u> On surface of floor. Green Room, Basement, Bldg F. *	+ .07	-.05	+2
30	980.21	980.278	<u>Elmhurst NY (3474C)</u> <u>KOLLSMAN INSTRUMENT CO.</u> On surface of floor. Maintenance Dept. Bldg A. North end of room on west side of loading bay, south side of building.	+ .07	-.05	+2
31	978.22	978.4562	<u>Eniwetok Atoll (6)</u> Bldg 10 on northeast end of island, about one mile north of MATS Terminal. In Rm 2. Concrete floor.	+ .24	-.18	+7
32		978.4596	<u>Eniwetok Atoll (7)</u> <u>MATS Terminal.</u> Center of waiting room on south side. Floor.			

* Excessive vibrations made it difficult to get precise readings.

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	Gravity Calculated gals	Gravity Observed gals	Location	Anomaly gals	Error mm Hg	Error Pressure- Altitude ft
33		980.768	Fort Kent Me Reference Station P-106.			
34	980.21	980.258	FOX (3458) On top of concrete block barometer stand. Calibration Room, Bldg 31.	+ .05	- .04	+1
35		981.0557	Frankfurt AM Germany (27) COMMERCIAL TERMINAL. Entrance to Gate 4.			
36		981.0656	Frankfurt AM Germany (26) EXCELSIOR HOTEL. Room 141. Floor.			
37	980.63	980.643	GEORGE (3424) On table, 29 inches above floor, 10 inches above barometer stand, K-2 Room, Bldg 304	+ .01	- .01	0
38		979.308	Georgetown Texas Reference Station P-310.			
39		979.571	Godley SC Reference Station P-862.			
40		978.5330	Guam (11) Near Agaña Naval Air Station. On concrete sidewalk by front porch of Hotel Tropics.			
41		978.5264	Guam (12) At Agaña Naval Air Station. Northeast corner of PAA waiting room, at entrance from field. Floor.			

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	Gravity Calculated gals	Gravity Observed gals	Location	Anomaly gals	Error mm Hg	Error Pressure- Altitude ft
42	978.29	978.5092	Guam (13) Guam Station No. 1. Floor.	+ .22	- .17	+6
43	978.29	978.5259	Guam (14) Guam Station No. 2. On table.	+ .24	- .18	+7
44	980.97	980.9755	Heidelberg Germany (22) Headquarters USAEUR, BOQ-3, Rm 455. Temporary station. Floor.	+ .01	- .01	0
45	980.97	980.9365	Heidelberg Germany (23) Heidelberg Station No. 1. Floor.	- .03	+ .02	-1
46	980.97	980.9668	Heidelberg Germany (24) Heidelberg Station No. 2. Floor.	.00	.00	0
47		979.396	Hilliard Fla Reference Station P-867.			
48		978.9329	Honolulu Hawaiian Islands (9) HONOLULU INTERNATIONAL AIRPORT. In center of lobby, opposite Japan Air Lines desk. Floor.			
49		978.9339	Honolulu Hawaiian Islands (3) HICKAM AIR FORCE BASE. MATS Terminal. In center court, 40 feet southeast of fire hose, 30 feet west of field end of court. Floor.			
50		979.858	Hopkinsville Ky Reference Station P-170.			
51	980.09	979.988	HOW (3462) On table, 3.0 ft above floor. Calibration room (ready room), Bldg 354.	- .10	+ .08	-3

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	Gravity Calculated gals	Gravity Observed gals	Location	Anomaly gals	Error mm Hg	Error Pressure- Altitude ft
52		979.973	<u>Isleton Calif</u> Reference Station P-1034.			
53	980.33	980.357	<u>ITEM (3468)</u> On top of slab, 2.8 ft above floor. Calibra- tion room, Bldg 354.	+ .03	- .02	+1
54		980.303	<u>Ithaca NY</u> Reference Station P-32.			
55	979.92	979.921	<u>JIG (3444)</u> Top of barometer stand, 3.0 ft above floor. Calibration Room, Plant 2.	.00	.00	0
56	980.03	979.981	<u>Kansas City Mo (3482)</u> <u>BENDIX AVIATION CORPORATION.</u> On table, 2.8 ft above floor. Mezzanine X-40.	- .05	+ .04	-1
57	979.19	979.212	<u>KING (3480)</u> Northwest corner, S Bldg. Floor.	+ .02	- .02	+1
58		979.510	<u>Kingston La</u> Reference Station P-718.			
59		978.3635	<u>Kwajalein Atoll (5)</u> In waiting room of Terminal and Weather Bldg. Floor.			
60		979.972	<u>Lawrence Kans</u> Reference Station P-1130.			

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	Gravity Calculated gals	Gravity Observed gals	Location	Anomaly gals	Error mm Hg	Error Pressure- Altitude ft
61		981.1948	London England (17) GROSVENOR HOUSE HOTEL. Room 532. Temporary station. Floor.			
62		981.2006	London England (19) GROSVENOR SQUARE. US Naval Headquarters, North Audley Street entrance. Floor of vestibule.			
63	981.17	981.2057	London England (18) London Station No. 1. On stand.	+ .04	- .03	+1
64	981.17	981.2849	London England (20) London Station No. 2. Floor.	+ .11	- .08	+3
65		979.5946	Los Angeles Calif (2) LOS ANGELES INTERNATIONAL AIRPORT. Center of lobby of Pan American Airways, between pillars. Floor.			
66	979.64	979.629	LOVE (3484) On table, 2.9 ft above floor. Calibration Room, S Bldg, 418.	- .01	+ .01	0
67		979.884	Lynn Haven Va Reference Station P-712.			
68		979.552	Mecca Calif Reference Station P-1019.			
69	980.56	980.588	Minneapolis Minn (3486) HONEYWELL REGULATOR COMPANY. Process Lab, 10th floor, Main Plant. Floor.	+ .03	- .02	+1

