GEOMETRICS

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DETECTION OF BURIED EXPLOSIVE ORDNANCE

CONCLUSION AND RECOMMENDATIONS

Magnetics is a proven tool and perhaps the most effective available for the detection of buried ordnance and other ferrous objects. Certain constraints and limitations exist however, but if properly considered within the context of the search problem, very good results can be expected.

The G-816 Magnetometer demonstrated has excellent characteristics for use in gridded search, is readily available and offers proven cost effective performance. (A G-816 with standard 1 gamma sensitivity sells for   with delivery in 2 to 3 weeks. Refer to the attached quotation for available options and quantity discount.)

Existing technology would allow the design of a new instrument offering overall improved search capability, yet retaining the same simplicity and portability of the G-816. Increased sensitivity (to 0. 1 gamma) is also possible and would provide improved detectability and classification of objects in all geographic locations. In view of the relatively modest development costs that would be involved, it is suggested that a new instrument design be seriously considered.

For the near term, it is recommended that a number of G-816 units with 0.25 gamma sensitivity be procured and placed into actual search operation using gridded methods. This will allow the necessary field team experience to be gained and provide an immediate and effective search capability at very nominal cost.

INTRODUCTION

Preliminary field tests were conducted at the U.S. Army Picatinny Arsenal test range on July 11 to assess the feasibility of GeoMetrics' Portable Proton Magnetometer, Model G-816 in the location of buried explosive ordnance. Only one day was available for conducting the test, and thus data were obtained in a hurried manner consisting of "quick look" profiles, some with vertical gradient (dif ference) measurements, over a variety of target types and sizes buried at differing but accurately (mown depths.

The instrument used in the test was a standard field magnetometer originally designed for man-carry geophysical surveys. Both 1 and 0.25 gamma sensitivities were available - selectable by switch with the measured data displayed as a 5 digit number (total field) directly in gammas. Each measurement cycle is initiated by a pushbutton and requires a total of 6 seconds to obtain and display. Measurements are not subject to the effects of temperature, orientation, leveling or normal movements in carrying. The sensor was mounted on an 8 ft. staff, with a 2 ft. staff section fixed to the opposite end allowing rapid readings at 2 ft. and 8 ft. heights above the ground. The instrument was operated by a Picatinny Arsenal technician (without previous experience in proton magnetometers) and after a few minutes of instruction, he found it simple and easy to use.

It should be noted that a proton magnetometer, as opposed to a fluxgate type, measures the scaler magnitude of the total intensity, allows quantitative data to be obtained from a single moving sensor, is intrinsically calibrated at all times and operates equally well in all earth's fields and dip angles.

<u>TEST SITE</u>

The presence of nearby magnetic materials (roadbed crushed rock, a buried water line, telephone and power line etc.) located North and South of the test site, resulted in high local gradients which in some cases exceed the target anomalies. In addition, individual pieces of the roadbed material were scattered (buried) close by the targets. Together these effects produced a somewhat limiting condition, but nevertheless are representative of actual field conditions that will sometimes be encountered. The superpositon of target and background anomalies was confusing until the data were plotted, but did not substantially hamper the overall search nor affect the results.

The targets were picked at random from the many available and from 1 to 3 profiles were run directly over and to each side of the target. The distance between the readings along each profile was either measured or stepped off by the operator. It is interesting to note that most profiles were not extended sufficiently beyond the target anomaly to fully determine the baseline and thus the true peak to peak amplitude. (This was not evident until the data were plotted.)

EVALUATION OF RESULTS(Refer to attached worksheets)

A number of preliminary conclusions may be drawn pertaining to the operation of the instrument itself, the detectability of the various objects, the determination of depth and preferred methods of operation for various survey problems.

1. A 750 lbs. bomb having an approximate ferrous mass of 450 lbs., may be clearly and easily recognized when buried 18 ft. beneath the surface with the magnetometer sensor 2 ft. above ground level. (A sensor to target separation of 20 ft.) Indeed, the anomaly is sufficiently large to obtain even greater range of detection, perhaps, as much as 30 ft. in all earth's fields having a dip angle greater than 45 degrees. However, in one of the

three tests over different bombs, each of 750 lb. size, the bomb buried at 15 ft. for a total bomb to sensor separation of 17 ft. did not provide a clearly recognizable signature. It was determined that this particular bomb had a large induced magnetic moment, possibly one-half the total magnetic effect, and the permanent moment w s polarized in opposition to the earth's field. It is also noted that the same combination of induced and permanent effects occurred on one of the five tests over 250 lbs. bombs, but not on the four tests over 100 lb. bombs.

2. Thus, as a first step in establishing the effective range of detectability for objects of various shape and mass, the proportion of permanent and induced moments must be determined to a rough order of accuracy. With this information, the grid or profile spacing can be selected for best efficiency in covering the target area and to insure a high probability that all objects will be located. As an example, for 750 lb. bombs at a dip angle of 60° and 1 gamma sensitivity, the effective detection range might be set at 14 feet and the profile spacing at 28 feet.

3. It would be useful to run a quick series of tests over ordnance placed on the ground whenever a search is conducted at a new geographic location. This provides reference data for each ordnance type at that particular

magnetic dip angle and the determination of optimum range of detection, profile separation and target classification.

4. The careful plotting and examination of target signatures (amplitude and width) allows a reasonable estimate of the object size. Thus an 81 mm shell or other small mass might be discriminated against, say a 100 lb bomb. It would, however, be difficult to discriminate a large bomb fragment from shells or other metallic debris of a similar size.

5. Calculations of depth are easily done to a rough accuracy and requires only that measurements be made at two elevations over the target. A simple cardboard slide rule could he constructed allowing the calculation to be done quickly and easily, even by relatively inexperienced personnel.

SEARCH METHODS AND INSTRUMENT REQUIREMENTS

It seems particularly important to determine the method of search that most nearly meets the majority of requirements, and then design or adapt existing instruments to fit the method selected. In this manner, the instrument performance can be optimized for specific objectives, such as rapid coverage of a large area or detailed precise coverage over small areas. Generally, these methods fall into 3 categories:

An accurately measured grid over the target area with measurements taken at intersecting grid lines and plotted in contour or profile form.

B. A series of adjacent profiles more or less equally spaced apart with measurements made continuously along the profile and interpreted in real time by the operator.

C. A combination of A and B.

GRIDDED SEARCH

To insure effective results, the instrument must provide measurements with a high degree of accuracy and a sensitivity of at least 1 gamma. Measurements must not be influenced by environmental effects and must be obtained rapidly with only a few seconds for set up and readout at each station. In addition, the data must not be ambiguous (subject to individual adjustment or interpretation) and without need of further correction.

