COMMONWEALTH OF AUSTRALIA

MINISTRY OF NATIONAL DEVELOPMENT

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AEROMAGNETIC SURVEYS

by

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INTRODUCTION

In the various methods of geophysical prospecting, sensitive instruments are used on or near the surface of the earth to measure effects which arise from differences between the physical properties of rocks, ores and minerals. The analysis and interpretation of these measurements permit conclusions to be drawn concerning the sub-surface geology and the presence or absence of orebodies, coal seams, and the like, or of structures likely to be favourable to the occurrence of oil, etc.

The principal physical properties of rocks which are useful in geophysical prospecting are density, elasticity, electrical conductivity, radio-activity and magnetic susceptibility. For example, the presence beneath the surface of rocks which are relatively heavier than the surrounding country rock affects the earth's gravitational field and is revealed by a gravity survey. Rock masses having elastic properties different from their surroundings transmit seismic waves with different speeds and their presence is revealed by a seismic survey.

MAGNETIC METHOD OF PROSPECTING

Similarly, the magnetic susceptibility of rocks, that is, the degree to which they become magnetised in a magnetic field, may be used to delineate some types of geological bodies and structures even though they lie hidden beneath the surface.

The earth has associated with it a magnetic field such as would be caused by a powerful magnet at its centre. At any point above, on or below the surface of the earth, the strength and direction of this magnetic field can be measured. If the crust of the earth were composed of rocks of uniform magnetic properties, measurements made on the surface of the earth of the strength and direction of the magnetic field would follow a regular and predictable pattern.

Due, however, to the non-uniform magnetic susceptibility of the rocks comprising the crust of the earth, there are small variations in the regular field pattern. These small variations in the magnetic field may be detected by sensitive magnetometers and are of interest to the geophysicist conducting magnetic surveys.

The magnetic susceptibility of rocks varies from being negligible for some types of sedimentary rocks to being relatively large for some types of igneous and metamorphic rocks. The presence of rocks of high magnetic susceptibility within a rock mass of lower susceptibility causes a distortion of the direction and strength of the magnetic field of the earth. This may be expressed as a concentration of the lines of force of the magnetic field of the earth through the material of higher susceptibility. These conditions would exist, for instance, in the vicinity of a basaltic intrusive into sedimentary rocks. Results from a systematic magnetic survey carried out in the area would reveal the presence of the basalt intrusion although it may not be evident at the surface. In practice, the problems under investigation are much more complex than in this simple example.

RESULTS OF GROUND MAGNETIC SURVEYS

Magnetic surveys have been used extensively all over the world during the last thirty years as a method of geophysical prospecting. Magnetic surveys were first conducted in Australia in 1929 by the Imperial Geophysical Experimental Survey and have been carried on since then more or less continuously by government organizations and mining companies.

Important new mineral deposits or extensions of existing ones have been discovered by magnetic surveys. Four examples are :-

(1) Some of the orebodies at Tennant Creek where gold is associated with haematite which has a high magnetic susceptibility.

(2) The extension of the valuable asbestos deposits at Baryulgil near Grafton, New South Wales.

(3) Extensions of deep leads containing tin in the New England district of New South Wales.

(4) Extension of features associated with the Broken Hill orebodies.

Until recently all of these surveys have been carried out using an instrument of the Schmidt type which is a vertical magnetic balance. The instrument is set on a tripod and readings are taken at measured intervals over the surface of the ground. In an area being surveyed, the spacing of reading stations is determined by the nature of the problem being investigated. If the survey is carried out over a basin or a suspected oil or coal field where the rock formation producing the magnetic anomaly, or distortion of the earth's magnetic field, is deep seated, it may be sufficient and certainly economical to make readings at half-mile intervals. However, in cases where relatively small shallow veins of mineralisation are being investigated it may be necessary to have a station separation as small as ten feet.

AERIAL MAGNETIC SURVEYS

Until 1943 all magnetic surveys had been made on the ground but the introduction of the airborne magnetometer in that year revolutionised magnetic surveying. The airborne magnetometer is the outcome of intensive scientific research which was conducted for military purposes in an attempt to produce an instrument capable of revealing the presence of a submerged submarine.

During World War I, it was realized that the presence of a large mass of steel, such as a submarine or a ship, would distort the magnetic field of the earth in its vicinity. At that time there was no instrument available which was of sufficient sensitivity and stability to reveal such an anomaly and which was also suitable for use in a ship or aircraft. The introduction of the magnetic "fluxgate" by German scientists in 1936 gave a great stimulus to the development in the United States of a saturated core magnetometer and finally to the Magnetic Airborne Detector.

