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Edwards Street Laboratory
Yale University
New Haven, Connecticut

ESL Technical Memorandum No. 28
(ESL 521: Ser 07)
12 February 1954

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Chief of Naval Research (Code 461)

Survey of the Magnetic Field at the Surface Due to an Underwater Electrode System Fed at 30 Cycles per Second

G. F. Pieper, R. P. Whorf,
A. H. Davis, and R. W. Jackson

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1. Introduction

During the spring of 1953 a system of electrical components was placed underwater in the approximate center of the West Passage of Narragansett Bay roughly due west of Prospect Hill on Conanicut Island. This system consisted of a feeder cable running from a hut at Fort Getty to the primary of a submerged impedance matching transformer, the transformer, insulated cables from the secondary of the transformer to electrode cables, and the electrode cables. The electrode cables were parallel, 200 meters apart, 300 meters in length, laid in about 10 to 15 meters depth of water. The details of the installation of the system and the accompanying shore installation at Fort Getty have been described previously.[1] Fig. 1 shows the approximate layout of the submerged equipment.

During the early summer of 1953, a series of measurements was made of the magnetic field just above the surface of the water due to exciting currents in the electrode cables and in the water between the electrode cables. The purpose of this report is to describe the techniques used in making these measurements and the results that were obtained.

2. Apparatus and Techniques

The three components of the magnetic field were measured with properly oriented search coils. Each coil consisted of 215 turns of No. 28 single cotenamel wire wound on a square frame one foot on a side. At the operating frequency of 30 c/s (used throughout the measurements) the Emf developed by the search coil in microvolts was equal to 3.75 times the magnitude of the magnetic field component in gammas. The search coils were attached to 2 x 4 inch spars that were rigidly mounted on the stern of a naval Torpedo Retriever boat. The coil used to measure the vertical component was rigidly fixed to its spar. The two coils used to measure the two horizontal components were mounted together in such a way that they could be rotated around a vertical axis by an operator in the boat. A sighting device was located at the operator's position by which he sighted on some convenient object on the distant shore. By keeping the sighting device lined up with the chosen object, the operator then maintained a fixed orientation of the search coils with respect to the underwater cables, regardless of changes in the direction of motion of the boat. The search coil apparatus is shown in the photographs, Figures 2, 3.

Signals from a search coil were presented at the input terminals of a high gain narrow bandwidth amplifier. The amplifier is described in detail in Technical Memorandum 29 (Reference 2). Briefly, the amplifier contained a logarithmic detector and an output circuit designed to feed a 0-1 milliampere D-C Esterline Angus recording milliammeter. At full sensitivity, 5 microvolts r.m.s. at 30 c/s was sufficient to cause full scale deflection of the pen on the recording milliammeter. The full bandwidth at 1/2 voltage points was about 25 c/s, with a deep notch at 60 c/s to reduce interference from power line frequencies. The logarithmic detector operated over a range of about 1 to 500; 3 cycle semilog paper was used with the recorder.

Customarily, two amplifiers, an appropriate power supply, storage batteries, and two recording milliammeters were carried on board the Retriever. Their arrangement is shown in Fig. 4.

The accurate field plots were made with the help of surveyors at Fort Getty and Prospect Hill to establish the position of the boat. During a run the boat was piloted back and forth through the area over the electrode system. At 30 second intervals a mark number was transmitted by VHF radio to the surveyors and to the boat. At the instant "mark", each surveyor on shore recorded the angular position of the boat, and an operator on the boat pressed a button to insert in the margin of each Esterline Angus chart record, by means of a second pen, a marker pip or group of pips. The course of the boat was assumed to have been straight during the 30 second intervals. The slowest speed at which the boat could maintain a reasonably straight course in spite of tidal currents and wind was about 4 knots, or about 400 feet per minute. The recording charts were run at 12 inches per minute.

The data thus obtained are presented in the form of contour plots showing lines of equal pen deflection as a function of position. The numbers given beside each line are on the basis of full scale pen deflection equals 1000 deflection units. A calibration giving the equivalent of each deflection unit in gamma (1 gamma = 10^{-5} gauss) is given on each plot. Frequent calibrations showed that the response of the apparatus was not always truly logarithmic. The deviations were not corrected for in the plots but the calibrations are available so that the corrections could be made at any time if desired. The absolute error introduced by this lack of correction is roughly 20% at worst; the relative error is smaller, probably less than 10%.