The gridded search method is of necessity quite slow and the effective area of search relatively small for each day's operation. In addition, the data are not meaningful to the operator except in a gross sense until tabulated and plotted. These factors, however, are not constraining in many cases and are offset by the ready availability, low cost and precise operation of available instruments.

PROFILE SEARCH

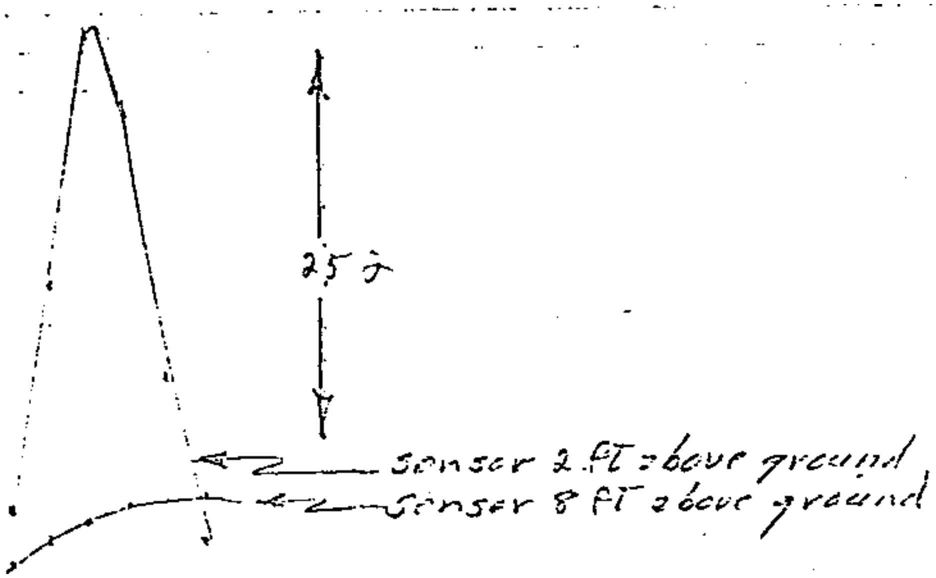
To increase the speed and thus the size of an area that can be covered, the instrument must have more rapid readout capabilities (one or two reads per second), an audio tone or meter display to indicate anomalous peaks, single or perhaps dual sensor (gradient) capability, and must not be sensitive to orientation or movement. A team of such instruments might cover, perhaps, one square mile per day with a fair probability that all objects of interest would. be located. Target anomalies could be flagged for later, more detailed coverage and examination.

The profile search method is less precise than the ridded search and has greater likelihood of missing deeply buried objects or low amplitude anomalies. Optimized instruments are not readily available or suffer from excessive cost, sensor motion or other constraints.

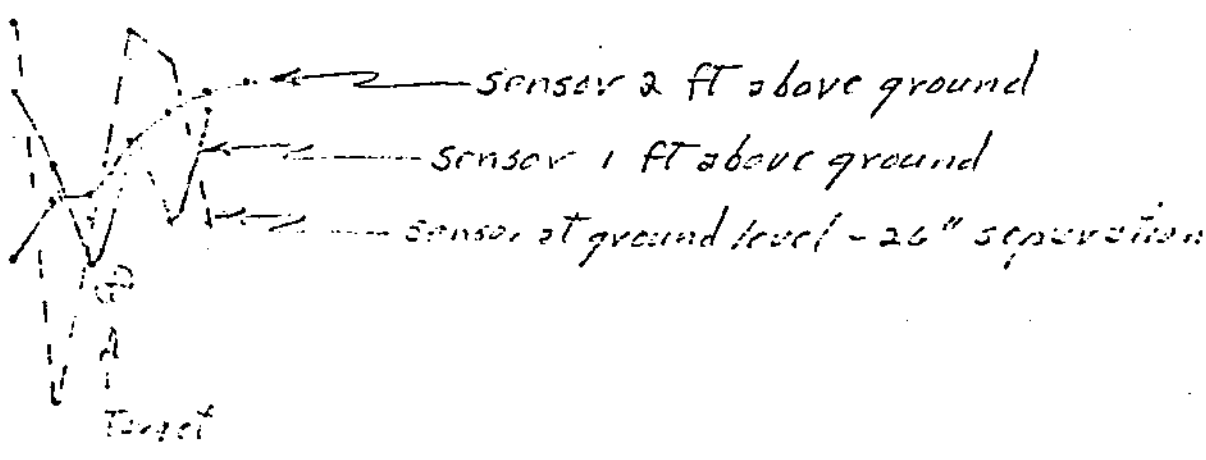
ANALOG PROFILE SEARCH

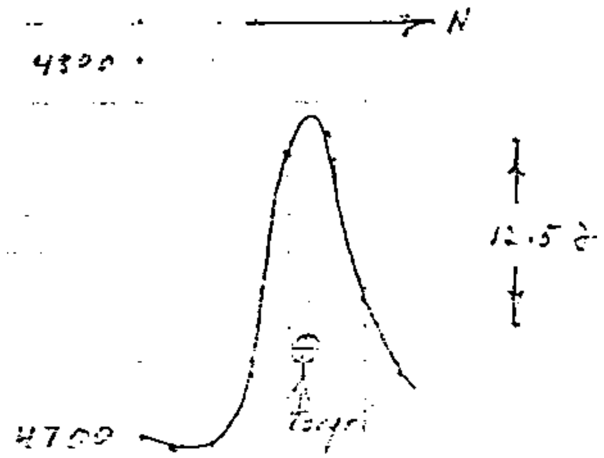
An alternative approach to the profile search method would be to include capability for analog strip chart recording as an integral part of the readout display, together with dual sensor (gradient) operation. While the use of dual sensors is inherently less sensitive, it removes the local geologic background , more sharply defines the anomaly, and in general provides improved definition. Recording the output on a strip-chart recorder allows rapid traverses over large areas with measurement and chart speed synchronized to the walking speed of the operator. Thus a series of adjacent profile records, if laid down side by side, would have a common start/stop line and would be reasonably accurate in distance along the profile length. This method of profile analysis provides a rapidly assembled graphic display of all targets and their approximate relative location over any given area. It would be quick and efficient, nearly as accurate as the ridded search and would allow 3 to 4 times the area to be covered.