The Magnetic Airborne Detector, or M.A.D. as it was termed, was first tried out as a geophysical prospecting instrument in 1943. The first tests were carried out in the U.S.A. over the iron ore deposits of New York State where intensive ground magnetic work had been done previously. The results from the airborne instrument were entirely satisfactory and were in complete agreement with those from the ground surveys. Thus, a reliable and sensitive airborne magnetometer was developed.

The basic essential of the airborne magnetometer is the measurement of a small electric current through a coil wound in the form of a cylinder on a core of material of very high susceptibility. If electric current is passed through such a coil it produces a magnetic field along its length. In the magnetometer, this current is made to produce a magnetic field equal in value and opposite in direction to the earth's magnetic field. Elaborate arrangements have been made to keep the direction of the produced magnetic field always opposite to the direction of the earth's magnetic field and to measure the required current within minute limits. The accuracy with which this current has to be measured will be appreciated when it is realized that changes in the earth's magnetic field of the order of one or two parts in 60,000 are significant.

In the short space of time since 1943 extensive aeromagnetic programmes have been undertaken by governmental and private organizations in both Canada and the U.S.A. Some spectacular results have been obtained and these have assisted in the discovery of oil fields and large deposits of minerals of economic value. One of the most notable successes was the discovery of the rich iron ore deposits at Larder Lake in Canada.

AREAS SURVEYED IN AUSTRALIA.

Since the Bureau commenced aeromagnetic surveys in Australia last year, three areas have been covered. The first was an area of 5,800 square miles in East Gippsland, Victoria, requested by the Victorian Department of Mines. The purpose of this survey was to determine the distribution of sedimentary rocks overlying basement as part of a programme for the search for oil. The results of the survey are presented as a contour map showing isogams, or lines drawn through points on the map where the strength of the earth's magnetic field is the same. A copy of this map is attached (Plate 1). Only a general interpretation of the significance of the map has been made but the pattern of the isogams conforms with what could be expected in those portions of the area where the detailed geology is known.

The map clearly emphasises the marked difference in the magnetic pattern obtained over shallow and deep bedrock. In areas where the bedrock is exposed or is at shallow depth, for example, north-west of Orbost and west of Alberton, the isogams are crowded together and have high values. In those places where the bedrock is deeply covered by sediments, the isogams are widely spaced and their pattern is generally smooth.

The area of principal interest is towards the centre of the map where the contour pattern indicates that there is a thick layer of sediments. Any ridges or hills in the bedrock under this area could give rise to the accumulation of oil in the overlying sediments. One such buried hill appears to be clearly indicated close to the north shore of Lake Wellington, about ten miles east of Stratford and Sale, where the magnetic contours have a roughly circular shape with a maximum intensity of 620. Further tests will be required to determine the size of this hill and its depth.

The second survey was carried out from Whyalla in South Australia during November, 1951, when 3,500 square miles of Eyre Peninsula were flown over. This is only a small portion of the work in this district requested by the Department of Mines of South Australia because aerial photographs needed for navigation were available for only portion of the area. The remainder of the area will be surveyed when an alternative method of navigation, namely, Shoran, is operating. The object of this survey was to locate any large deposits of iron ore which may lie hidden beneath the surface. The rich iron ore deposits of Iron-Knob and Iron-Baron occur in the Middle-Back Series in association with haematite quartzite which is highly magnetic. The theory has been put forward by competent geologists that there may be repetitions of the Middle-Back Series in the area. A magnetic contour map of the area surveyed has not yet been completed, but a preliminary examination of the results shows that the Middle-Back Series continues further in a north-south line than was previously known.

The third survey was over the Wallaroo-Moonta copper field in South Australia and was requested by the South Australian Government. About 1,900 square miles of country were flown over. Very little is known of the geology of this area because there are very few outcrops and the object of the survey was to map the sub-surface structure. This is possible because of the association of magnetic material with certain of the geological beds. The copper deposits are thought to be associated with geological structures which might be revealed by the survey. The results of this survey are now being plotted but it is too early yet to draw final conclusions.

Altogether 11,200 square miles have been covered during 330 hours flying. The spacing of the flight lines was at half-mile intervals in the Wallaroo-Moonta district and at one-mile intervals in the other areas.