3. Results

The first series of runs was done without surveyors simply to check out the system. A difficulty was apparent immediately in that no signal was obtained from the crossing of the East electrode cable, while one was apparent from crossing of the West electrode cable. Further localizing measurements indicated that the trouble might be caused by a break in the insulated cable between the transformer secondary and the East electrode cable about 60 yards from the transformer. A diver went down at this place and found that this was indeed the trouble. The cable ends were grappled for, brought up, and spliced and no further difficulty of this sort was encountered. It might be pointed out that the break must have occurred during the laying of the cable, since the report of the sub-contractor who installed the cable[1] states that the load power factor was measured to be 0.61. This same power factor was measured in the runs referred to above before the break had been repaired, whereas a power factor of essentially unity was obtained after the splice of the broken cable.

The parallel straight lines on the plots show where the electrodes were thought to be, from the original plans and from transit observations during the laying. The point marked in the upper part of each plot marks the location of the matching transformer. The plots indicate clearly some deviation of the electrode cables from the assumed positions. Otherwise the plots show the magnetic field distribution quite reasonably symmetrical, and qualitatively of the shape one might expect from rather elementary D-C considerations.

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References

1. Roberts and Linden. "Report of Project Arlington" May 26, 1953.

2. Pieper, G. F. and Jackson, R. W. "Apparatus for Survey of a Magnetic Field Pattern at the Ocean Surface Established by Equipment Operating at 30 Cycles per Second on the Ocean Bottom." Technical Memorandum, No. 29, dated 12 February 1954, Edwards Street Laboratory, Yale University.