105 mm shell—vertical
22" depth below ground surface
0.25 gamma sensitivity

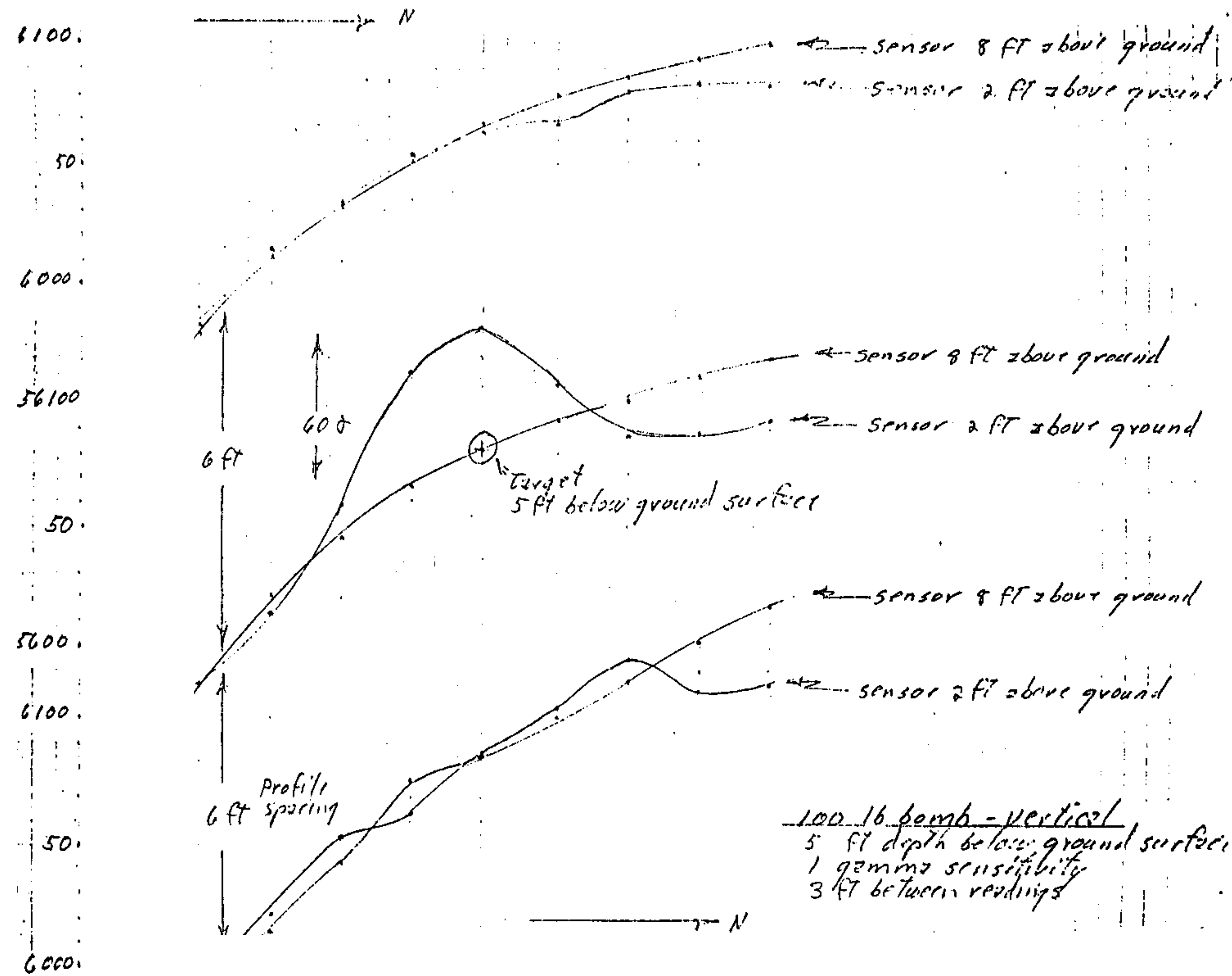


105 mm shell-Horizontal west
26" depth below ground surface
0.25 gamma sensitivity





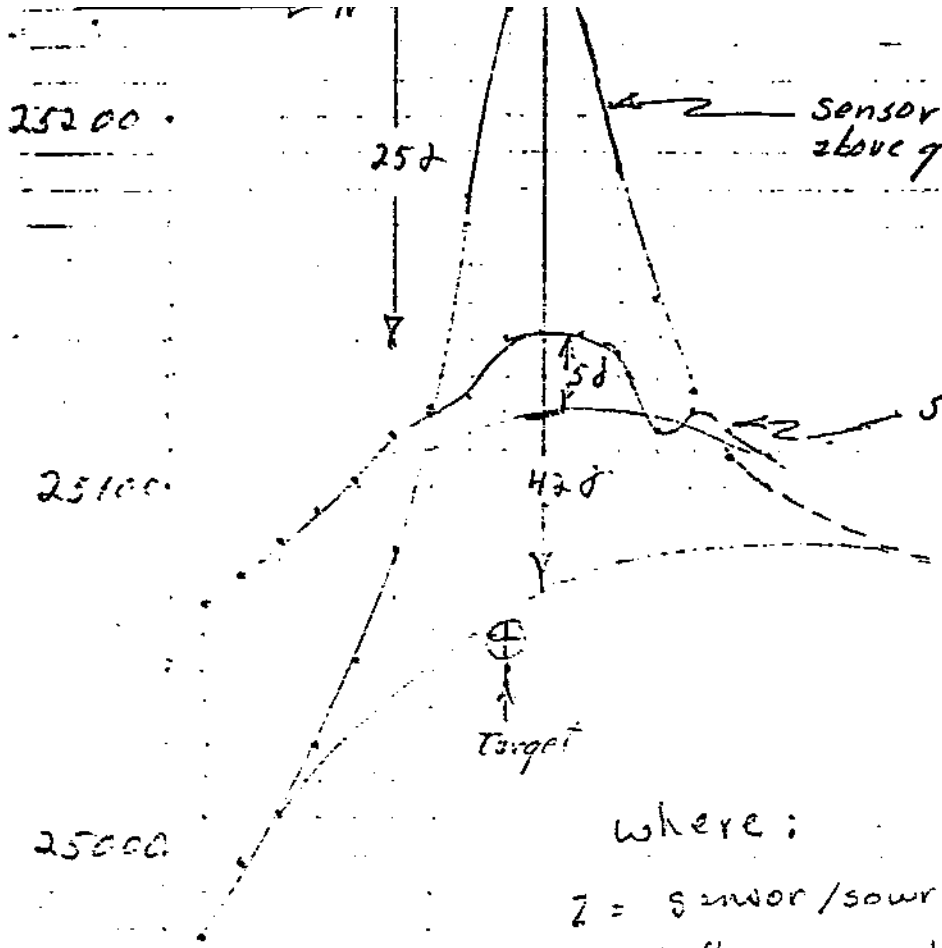
81 mm mortar. Horizontal West
12" depth below ground surface
sensor 2 ft above ground
0.25 gamma sensitivity