ADVANTAGES OF AERIAL METHOD

The rapidity with which an area can be surveyed depends upon the spacing of flight lines, which in turn depends on the nature of the magnetic anomaly expected. Irrespective of the flight line spacing, the time required for an aerial survey is less than one per cent of that which would be required by a ground survey party. The time taken for the reduction of results from a given area is about the same in both cases.

Apart from the great saving of time required to survey a given area, the other advantages of aeromagnetic surveys as against ground surveys are :-

(1) An aeromagnetic survey can cover areas inaccessible from the ground, for example, over water, marshes, or very rough country.

(2) The airborne magnetometer draws a continuous magnetic profile along the flight line, whereas from a ground survey only spot values at reading stations are available.

(3) The cost of airborne surveys in U.S.A. is calculated to be between 5 and 15 dollars per linear mile, whereas the cost of ground surveys may exceed 100 dollars per mile.

(4) Airborne surveys are not affected by local extraneous magnetic disturbances, such as those due to water pipes, iron roofs, etc., or to a thin surface layer of magnetic laterite.

As stated above, the airborne magnetometer gives a continuous reading of the intensity of the magnetic field of the earth. This is achieved by having the current through the magnetometer recorded on an Esterline-Angus recording milliammeter.

The recorder is a pen-writing instrument which makes an inked line on recording paper which passes under the pen at the rate of three inches per minute. A record*taken while flying over the Middle-Back Series is attached, together with a copy of the profile plotted from it (Plate 2).

USE OF SHORAN

During aeromagnetic surveys, it is essential that the position of the aircraft be known to within 100 feet. A radio-altimeter is used to keep the aircraft at a set height above terrain. Also, for positioning the aircraft photographic methods have been used up till the present time. Recently, however, a radar navigation device, known as Shoran, has been obtained and installed in the aircraft. The aircraft is now equipped for aeromagnetic surveys over any part of Australia whether aerial photos are available or not.

PROGRAMME OF WORK

It is relatively easy to adapt the Bureau's aircraft VH-BUR for other types of airborne survey. Arrangements are now being made to mount an airborne scintillometer in the plane for use in the search for uranium deposits at Rum Jungle in the Northern Territory and elsewhere.

During the aeromagnetic surveys carried out so far much valuable experience has been obtained by the officers concerned with this project. Much experimental work had to be undertaken during the preliminary flights to develop a technique and the equipment had to be modified to suit local conditions and the particular requirements of the job. The experience gained by the officers will equip them for carrying out surveys with the airborne scintillometer.

Before the aeromagnetic project was embarked upon, the States were consulted as to their requirements for this type of work. Some of the items on the programme of commitments in the various States and Territories are :-

(1) Survey in the vicinity of Rum Jungle in the search for uranium deposits.

(2) Surveys in the vicinity of Radium Hill in the search for uranium, requested by the South Australian Government.

(3) Completion of surveys on Eyre Peninsula in the search for iron ore deposits, requested by the South Australian Government.

(4) Surveys over the Desert Basin of Western Australia in the search for oil.

(5) Surveys over the West Australian goldfields at the request of the West Australian Government.

(6) Surveys in the Cloncurry district of Queensland in the search for uranium and copper deposits, partly requested by the Queensland Government.

(7) Surveys in the vicinity of Tennant Creek, Northern Territory, in the search for gold.

(* included only in original copy of report.)