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	Gravity Calculated gals	Gravity Observed gals	Location	Anomaly gals	Error mm Hg	Error Pressure- Altitude ft
70		980.600	Minneapolis Minn Reference Station P-74			
71		980.2270	New York NY (16) IDLEWILD AIRPORT. USC&GS gravity meter station Idlewild No. 1.			
72		980.2825	New York NY (15) LA GUARDIA AIRPORT. At corridor outside waiting room of American Airlines. Floor.			
73		980.282	New York NY LA GUARDIA AIRPORT. Gangway No. 4 (Woollard 1950-51).			
74		979.573	Niland Calif Reference Station P-1020.			
75	979.88	979.886	Norfolk Va (3470) NAVAL SUPPLY CENTER. Top of barometer stand, 2.3 ft above floor. Calibration Room, Bldg 137, Special Weapons Supply Depot.	+ .01	- .01	0
76	978.69	978.9573	Oahu Hawaiian Islands (4) Oahu station. On table.	+ .27	- .21	+8
77		979.0320	Oahu Hawaiian Islands (8) Northwest of Waianae, Oahu. At USC&GS pendulum station No. 16. Floor of warehouse.			
78		979.963	Olathe Kans Reference Station P-1153.			

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	Gravity Calculated gals	Gravity Observed gals	Location	Anomaly gals	Error mm Hg	Error Pressure- Altitude ft
79		980.9517	Paris France (29) INVALIDES AIR TERMINAL, Southeast corner of lower-level departing waiting room. Floor.			
80		980.9133	Paris France (30) ORLY AIRPORT. Air France, Gate 2 to the field.			
81		980.9434	Paris France (35) PALAIS D'ORSAY HOTEL, Room 547. Floor.			
82		979.577	Pasadena Calif Reference Station P-314.			
83	979.67	979.668	Point Mugu Calif (3430-1) NAVAL AIR MISSILE TEST CENTER. On table, 3.0 ft above floor, F. & F. Lab, Bldg 354.	.00	.00	0
84	979.67	979.669	Point Mugu Calif (3430-2) NAVAL AIR MISSILE TEST CENTER. On the floor near manometer. Room 141, Bldg 36.	.00	.00	0
85	979.59	979.565	Pueblo Colo (3460-1) PUEBLO ORDNANCE DEPOT. On table, 3.2 ft above floor. West porch, 2nd floor, Bldg 520.	-.02	+.02	-1
86	979.59	979.567	Pueblo Colo (3460-2) PUEBLO ORDNANCE DEPOT. On floor, pressure calibration room, Bldg 529.	-.02	+.02	-1

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	Gravity Calculated gals	Gravity Observed gals	Location	Anomaly gals	Error mm Hg	Error Pressure- Altitude ft
87	979.52	979.490	ROGER (3448) Within the proposed Q area, near the proposed site of the S structure, at Traverse Station (core station) F. E. 26. The elevation and coordinates of this station are on file in the office of the District Engineer, Corps of Engineers.	-.03	+.02	-1
88	980.35	980.348	Romulus NY (3472) SENECA ORDNANCE DEPOT. On concrete step on south side of Bldg 97, a small brick block storage building south of the proposed Q area. The elevation and coordinates of this point may be obtained from the post engineer, should it become necessary to determine a precise value of gravity by computation for the calibration room. As it is within a thousand feet of the Q area, this gravity value should be satisfactory for pressure corrections.	.00	.00	0
89	979.60	979.565	Salton Sea Calif (3422) SALTON SEA TEST BASE. On table, 3.2 ft above floor, Bldg 44, Area 1.	-.03	+.02	-1
90	979.19	979.208	San Antonio Tex (3481) KELLY AIR FORCE BASE. Calibration Room, Bldg 1520. Building under construction. Reading reduced to level of the completed floor.	+.02	-.02	+1
91	979.53	979.524	San Diego Calif (3434) NAVAL SUPPLY DEPOT. On table, 3.2 ft above floor. Special Weapons Shop, Bldg 139, Special Weapons Supply Annex (Storage Section.)	-.01	+.01	0

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	Gravity Calculated gals	Gravity Observed gals	Location	Anomaly gals	Error mm Hg	Error Pressure- Altitude ft
92		979.531	San Diego Calif Reference Station P-240.			
93		980.357	Springfield Mass Reference Station P-540.			
94	980.09	980.097	Towson Md (3456) BENDIX AVIATION CORPORATION. Surface of floor. Standards Room, Main Bldg. Friez Instrument Division.	+ .01	- .01	0
95		979.325	Trinidad Colo Reference Station P-1169, six miles south of Trinidad.			
96		979.599	Ventura Calif Reference Station P-250.			
97		978.8818	Wake Island (10) Terminal Bldg, outside Weather Bureau door. Floor, approximate elevation 10 feet.			
98	980.39	980.384	Wheatfield NY (3478) BELL AIRCRAFT CORPORATION. On table, 2.6 ft above floor. Standards and Calibration Laboratory.	- .01	+ .01	0
99	981.03	981.0596	Wiesbaden Germany (25) WIESBADEN AIR FORCE BASE. On porch under Terminal Bldg tower. Floor.	+ .03	- .02	+1

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	Gravity Calculated gals	Gravity Observed gals	Location	Anomaly gals	Error mm Hg	Error Pressure- Altitude ft
100		979.932	Yorktown Va Reference Station P-845			
101	979.55	979.519	Yucca Lake, Nevada Test Site (3440) Surface of concrete slab at floor level. Northeast corner, Weather Bldg.	-.03	+.03	-1

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