N
6100
50
6000
56100
50
5600
6100
50
6000
sensor 8 ft above ground
sensor 2 ft above ground
sensor 8 ft above ground
sensor 2 ft above ground
sensor 8 ft above ground
sensor 2 ft above ground
6 ft
60 γ
Target
5 ft below ground surface
Profile
6 ft spacing
N
100 lb bomb - vertical
5 ft depth below ground surface
1 gamma sensitivity
3 ft between readings

100 lb bomb - vertical
8 ft depth below sur

0.25 gamma sensitivity
2 ft between readings



$$Z = \frac{\Delta Z}{\left(\frac{T_{Z_1}}{T_{Z_2}+\Delta Z}\right)^{1/3} - 1}$$

$$Z = \frac{6}{\left(\frac{42}{5+6}\right)^{1/3} - 1} = 10.7 \text{ ft}$$

between Target and sensor 2 ft above ground

where:

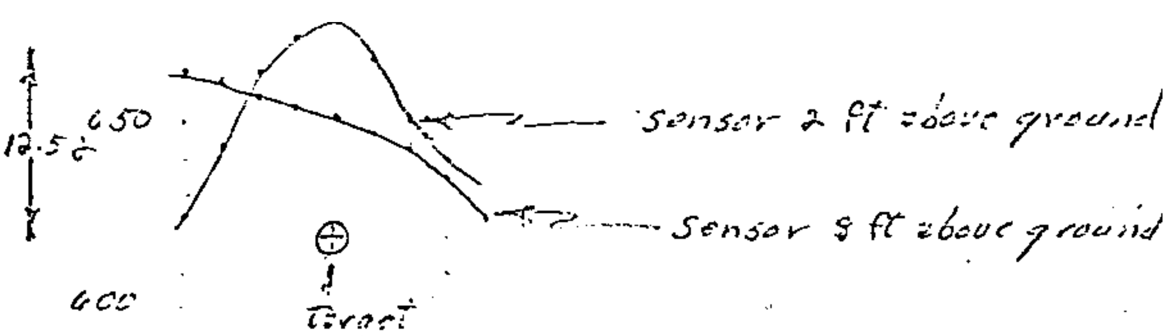
Z = sensor/source separation (ft)

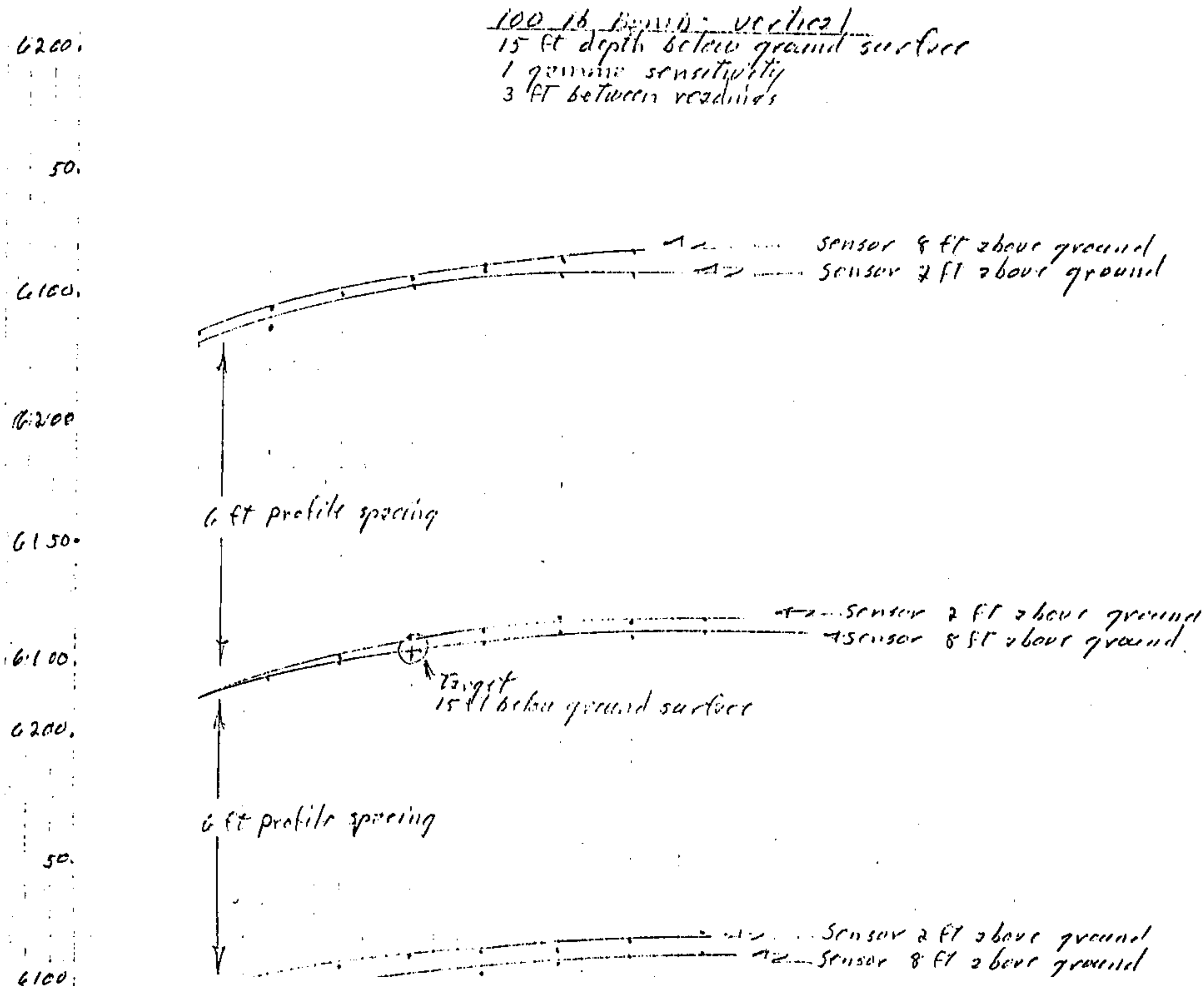
ΔZ = Difference in height between sensors (ft)