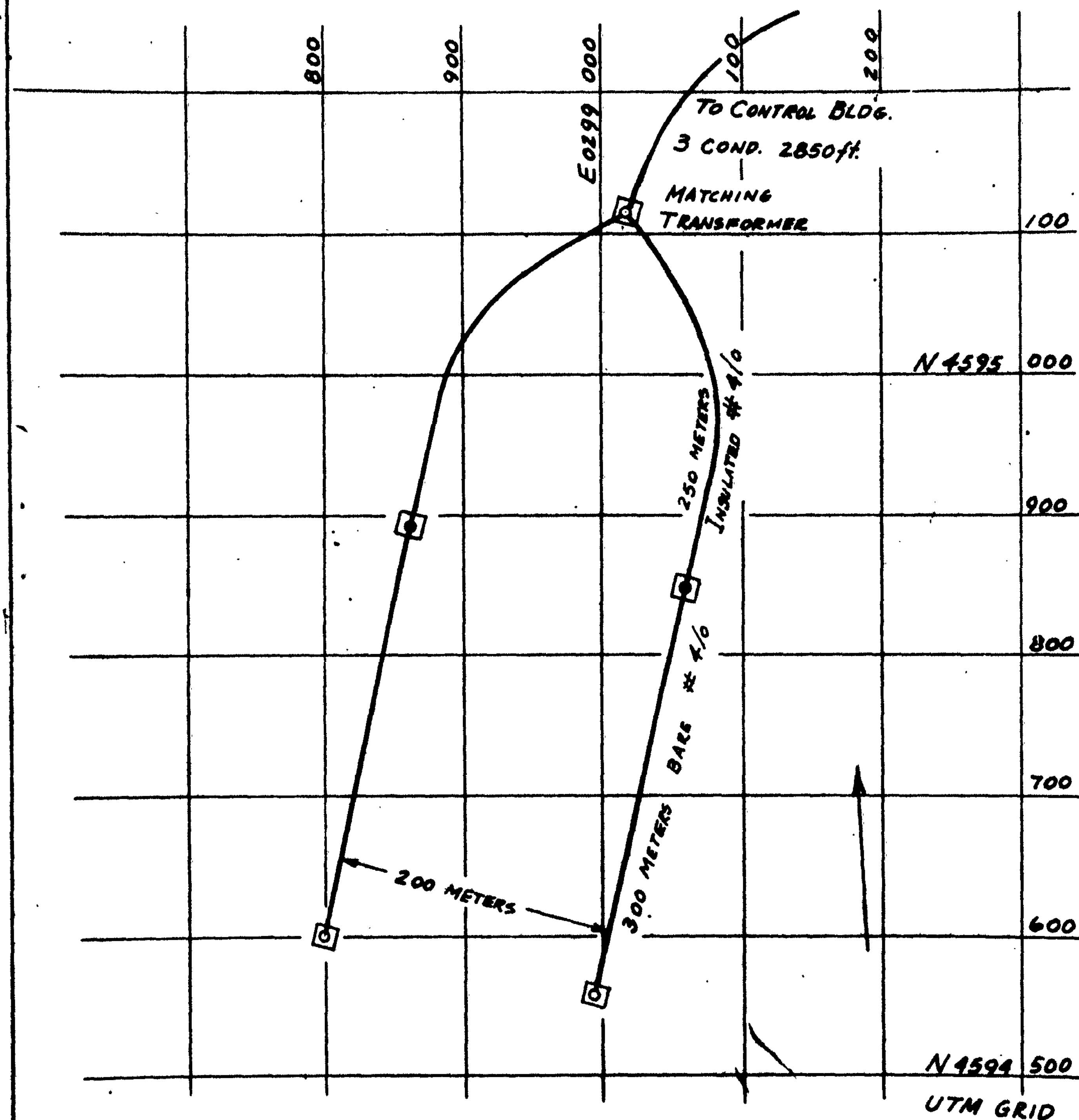
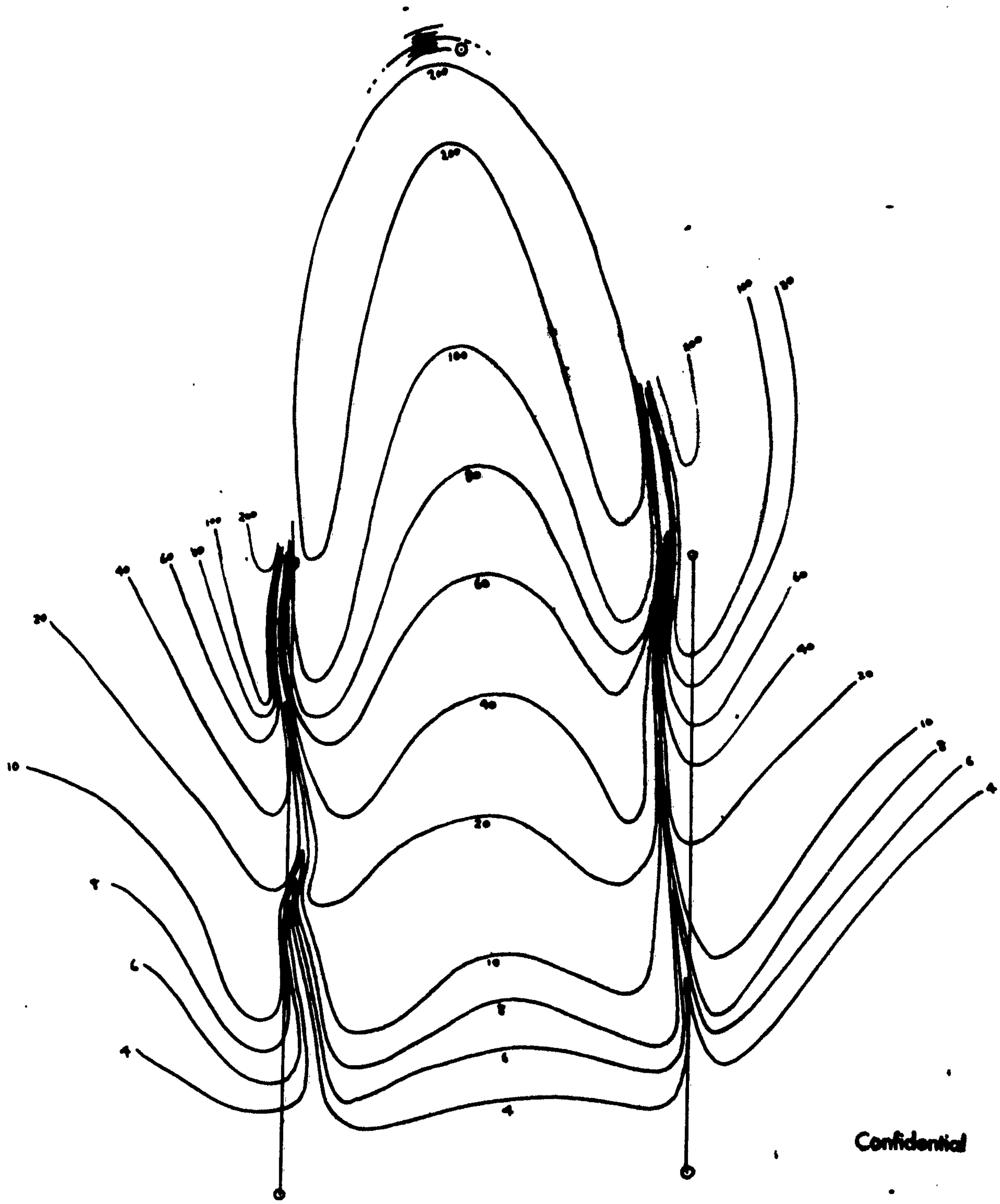