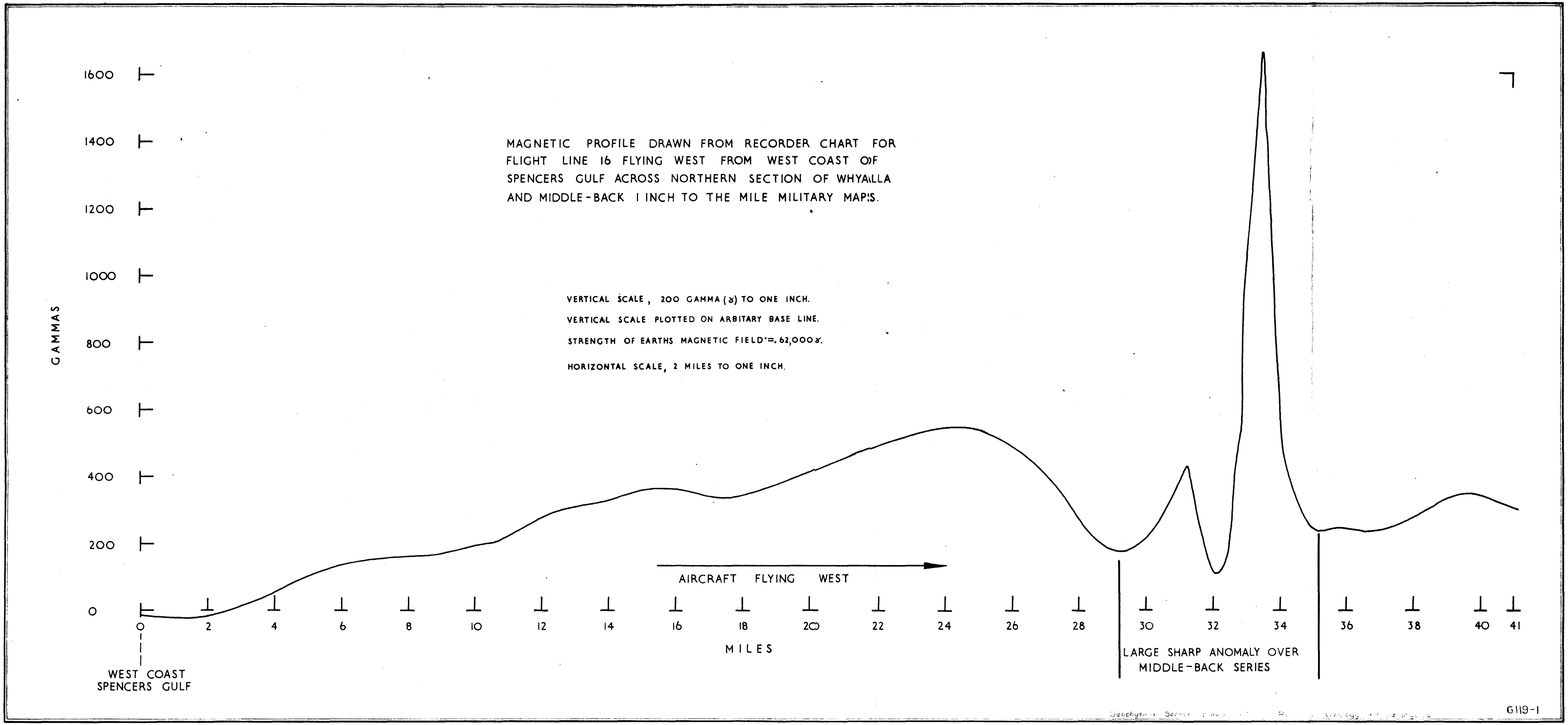
THE AEROMAGNETIC EQUIPMENT

Some details of the aircraft and equipment at present in use are shown in the attached photographs. It will be noted that most of the complex equipment is concentrated forward in the plane and the detecting unit is mounted aft, and all disturbing objects removed from its vicinity. Overseas experience has shown that a D.C.3 aircraft is most suitable for this type of work since it combines safety in low flying with the ability to lift the substantial weight of equipment involved in the operation.

E. McCarthy

(E. McCarthy)
Geophysicist.

Melbourne.
28th May, 1952.


MAGNETIC PROFILE DRAWN FROM RECORDER CHART FOR FLIGHT LINE 16 FLYING WEST FROM WEST COAST OF SPENCERS GULF ACROSS NORTHERN SECTION OF WHYALLA AND MIDDLE-BACK 1 INCH TO THE MILE MILITARY MAPS.
VERTICAL SCALE, 200 GAMMA (γ) TO ONE INCH.
VERTICAL SCALE PLOTTED ON ARBITARY BASE LINE.
STRENGTH OF EARTHS MAGNETIC FIELD = 62,000γ.
HORIZONTAL SCALE, 2 MILES TO ONE INCH.
GAMMAS
1600
1400
1200
1000
800
600
400
200
0
AIRCRAFT FLYING WEST
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
41
MILES
WEST COAST SPENCERS GULF
LARGE SHARP ANOMALY OVER MIDDLE-BACK SERIES
G119-1

AUSTRALIA 1:253,440.

VICTORIA

EAST GIPPSLAND.

PART OF J55/6,7,10,11 ZONE 7.

EAST GIPPSLAND

Plate 3. D.C.3 aircraft used in aeromagnetic surveys.

Plate 4 View through main doorway of aircraft showing magnetometer detector head on its mounting.

Plate 5 Inside the aircraft looking aft towards the magnetometer detector head.

Plate 6 G. B. Clarke and J. K. Newman, geophysicists, adjusting the magnetometer detector head.

Plate 7 J. K. Newman, geophysicist, operating the magnetometer recording equipment during flight.