T_{Z_1} = Difference in gammas between sensor 1 and normal Fie

T_{Z_2} = Diff. in γ between sensor 2 and normal unanomalous field

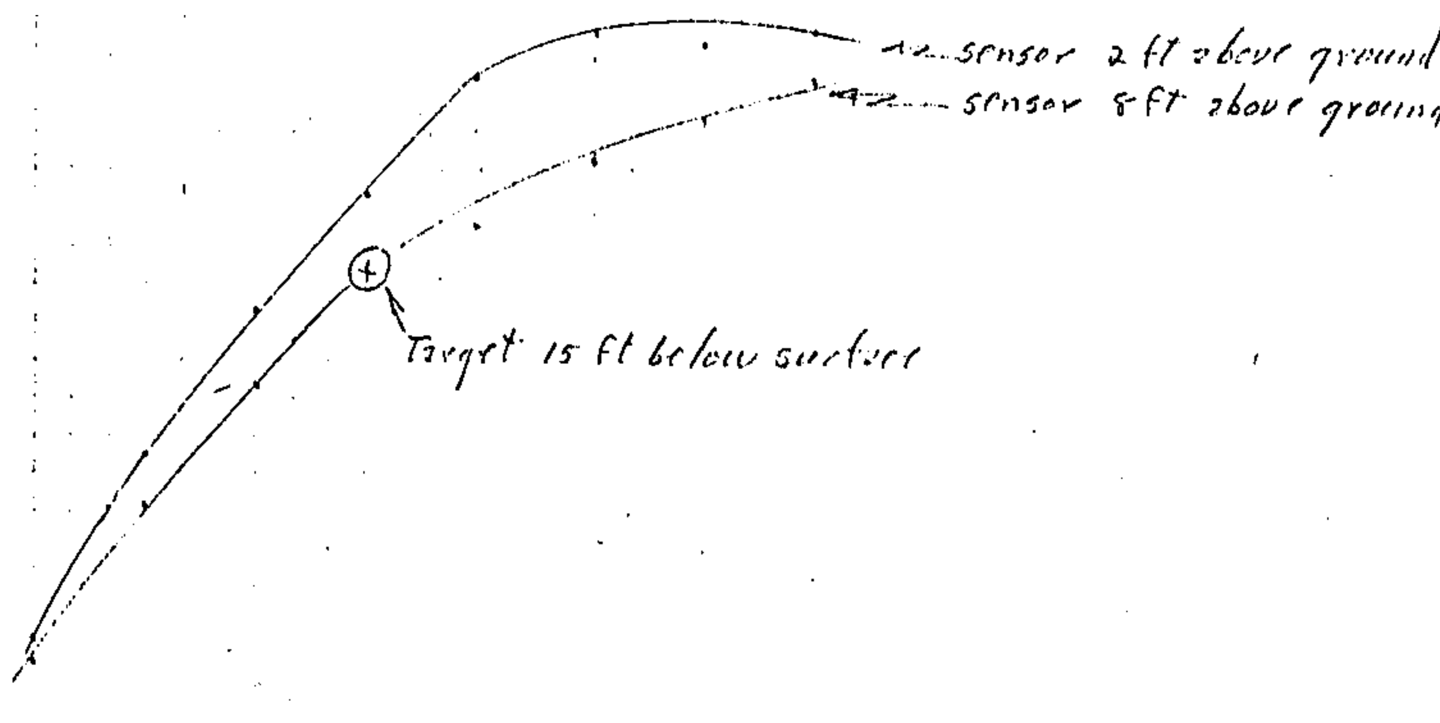
100 lb bomb - vertical
10 ft depth below surface
0.25 gamma sensitivity

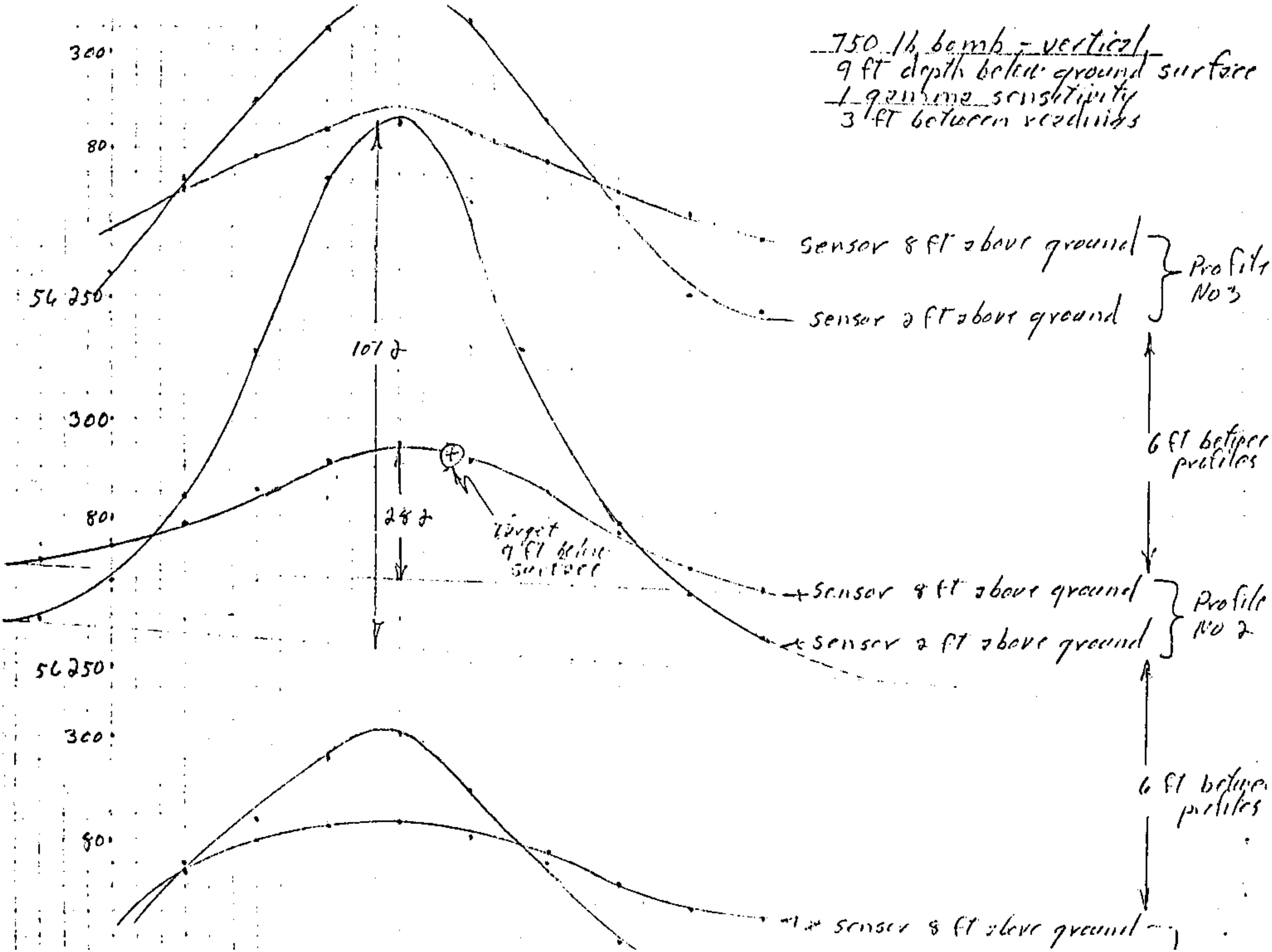



100 lb Bomb - vertical
15 ft depth below ground surface
1 gamma sensitivity
3 ft between readings
6200.
50.
6100.
6200
6150.
6100.
6200.
50.
6100.
Sensor 8 ft above ground
Sensor 2 ft above ground
6 ft profile spacing
Sensor 2 ft above ground
Sensor 8 ft above ground
Target
15 ft below ground surface
6 ft profile spacing
Sensor 2 ft above ground
Sensor 8 ft above ground

