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Helicopter Gravity Survey Techniques in Tropical Swamps and Jungles

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Paper Presented at Fourth ECAFE Symposium on the Development of Petroleum Resources of Asia and the Far East, Canberra, October - November 1969

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SUMMARY

Conventional helicopter gravity techniques as carried out in Australia cannot be used in areas covered by swamps or dense jungles. This report describes a method whereby a remote levelling and reading gravity meter is used from a hovering helicopter to circumvent these difficulties of terrain and vegetation. The operating helicopter configuration as used on a trial survey in 1968 in the Territory of Papua and New Guinea was not a total success due mainly to the poor performance of the helicopter under high temperature and altitude conditions. Another trial survey is planned for the latter part of 1969 using a more powerful helicopter and also incorporating closed circuit television equipment (for better helicopter control whilst in a hover) and radio doppler equipment (for accurate dead reckoning in areas having no aerial photographic coverage).

INTRODUCTION

The Bureau of Mineral Resources, Geology and Geophysics (BMR) is currently conducting a reconnaissance gravity survey aimed at completing the coverage of mainland Australia (Darby and Vale, 1969) with a station density of at least 1 per 50 square miles (128 square kilometers). As a natural extension to this project it is planned to conduct a helicopter gravity survey over the Territory of Papua and New Guinea (T.P.N.G.). Due to complex geological structure it is thought desirable to increase the station density to at least 1 per 16 square miles (40 square kilometers). The T.P.N.G. presents special terrain problems of swamp, tropical forest and mountains which hinder helicopter surveys and make it difficult to maintain the proposed station density. A viable technique whereby gravity readings could be obtained in a wide variety of terrain conditions was thought to be that of lowering a self-levelling gravity meter adaptable to solid or spongy ground and water covered areas from a hovering helicopter. This technique has been used in Canada by Canadian Air Borne Control Surveys Ltd (R.B.Galeski, pers. comm.) in snow covered areas. Consequently during the latter part of 1968 the BMR conducted an experimental survey using this technique with the aim of developing it to the point where a major survey to cover the entire territory could be planned.

TERRAIN

The survey area is shown in Plate 1 which outlines the physiographic and vegetation types.

There are three major physiographic units:

1. Sepik - Ramu Plains
2. Central Highlands
3. Coastal Ranges

1. Sepik-Ramu Plains

These include swamplands and low hills that rise irregularly from them. They are drained by many highly convolute channels, the larger ones running between levees slightly above the general swamp level. The mean elevation of the swamp is only about 50 feet (15 meters), for instance at Pagui, 200 river miles (322 kilometers) from the sea, the elevation of the Sepik River is only 40 feet (12 meters). Low hills, the remnants of drowned topography, together with the river levees form the only dry ground in the swamp region and so are the normal site for villages. At some places - south of Angoram, for instance - large villages have been erected on stilts in the swamp. Vegetation within the swamp consists largely of sago forest, normally marshy underfoot, and forming a dense cover broken only by streams. In the more inundated areas tall grasses predominate. The drier areas above the general swamp level are clothed in dense rain-forest, although hills lying between the Sepik and Ramu mouths have a cover of kunai grass. Rainfall in the district is relatively low - 98 inches (250 centimeters) per annum at Ambunti and 82 inches (208 centimeters) per annum at Angoram, with a dry season between June and August.

Access within this area is by boat or helicopter only. There are no roads or air-strips, leaving rivers and minor waterways as the only practicable routes. On the Sepik and the larger tributaries boats can be used, whilst coastal vessels of about 200 tons can reach Ambunti. Native traffic, including out-board powered double-canoes, is restricted to the slow-moving waters of the Sepik and the lakes. An out-board powered barge operating up to Aiome is the only commercial craft on the Ramu River.

2. The Central Highlands

These include a number of mountain ranges - the Bismarck, Schrader, and Central Ranges - within the survey area, and high-altitude inter-montane valleys, notably the Lai (near Wabag), and the Wahgi (Mt. Hagen). Relief is extreme, with a maximum elevation of 15,400 feet (4,694 meters) at Mt. Wilhelm, although the highest elevation attained on this survey was a point on Mt. Hagen at 12,500 feet (3,820 meters). Rivers typically are fast flowing, and so run in deeply incised gorges; the Jimi River is an extreme example, and has a gorge up to 2,500 feet (762 meters) deep. The high stream-velocities restrict the formation of sand and gravel banks, eliminating many possible helicopter landing grounds.

