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EXPERIMENTAL SHIP-BASED HELICOPTER AEROMAGNETIC SURVEY

(Report, 18 figures and 13 plates)

P. Sawatzky

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Illustrations

Abstract

The problems inherent in using a magnetometer on board a ship-based helicopter are discussed and the adaptations of equipment required and the techniques employed are described.

The author concludes that the efficiency of magnetometer surveys conducted at sea can be increased by using helicopters and that the skill and initiative of the personnel involved in the project is of great importance.

EXPERIMENTAL SHIP-BASED HELICOPTER AEROMAGNETIC SURVEY

Introduction

In the past, ship-borne magnetometer surveys have been rather slow and unproductive compared with aerial magnetometer surveys conducted over land. Besides the obvious difference in speed between ships and aircraft there were other factors that reduced the anticipated amount of survey data.

In Canada, the ships engaged in surveying frequently operate in northern waters, where ice may prevent the towing of a sensing head. Another factor responsible for loss of data is the nature of other work being carried on at any particular time. For instance when Bathythermograph samples are being taken, the survey ship generally has to be stopped. This requires that the magnetometer sensing head be brought on deck to prevent the tow-cable from becoming fouled in the propellers. Even if the sensing head is streamed again immediately after the ship resumes its course there is a break in the magnetic data. Another reason for loss of data is the possible incompatibility of various types of survey instruments operated simultaneously; for example a seismic Sparker and magnetometer cable towed behind the same ship generally results in poor magnetometer data.

These facts indicated that there was a need to find a method of gathering the magnetic data that would not be affected by such drawbacks.

The Problem

Aircraft are capable of producing or gathering magnetic data at a much faster rate than ships and are not affected by most of the drawbacks noted above. However, many areas where it might be desirable to conduct detailed magnetometer surveys, such as the oceans of the world, are too far from existing airports. Furthermore many large bodies of water over which aerial surveys could be conducted due to their proximity to airports, are not covered by accurate navigational aids such as Decca or Loran.

Survey ships on the other hand generally are equipped with a sufficient variety of instruments to enable their position to be determined relatively accurately. In many cases where no permanent navigational aids are available, portable Decca stations are set up so that the survey may be conducted.

Besides the many navigational aids with which the modern survey ships are equipped, they frequently carry helicopters for ice patrol work, supplying shore parties etc.

It therefore seemed logical that an attempt should be made to use the available facilities to the best advantage, namely, to use the helicopter as a survey aircraft. The problem then remained to develop a reliable method for determining the aircraft position with respect to the ship and recording this information.

Equipment Required on the Ship

In order that the aircraft position might be determined with any degree of accuracy, the ship's position and the helicopter's position with respect to the ship in terms of range and bearing were required simultaneously. In addition the magnetic data had to be presented in such a form that it could easily be tied to a specifc helicopter location.

These conditions could be met by deciding upon a flight pattern monitoring it on a radar screen aboard ship, and directing the helicopter pilot along the desired flight path via radio (Pl. 1). To obtain the required permanent record of the ship and helicopter positions and the magnetic data, the required instruments were placed beside a radar repeater, and photographed as a group at short intervals.

As the helicopters that are normally carried on board survey ships have a rather limited load carrying capacity it was decided to use a telemetering proton free precession magnetometer in the helicopter similar to the one that was developed and operated successfully during the winter of 1962 (Washkurak and Sawatzky, 1966). This left most of the heavy magnetometer equipment on board the ship, where there was more space to accommodate it. It had the added advantage that it made it relatively easy to obtain all pertinent data at one location. Figure 1 illustrates the relationship between the various units located on the helicopter and those on the ship.

For the experiment, a light-tight box, lined with black cloth to reduce reflections, was constructed and fitted around a model 45 Decca radar repeater. A Carl Mark VII 35 mm camera was placed on the end of the box which was attached to the radar in such a manner that it could be removed completely in a matter of minutes to permit servicing of the radar when required. When assembled however, it was attached so firmly to the radar chassis that no relative motion between the radar screen and the camera was apparent, an important fact in view of the severe vibrations encountered on the ship. This was very important because the photographs had to be obtained by means of time exposures of nearly three seconds duration – the length of time required for the scanner to rotate through 360°.