100 lb bomb - vertical
15 ft depth below ground surface
0.25 gamma sensitivity
3 ft between readings

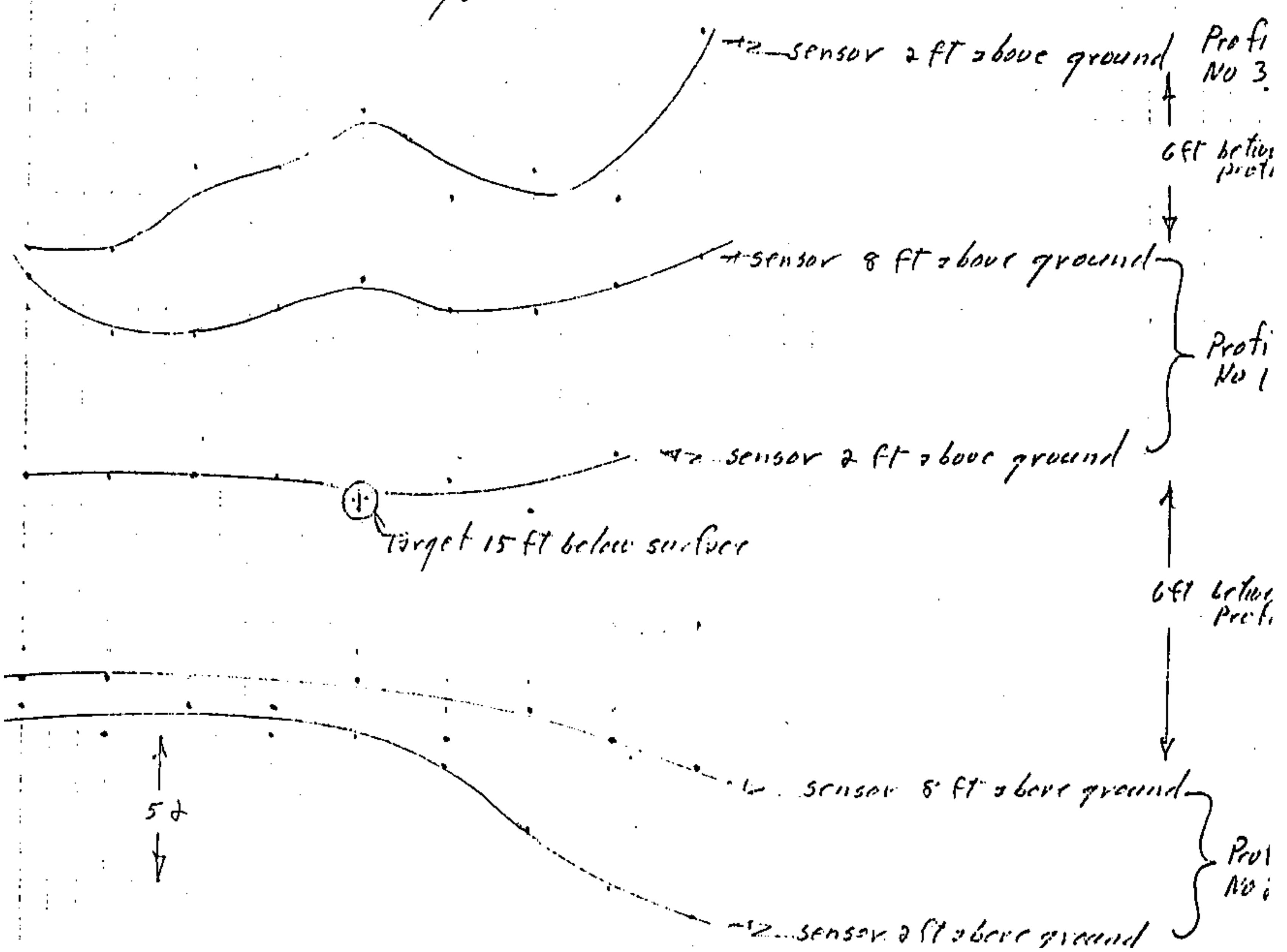
→ N

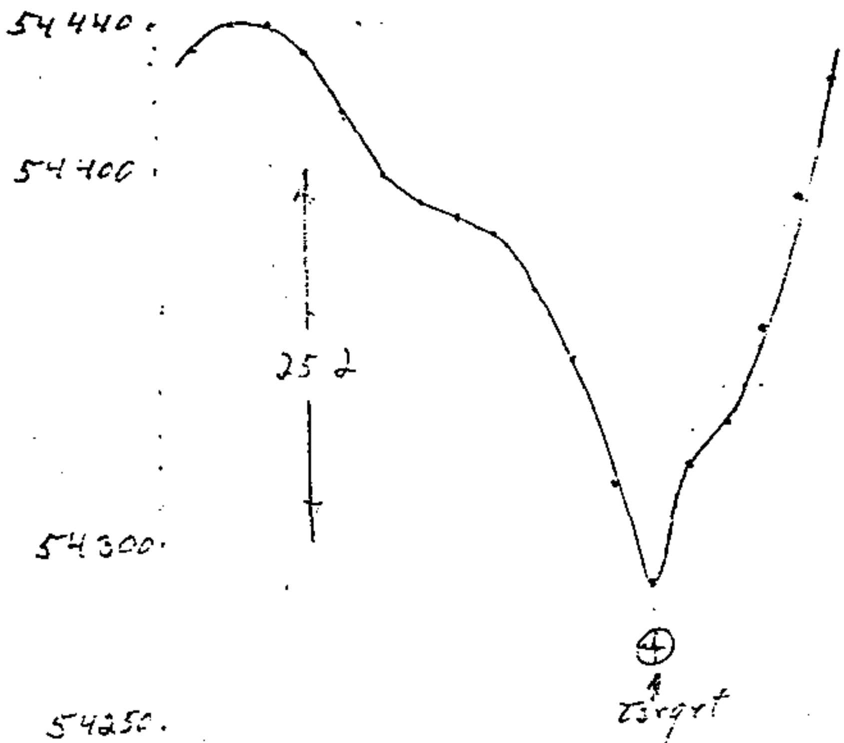




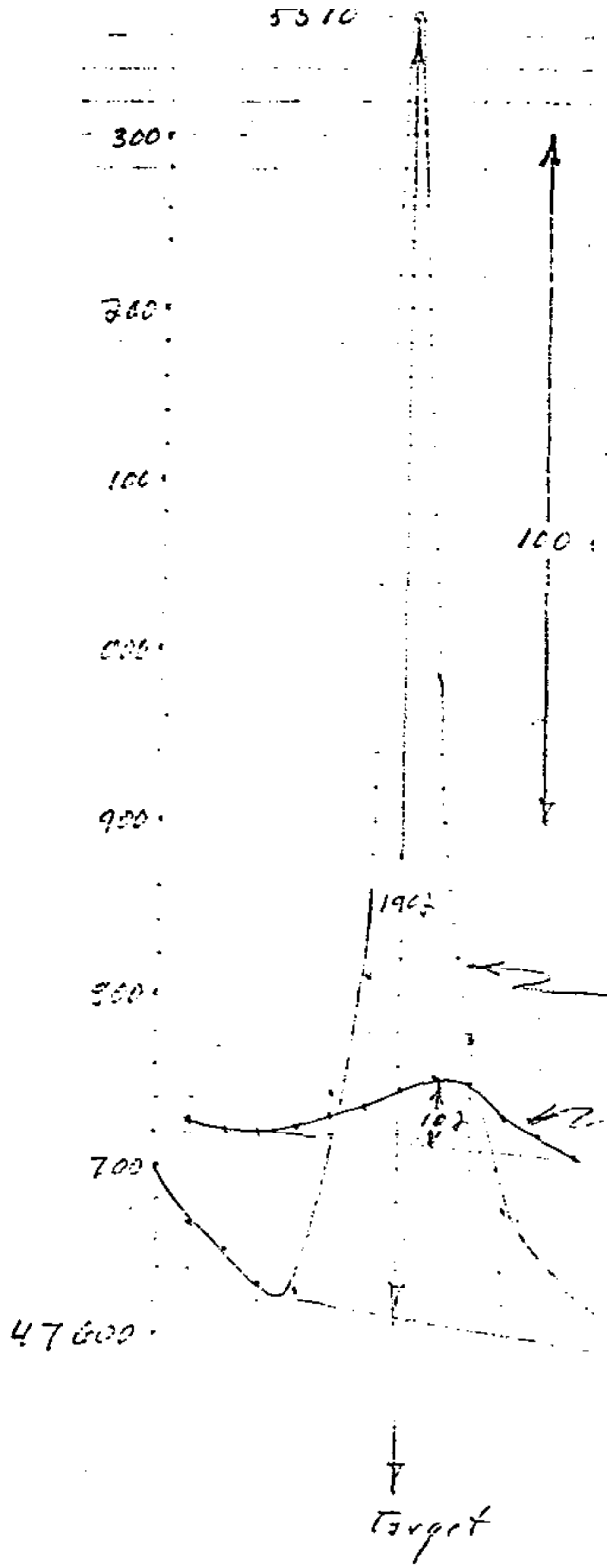
750 lb bomb - vertical
9 ft depth below ground surface
1 gamma sensitivity
3 ft between readings
300
80
56 250
300
80
56250
300
80
107 γ
28 γ
target 9 ft below surface
sensor 8 ft above ground
sensor 2 ft above ground
Profile No 3
6 ft between profiles
sensor 8 ft above ground
sensor 2 ft above ground
Profile No 2
6 ft between profiles
sensor 8 ft above ground

750 lb bomb - Vertical
15 ft depth below surface
1 gamma sensitivity
3 ft between readings





250 lb bomb - vertical
18 ft depth below surface
sensor 2 ft above surface
1/4 gamma sensitivity
2 ft between readings