Vegetation varies both with locale and altitude. Most of the mountain ranges are covered in dense rain-forest, only rarely broken by villages and gardens. At high altitudes - above about 10,000 feet (3,050 meters) - the forest gives way to a tundra-like vegetation of mosses and short grass. In the Jimi and Lai Valleys there are extensive plains of kunai grass.

In the flatter Wahgi and upper Lai valleys, the area has been cultivated extensively. Both gardens (growing taro etc.) and larger plantations of tea, and coffee are present. Cattle raising has also commenced in the Baiyer River Valley near Mount Hagen.

The climate, although pleasantly cool to work in, is frustrating from the surveying aspect. Rainfall is between 130 inches (330 centimeters) per annum at Kompain and about 300 inches (762 centimeters) per annum in the appropriately named Rain Mountains. Cloud usually fills the valleys until about 10 am, and rarely leaves the mountain peaks. Frequently one valley can be free of cloud, but all the surrounding country obscured.

Access is excellent. A good road network exists along the axis of the Highlands, and is sufficiently complex to allow a reasonable distribution of fuel for helicopter use. Air-strips of varying standards serve the rest of the populated area, and all have regular services provided by the major airlines or the mission services.

3. <u>The coastal range</u>

This is an envelope term designed to cover the area north of the Sepik, including the Torricelli - Prince Alexander Mountains, and the area east of the Ramu, including the Adelbert Mountains.

The mountain ranges are fairly low - less than 400 feet (122 meters) elevation, but can be exceedingly rugged, consisting in many places of apparently random-oriented razor-backed ridges so narrow that a helicopter can only balance with power on at the apex.

To the south of the Torricellis, extensive kunai plains stretch to the Sepik River, and provide survey conditions similar to those found in Australia. A narrow coastal fringe consists largely of up-lifted coral reefs, although alluvium-flats occur near the mouths of the larger rivers e.g. the Gogol River to the south of Madang.

Although the dominant vegetation-type is again rain-forest, appreciable in-roads on it have been made by the native population, both in the construction of village sites and gardens, and the establishment of extensive coconut plantations on the coast. Near Bogia, and to a lesser extent elsewhere, many small kunai patches occur; most of these are probably restricted to a soil-type too poor to support other vegetation, but others are burned occasionally by natives during hunting.

Access for positioning fuel is again excellent.

In order to achieve an approximate 4-mile (6.5 kilometer) grid of observation points the following range of sites were the best available.

1. Coastal and river beaches
2. Villages and gardens within rain forest
3. Kunai grass patches
4. Spongy swamp through openings in the sago, etc.
5. Underwater in rivers, swamps and off narrow beaches.

Of these, coastal and river beaches are suitable for conventional landing and observation with standard gravity meters. Villages and gardens are often suitable for landing but in a number of cases the risk of damage makes it undesirable to land if this can be avoided. Furthermore, in the rain forests the area available for landing is often not sufficient for descent and take off between the surrounding trees. Kunai grass can provide a safe landing but sword grass can represent a hazard to an observer making a conventional ground observation. Spongy swamp and underwater sites are of course usually impossible for conventional ground observations.

In order to be able to utilise all possible sites the experimental use of a conventional underwater gravity meter adapted for use from a hovering helicopter and modified to accept larger than usual tilts was tried. Because of the experimental nature of the hover technique the survey was planned to rely on conventional methods and the maximum number of stations were so occupied but a fair assessment of the hover technique with the equipment available was made.

Comparative per-station-costs of the two methods are not yet possible but once a party is set up with an effective hover system it is probably desirable to read all stations with it. In the case of good landing sites the helicopter would rest on the ground a short distance from the meter while the reading was taken.