Fig. 1. Layout of Submerged Electrode System

FIG. 2. FIELD SURVEY APPARATUS MOUNTED IN RETRIEVER, SHOWING COILS FOR HORIZONTAL COMPONENTS IN POSITION FOR MEASUREMENT, COIL FOR VERTICAL COMPONENT LASHED IN STOWAGE POSITION.

FIG. 3.
HORIZ. COMP'T
COIL SIGHTING
DEVICE IN USE

FIG. 4.
AMPLIFYING
& RECORDING
EQUIPMENT



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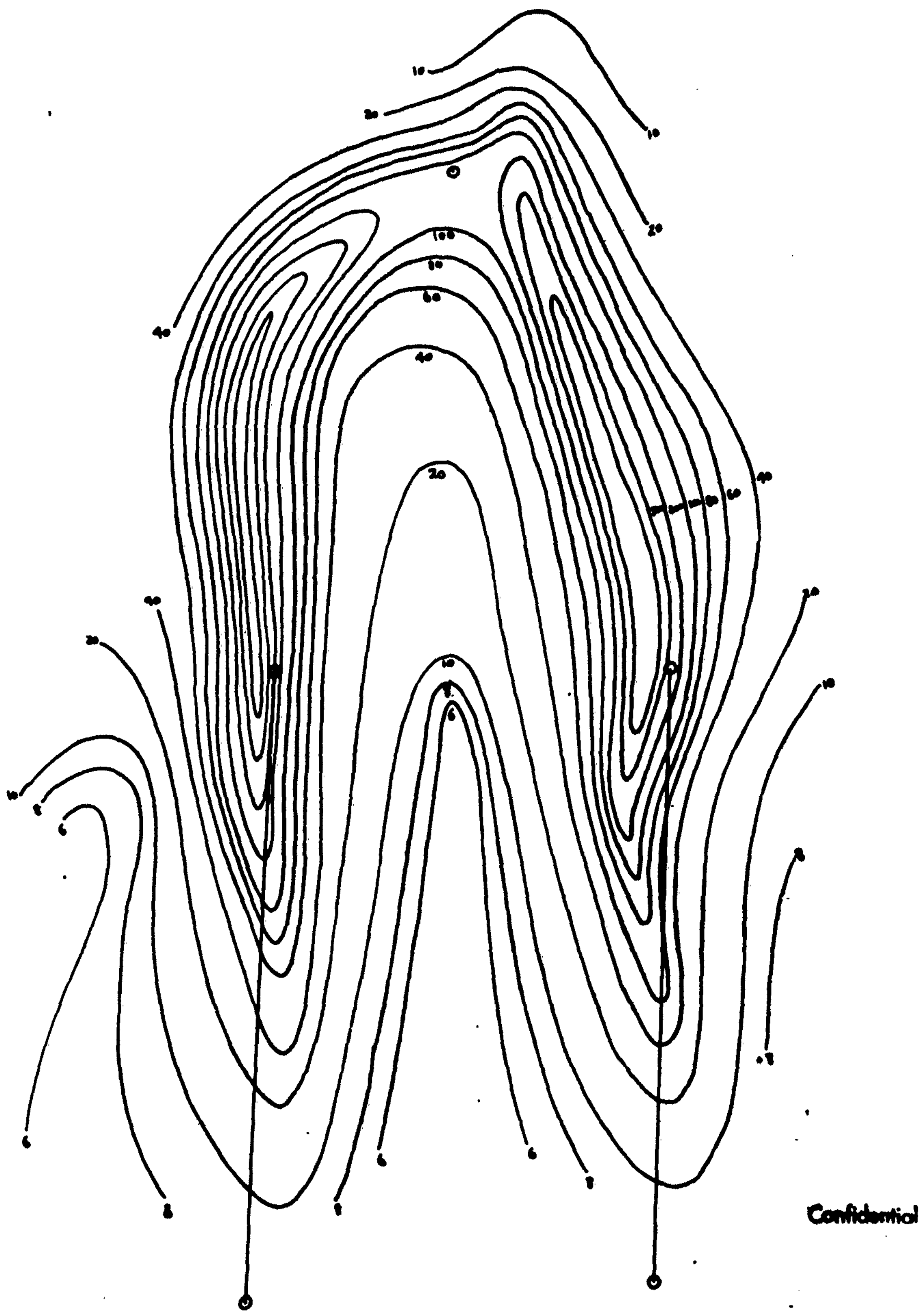
VERTICAL FIELD