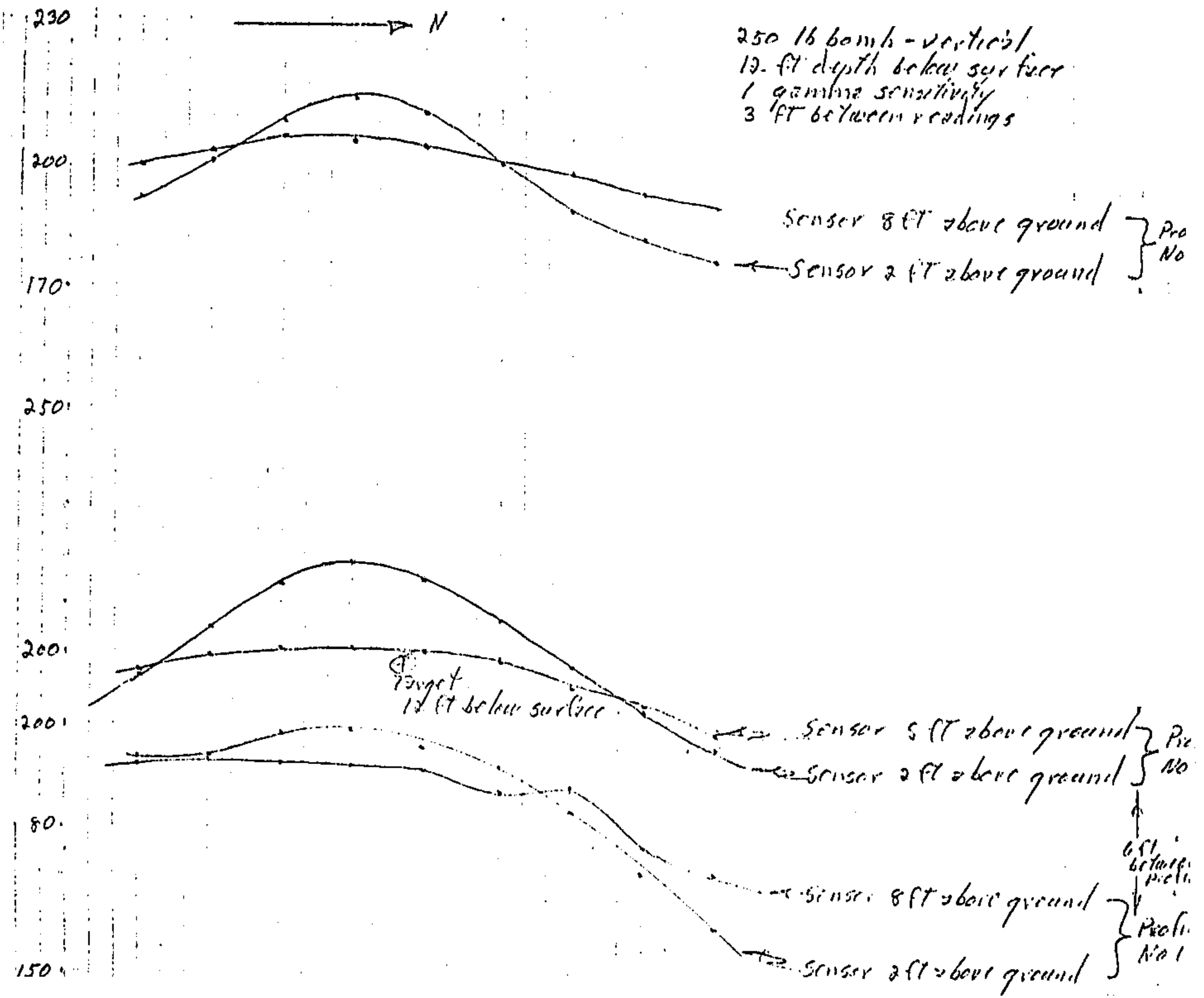


250 lb bomb Horizontal West
27" depth below ground surface
0.25 gamma sensitivity

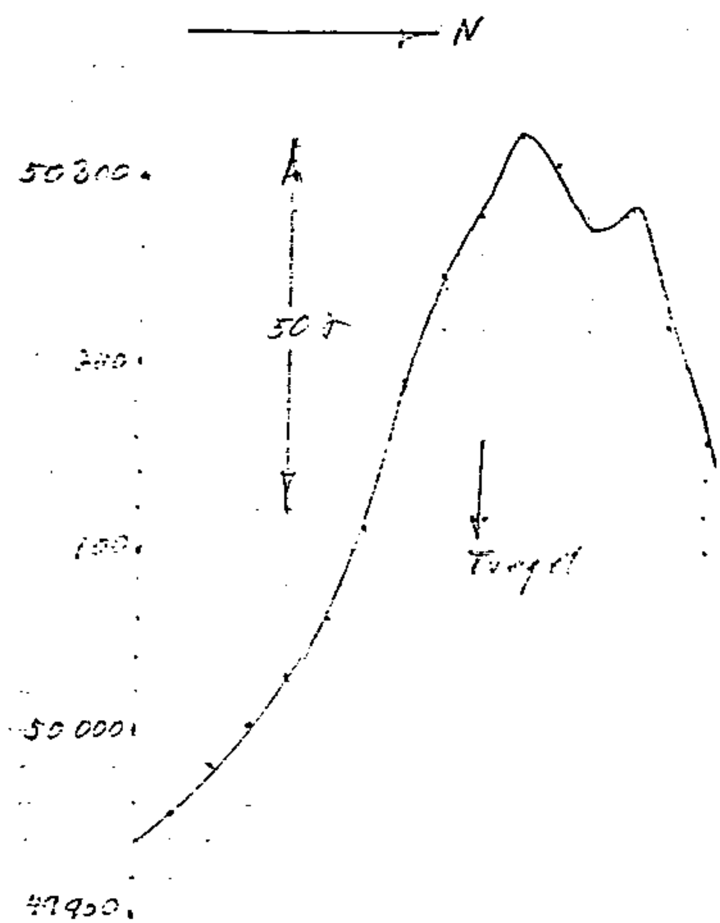
$$Z = \frac{\Delta Z}{\left(\frac{TZ}{TZ + \Delta Z}\right)^{1/3} - 1} =$$

$$Z = \frac{6}{\left(\frac{190}{10 + 6}\right)^{1/3} - 1} = 4.7 \text{ ft}$$

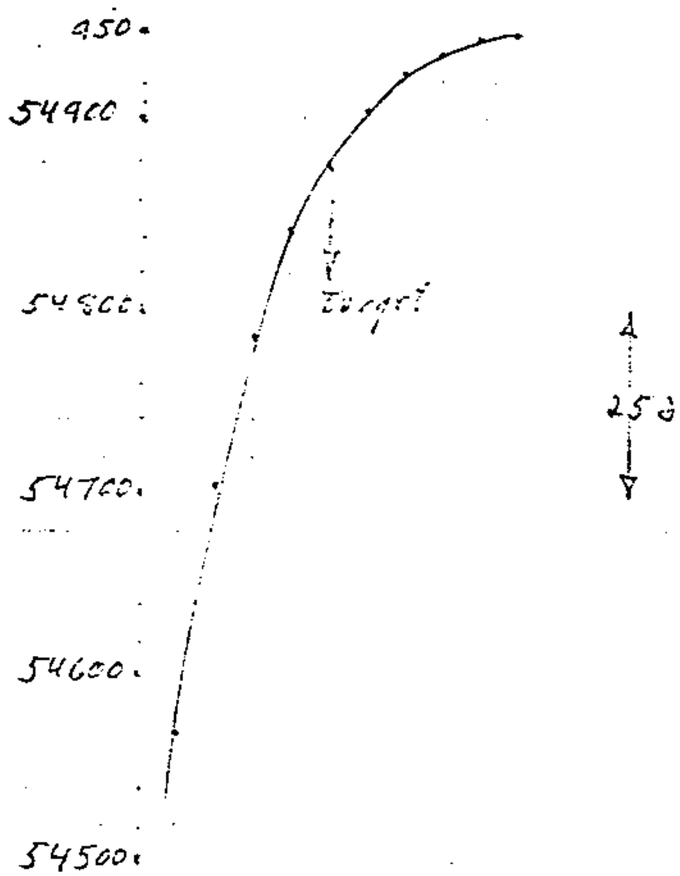
between target and sensor 2 ft above ground



230
N
250 lb bomb - vertical
12 ft depth below surface
1 gamma sensitivity
3 ft between readings
200
Sensor 8 ft above ground
Sensor 2 ft above ground
170
250
200
Target
12 ft below surface
200
Sensor 5 ft above ground
Sensor 2 ft above ground
80
6 ft between
Sensor 8 ft above ground
Sensor 2 ft above ground
150



250 lb bomb - vertical
9 ft depth below ground surf.
sensor 8 ft above ground
0.25 gamma sensitivity



250 lb bomb-vertic
12 ft depth below surfa
Sensor 2 ft above groun
0.25 gamma sensitivi
2 ft between reading