INSTRUMENTATION USED IN 1968

Gravity Meter

The gravity meter used was a damped underwater La Coste-Romberg meter which had been adapted for use in a helicopter operation. The main adaptation was the modification of the levelling mechanism to enable self levelling from up to 20-degree tilt, which is a greater angle than is normal for underwater surveys. The gravity meter must be highly damped so that readings can be obtained on unstable surfaces e.g. mud.

The gravity meter was encased in an aluminium container waterproofed to withstand depths of 500 feet (152 meters). A vent was attached to the outside of the case which gave access to the water pressure capsule which is used for obtaining the water depths.

The control console in the helicopter is a standard La Coste-Romberg underwater meter panel (Fig. 1).

Helicopter

The helicopter used in the test survey was a small jet turbine type. This type of helicopter was chosen because it was believed that its relatively high payload and performance characteristics would enable the technique to be tested under most climatic and terrain conditions.

The only major item of equipment installed in the helicopter and requiring helicopter modification was the winch and sliprings (Fig. 2). The winch was driven by a ½ horse power electric motor. Contact from the cable to the console is by means of sliprings. The winch was attached underneath the helicopter and the assembly was designed for quick release when the releasable hook was activated.

Accessories

a) The winch and gravity meter could be inspected from the cabin by either the pilot or observer by means of two sets of mirrors (Fig. 3). One of the mirrors on the pilot's side could be rotated so that the meter is kept under observation as it is lowered from the aircraft.

b) In the helicopter a set of intercommunication equipment for pilot-observer communication is essential as there must be close cooperation in case of emergency.

c) Field readings were recorded by voice using a magnetic tape recorder and subsequently transferred to field sheets.

d) Barometric readings for heighting purposes were taken in the helicopter while in hover or resting on the ground. If in hover the height of the aircraft above the ground was measured by calibration marks on the cable at a moment when the cable was held taut.

RECOMMENDATIONS

The performance of some of the equipment was not as good as was expected and another short experimental survey is planned for 1969 in which certain modifications to the system are planned.

Gravity Meter

The performance of the La Coste-Romberg gravity meter was erratic with some drifts of over 2 mgals in a 2 hour period. This is not typical for these meters and tests are currently being carried out to determine the cause.

The gravity meter was kept on heat from the helicopter batteries. No relay external from the control console was available and the meter could not be kept on heat when detached from the helicopter. As 4-5 hours are required to re-heat the gravity meter considerable delays were sometimes incurred after the gravity meter was detached from the helicopter. In future provision will be made to keep the meter on heat when detached from the helicopter.

Gravity Meter Console

This performed well except for a rheostat coming loose from the frame. This may have been caused by the high vibration environment and suggests frequent maintenance checks are required. A fast speed setting for the meter beam balancing control would be desirable in areas with large gravity differences particularly in areas of rapid change of elevation.

Sliprings

The sliprings performed well except for one occasion when they produced unreliable readings after accidentally becoming immersed in water. It is desirable to have the sliprings effectively waterproofed.

Winch

The ½ horse-power motor was under powered and burnt out twice. In future a 1 horse-power motor should be used. A cable laying device is desirable to avoid jumble winding of the cable but this is not critical. The winch mechanism should not be sensitive to water immersion.

Mirror System

This was not satisfactory as neither the pilot nor observer was able to observe continuously the cable, winch, gravity meter and ground. The observer had to lean out of the helicopter and give advice to the pilot as the meter was placed on or raised from the ground. A closed circuit television system will be installed for the next tests so that the pilot can observe the lowered gravity meter and the ground where it is to be placed. A double mirror system to give the observer and pilot a simultaneous view of the winch will also be added.

Doppler Navigation System

Many areas of T.P.N.G. have gaps in the aerial photograph coverage where precise location of stations is not possible. It is hoped that on the 1969 survey a Doppler Navigation System will be installed in the helicopter to give high quality dead reckoning to stations between points of control.