OPERATION 118
29 JUNE 1953

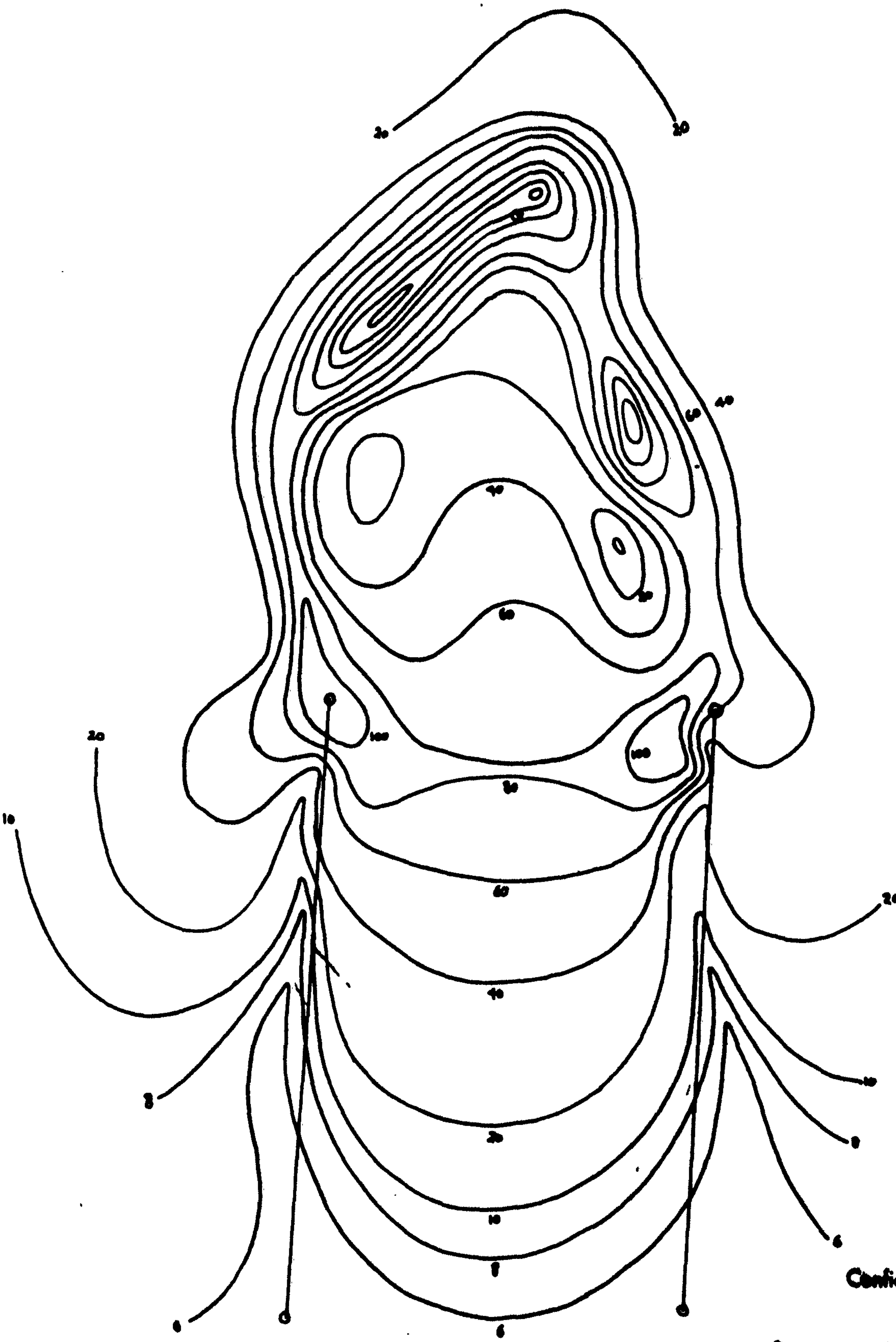
FIG. 5. 1 UNIT = 0·16 γ



HORIZONTAL FIELD
E-W COMPONENT

OPERATION 118
6 JULY 1953
R.P.W.