The purpose of the instruments that were photographed is somewhat self explanatory as may be seen from Figure 2. The decometers enabled positioning of the ship precisely at the instant the photographic exposure was made. The radar screen was used to locate the helicopter at the same instant in terms of range and bearing. The Hewlett-Packard (HP) counter displayed the magnetic field value at the point that the helicopter had occupied just before the exposure was made. A chronometer equipped with a long sweep second hand was included to show the precise instant at which the exposure was begun. The frame counter was added for the convenience of the compilation staff.

The Airborne Magnetometer

During a previous magnetometer survey using a helicopter the sensing head had been towed at the end of a 100 foot cable (Washkurak and Sawatzky, 1966). This worked very well, but it was decided that a sensing head mounted in a fixed

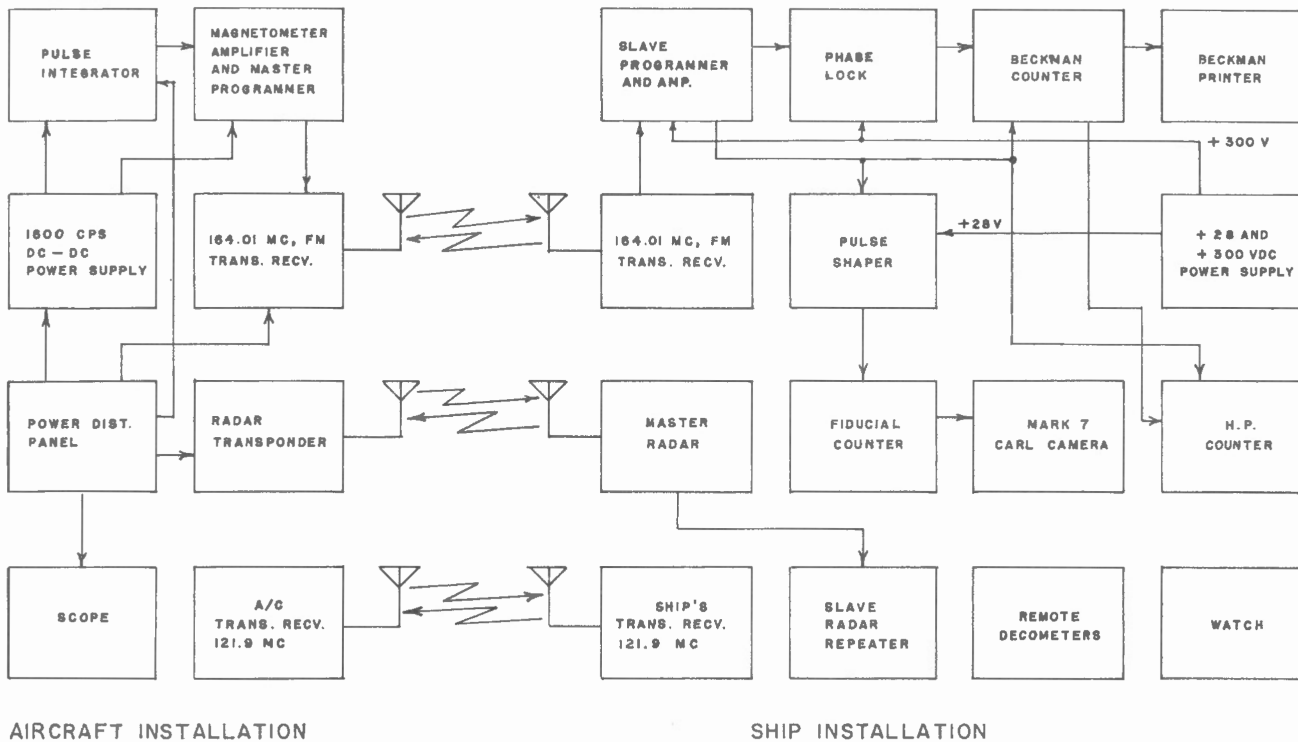


FIG. I BLOCK DIAGRAM SHOWING THE RELATIONSHIP BETWEEN THE VARIOUS PIECES OF EQUIPMENT.