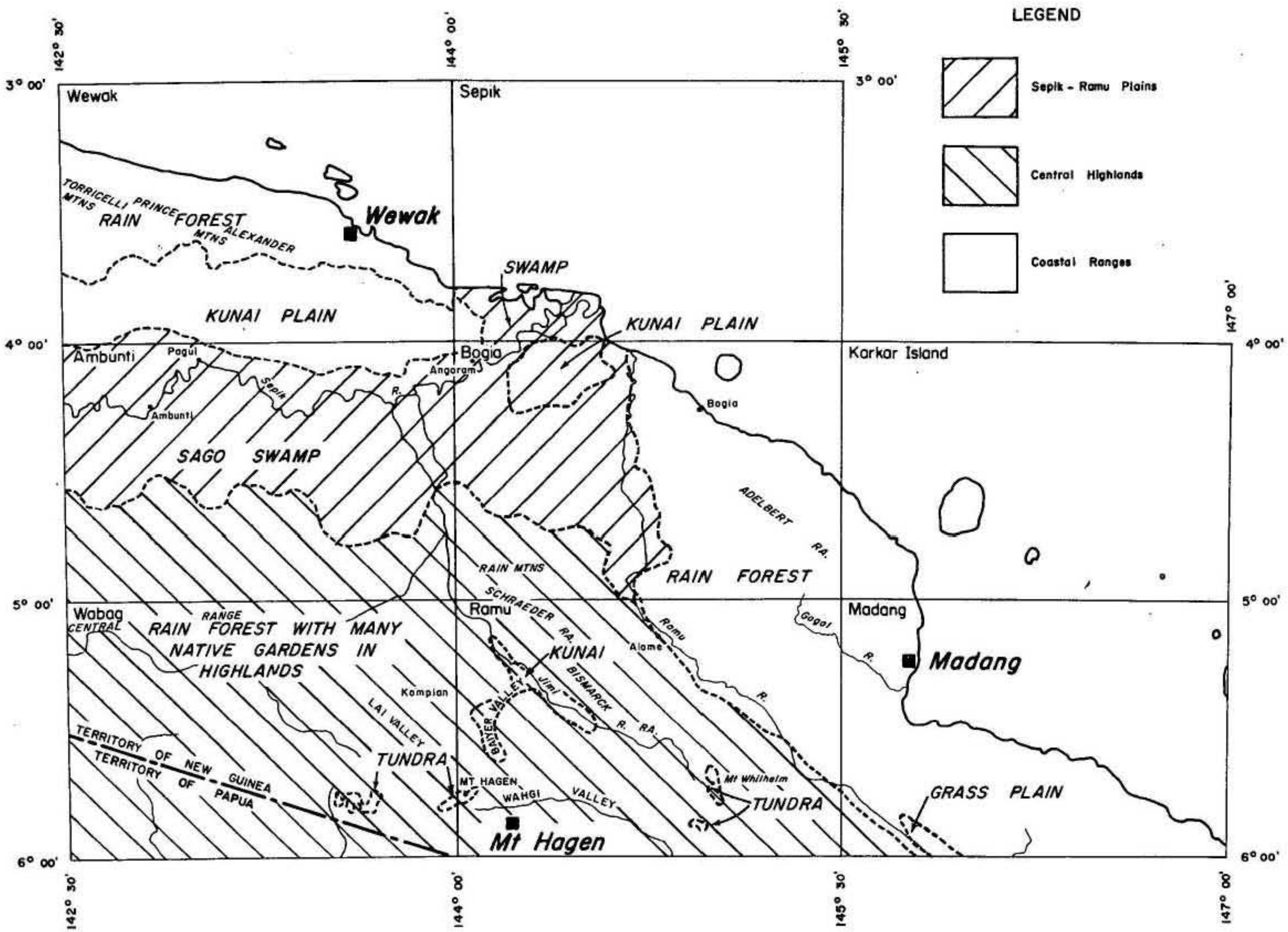
Helicopter

The helicopter was shown to be under-powered for this type of work. Payloads, particularly when attempting to hover, in high temperatures and high altitudes are not adequate. When operating under normal all-up weight which was necessary for satisfactory sortie range the helicopter often would not hover out of ground effect. Temperature conditions forced a derating of the expected available sustained engine power. It was not therefore possible to adequately test the hovering technique in jungle areas. What is needed is a helicopter with a higher power/weight ratio and greater endurance. During the 1969 survey the use of a slightly larger helicopter which it is hoped will have the additional necessary power/weight ratio and temperature and altitude performance is being considered.