FIG. 6. 1 UNIT = 0·11 γ



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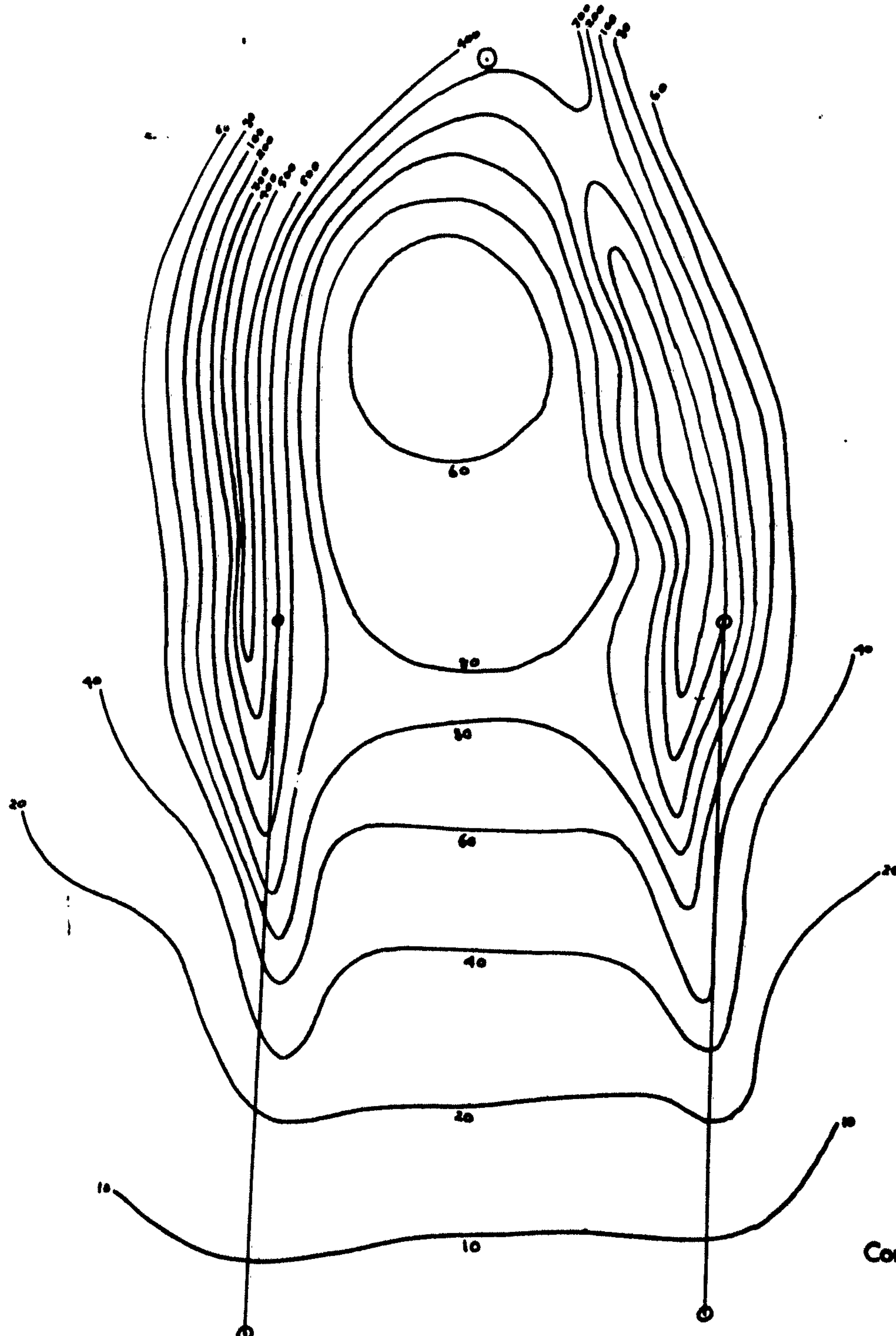
HORIZONTAL FIELD
N-S COMPONENT

OPERATION 118
6 JULY 1953
R.F. Whorf

FIG. 7. 1 UNIT = 0·11 γ



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Total Horizontal Field

Operation 118
6 July 1953
R. P. Whorf

Fig. 8. 1 UNIT=0·11γ