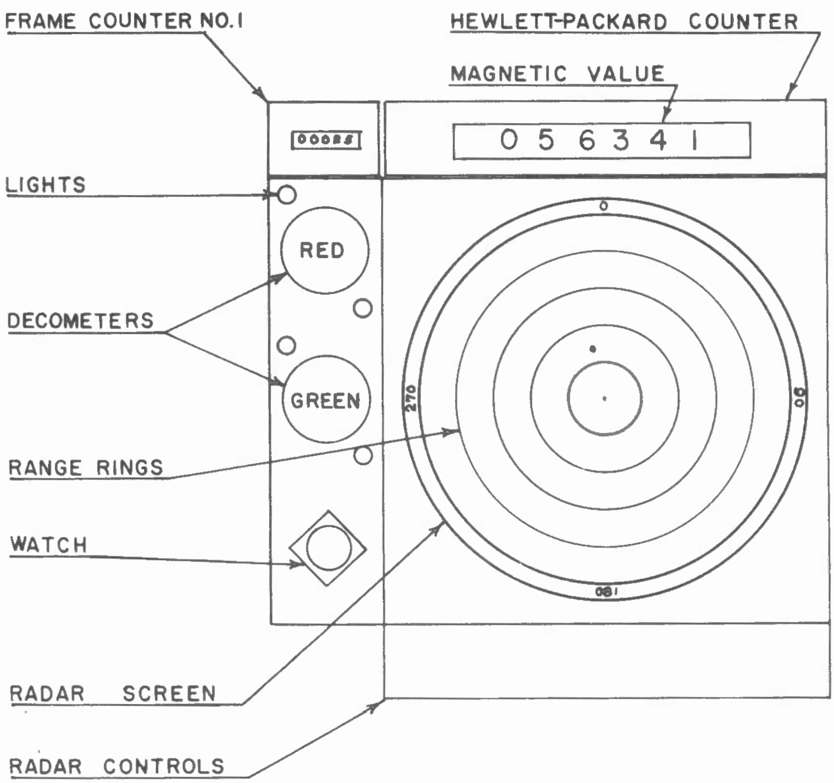


FIG. 2 INSTRUMENTS THAT WERE PHOTOGRAPHED TO OBTAIN A PERMANENT RECORD OF THE SHIP'S POSITION AND THE HELICOPTER'S POSITION WITH RESPECT TO THE SHIP IN TERMS OF RANGE AND BEARING, PLUS THE MAGNETIC VALUE AT THE POINT OCCUPIED BY THE HELICOPTER.

position would be safer during operations from a ship. As the helicopter contains a considerable amount of steel it was necessary to mount the sensing head on a boom, some distance ahead of the helicopter cabin (Pl. 2, 3).

The airborne electronic gear required for the survey was mounted in a light, sturdy rack, which in turn was bolted to the floor of the helicopter cabin. Because the helicopter was to be shared with others, the instrument rack and boom to which the sensing head was attached was arranged so that it could be removed in a matter of minutes.

Flight Path Control and Flight Patterns

During the course of the experiment two types of flight patterns were attempted. Figure 3 shows an idealized square wave pattern across the ship's course, and how it should appear on the radar screen due to the relative motion between the ship and the survey aircraft. Figure 4 shows the type of coverage that it should be possible to obtain using this pattern. Figure 5 shows an idealized zig-zag pattern and how it would appear on the radar screen. Figure 6 shows the type of survey coverage that it should be possible to obtain with this type of pattern.

For the first few flights the square wave flight pattern was attempted. An "X" of the desired size and shape was inscribed on clear plastic and attached at the appropriate point on the radar screen. The aircraft controller then attempted to guide the helicopter, via radio, so that the pip representing the helicopter would follow the inscribed pattern. In later flights the zig-zag flight pattern was attempted with somewhat better results probably due to its simplicity.