With the gravity meter and winch mounted beneath the helicopter the helicopter cannot land with the gravity meter in the wound in or carrying position. The only way a landing can be made is for the gravity meter to be placed on the ground and the helicopter to back off and land behind the meter. It would be an advantage to mount the winch in the body of the aircraft and to land with the gravity meter slung beneath the helicopter but above the level of the skids.

REFERENCES

DARBY, F. & VALE, K.R., 1969. Progress of the Reconnaissance Gravity Survey of Australia. Fourth ECAFE Petroleum Symposium, Canberra, 1969.



HELICOPTER GRAVITY SURVEY TECHNIQUES IN TROPICAL SWAMPS AND JUNGLES

PLATE I

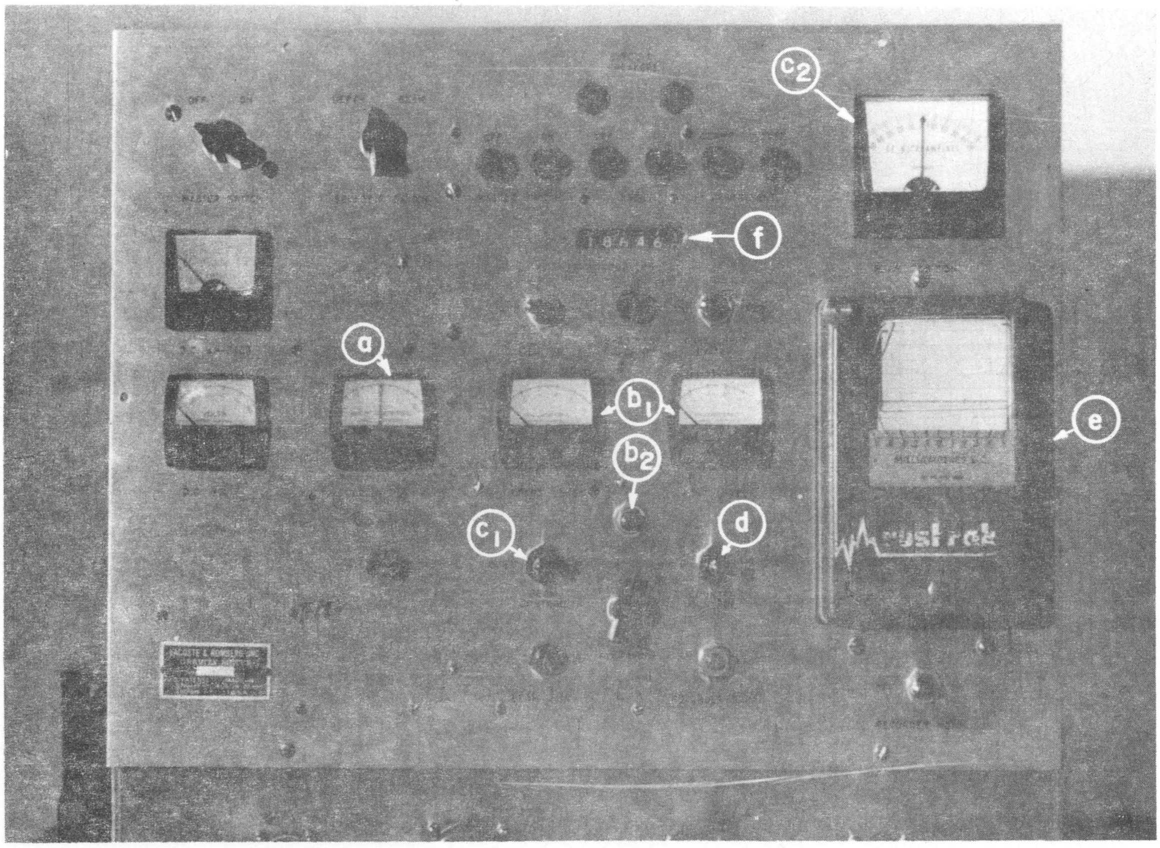


Figure 1. GRAVITY METER CONTROL CONSOLE WHICH IS MOUNTED IN FRONT OF THE OBSERVER ON LEFT HAND SIDE OF FRONT COMPARTMENT OF HELICOPTER.

a. Indicator of extreme tilt of gravity meter i.e. the meter cannot be levelled.

b_1 Indicators for the transverse and longitudinal levels which are operated by pressing the high speed level button b_2.

c_1 Electrostatic beam control for centering the beam as indicated on dial c_2.

d. Two way switch to adjust beam position, thus altering the gravity reading.

e. Chart recorder which serves as a fine control for the beam.

f. Digital readout of gravity meter reading.