Plate 8 Members of the aeromagnetic survey party; Flight Engineer R. Evans, Captain L. Cameron (pilot), Geophysicists K. Kennedy, J. Barlow, J. K. Newman, G. B. Clarke and T. Riddell.

Plate 9   E. McCarthy, geophysicist, adjusting Shoran aerials on underside of aircraft.

Plate 10 Erecting aerial for Shoran beacon. Equipment is mounted in wireless signal van.

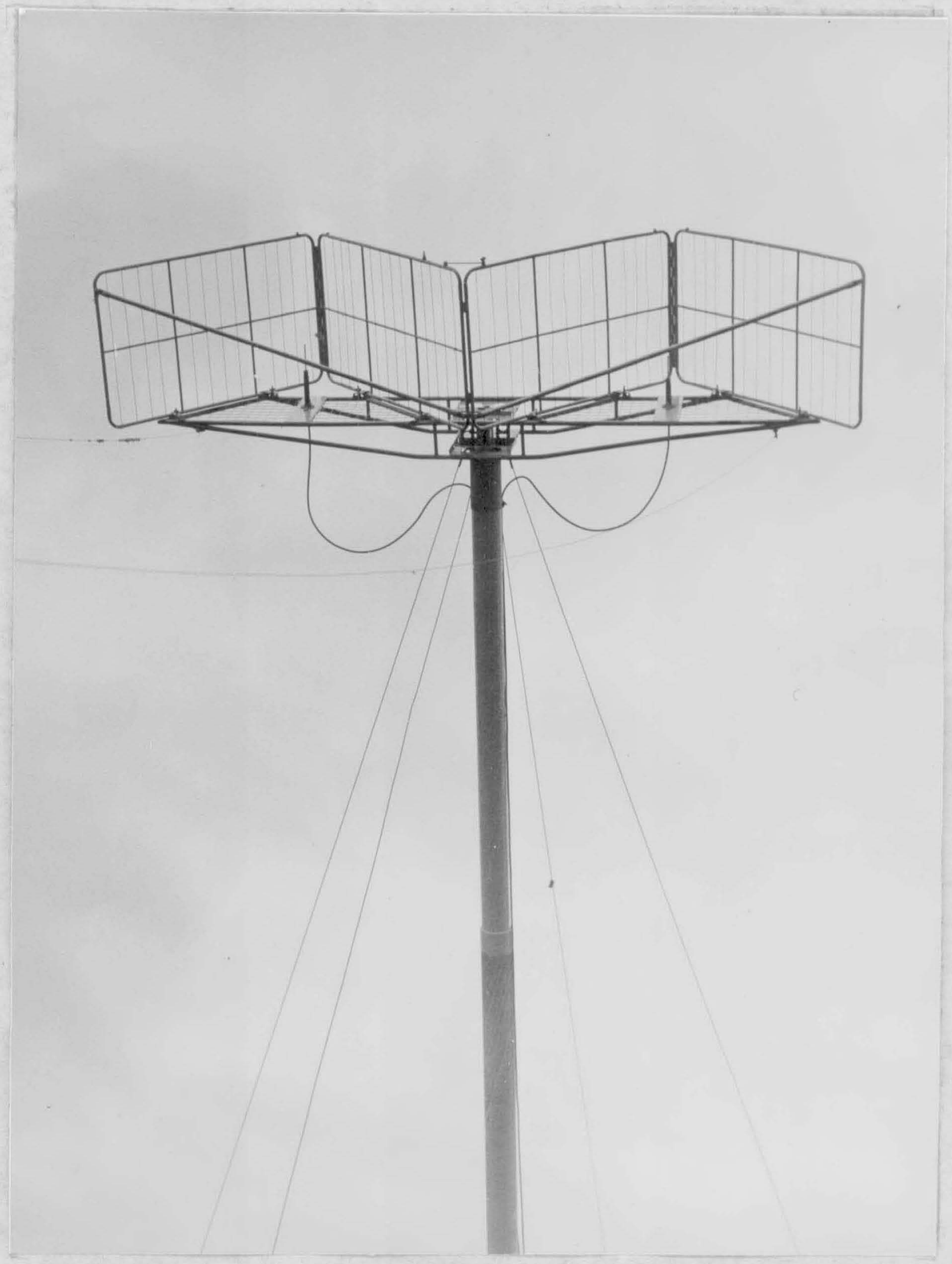


Plate 11 Close-up view of transmitting and receiving aerials used with Shoran beacon.

<u>Plate 12</u> Interior view of wireless signal van showing Shoran beacon equipment being operated by J. K. Newman.