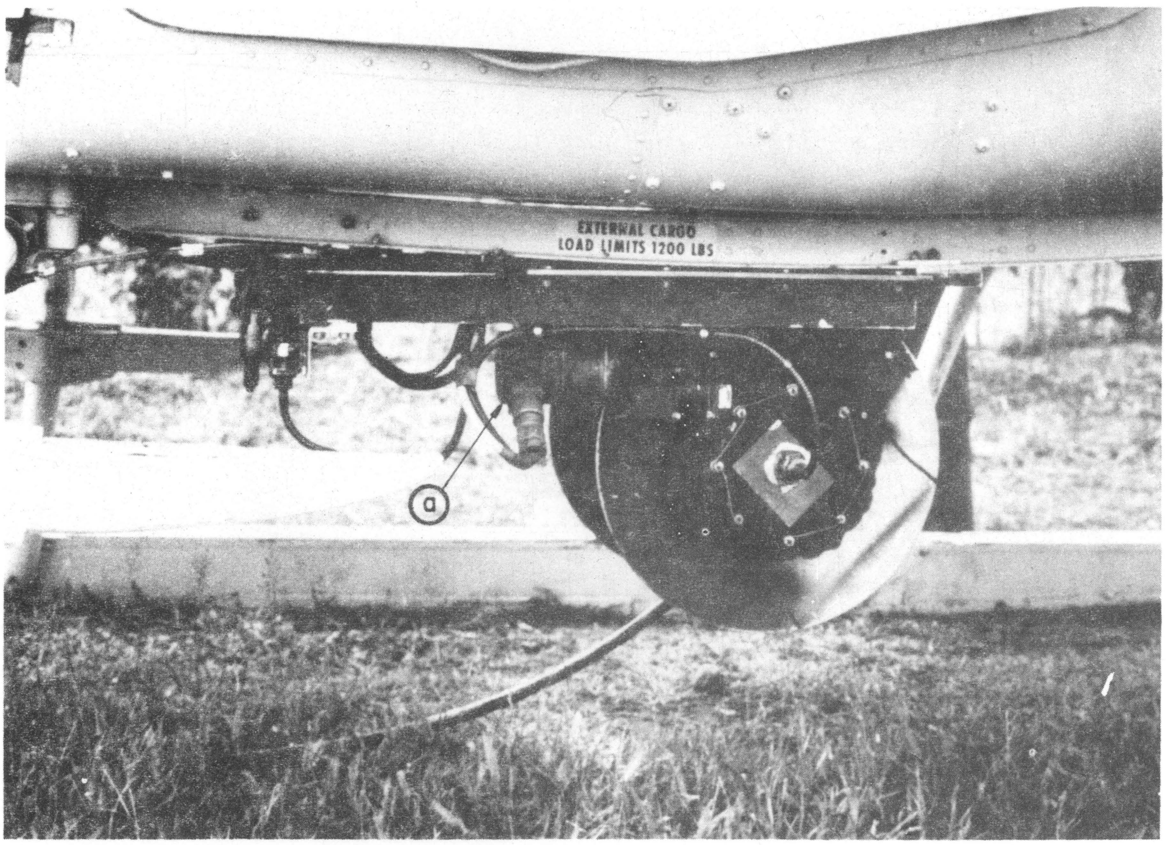


Figure 2. WINCH ASSEMBLY ON HELICOPTER

a. ½ horse power motor.

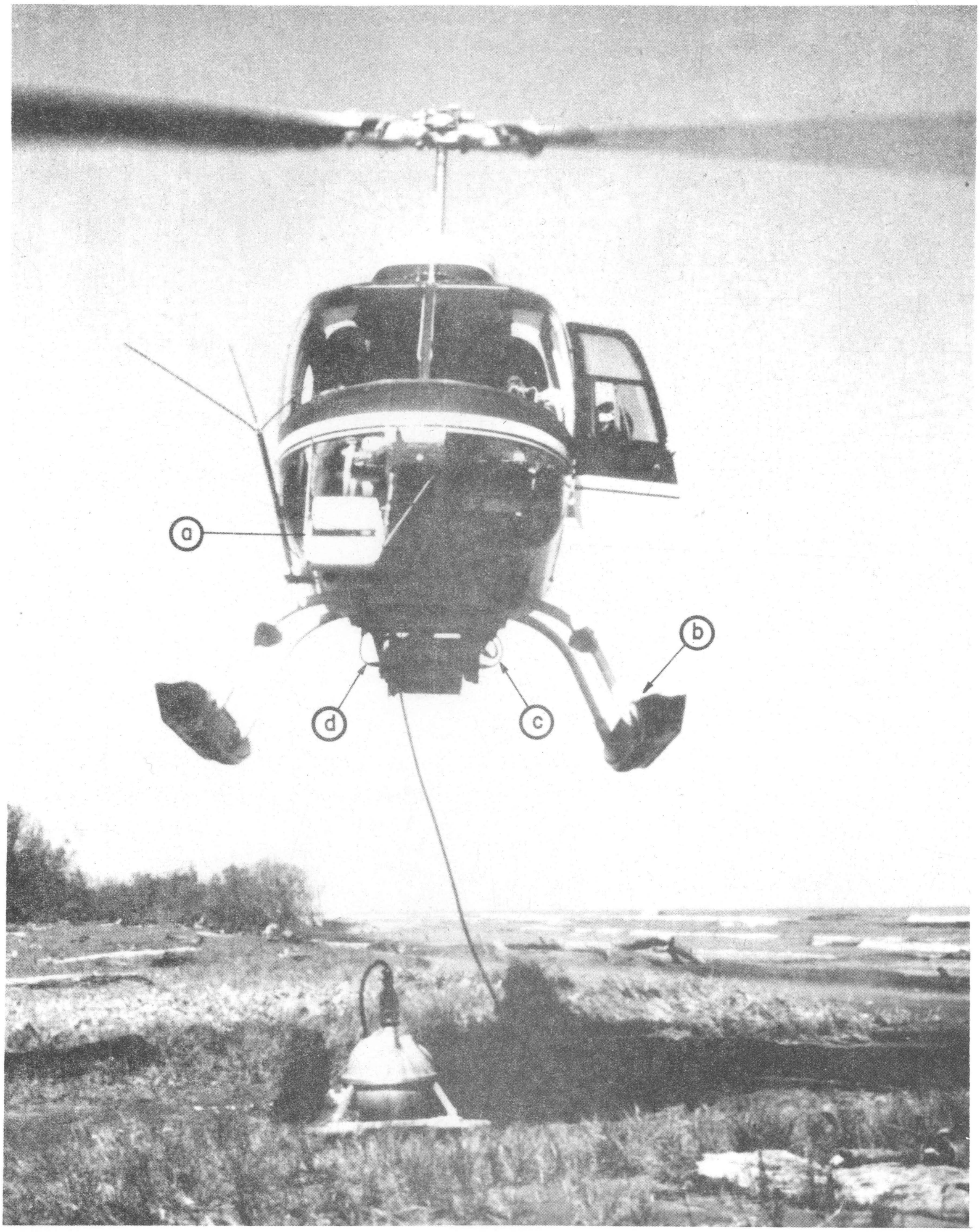


Figure 3. HOVERING TECHNIQUE IN OPERATION

a. A set of mirrors on the pilot side of the helicopter. One mirror is fixed and enables the pilot to watch the winch. The second mirror is rotated, by an electric motor activated by the pilot, and is used for following the meter down as it leaves the winch. However it is only useful for distances up to 20 feet below the aircraft.

b. A third mirror which enables the observer to monitor the status of the winch.

c. Flexicable cable connected to digital recorder of winch revolutions.

d. Cable connecting slip rings to meter console.