Difficulties and Possible Solutions

It was found that guiding the helicopter pilot along the desired track was a bit more difficult than had been anticipated. The difficulties were of three basic types:

1. Technical; radar and radio.
2. The effect of winds, tides and ship's traffic.
3. The human factor.

Radar

When the initial preparations for the experiment were undertaken, the new Canadian Hydrographic ship CGS Hudson was to have been used. All the equipment was new but unfortunately this ship had to go into dry dock during the time the experiments were conducted. The magnetometer and associated equipment was transferred to an older ship, CGS Baffin. As already noted, a Model 45 radar was used. This unit was not new and its definition was poor, and the useful range was limited to less than six miles under ideal conditions, even when aided by a helicopter-mounted transponder which intensified the pip representing the helicopter. This radar also had poor noise rejection which showed up as sea clutter, even on calm days, and filled the centre portion of the screen representing a circular area of two miles radius. These

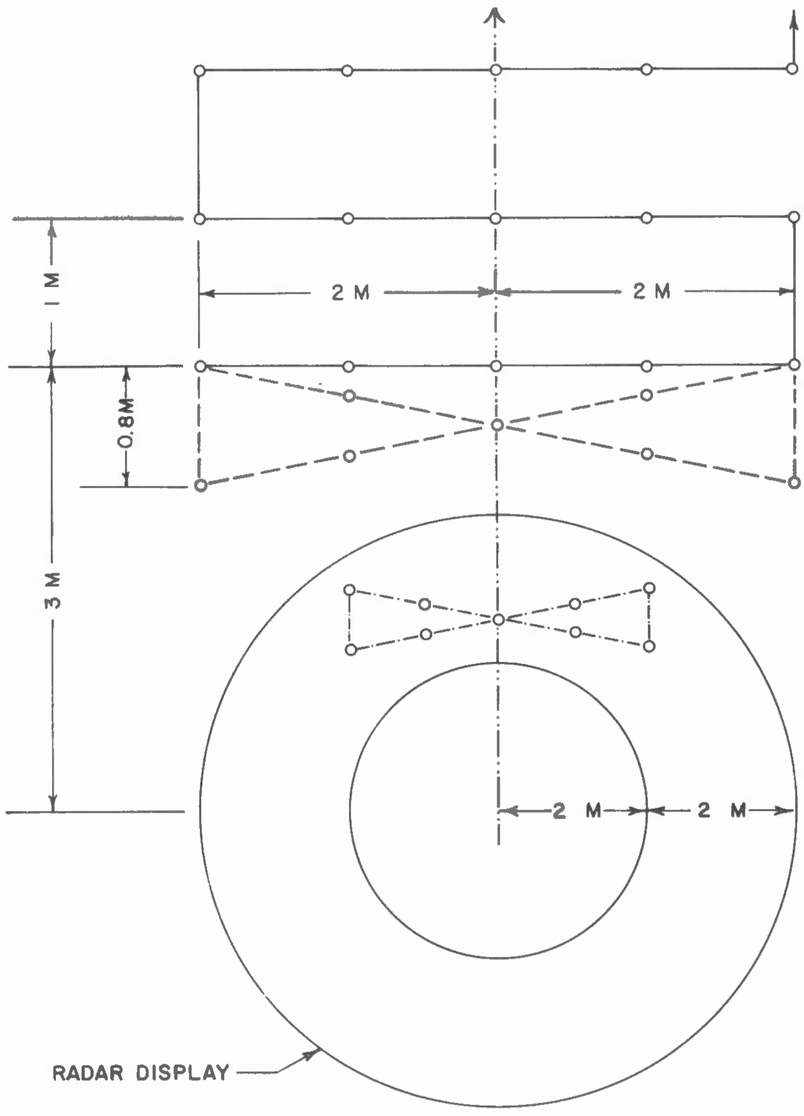


FIG. 3 SQUARE WAVE PATTERN, AND HOW IT APPEARED ON THE RADAR SCREEN

-··-··- PATH OF THE SURVEY SHIP

——— ACTUAL FLIGHT PATH OF THE AIRCRAFT

— — — — THE FLIGHT PATH AS IT WOULD APPEAR DUE TO THE RELATIVE MOTION BETWEEN THE SHIP AND THE AIRCRAFT

-·-·- THE FLIGHT PATH AS SEEN ON THE RADAR SCREEN.

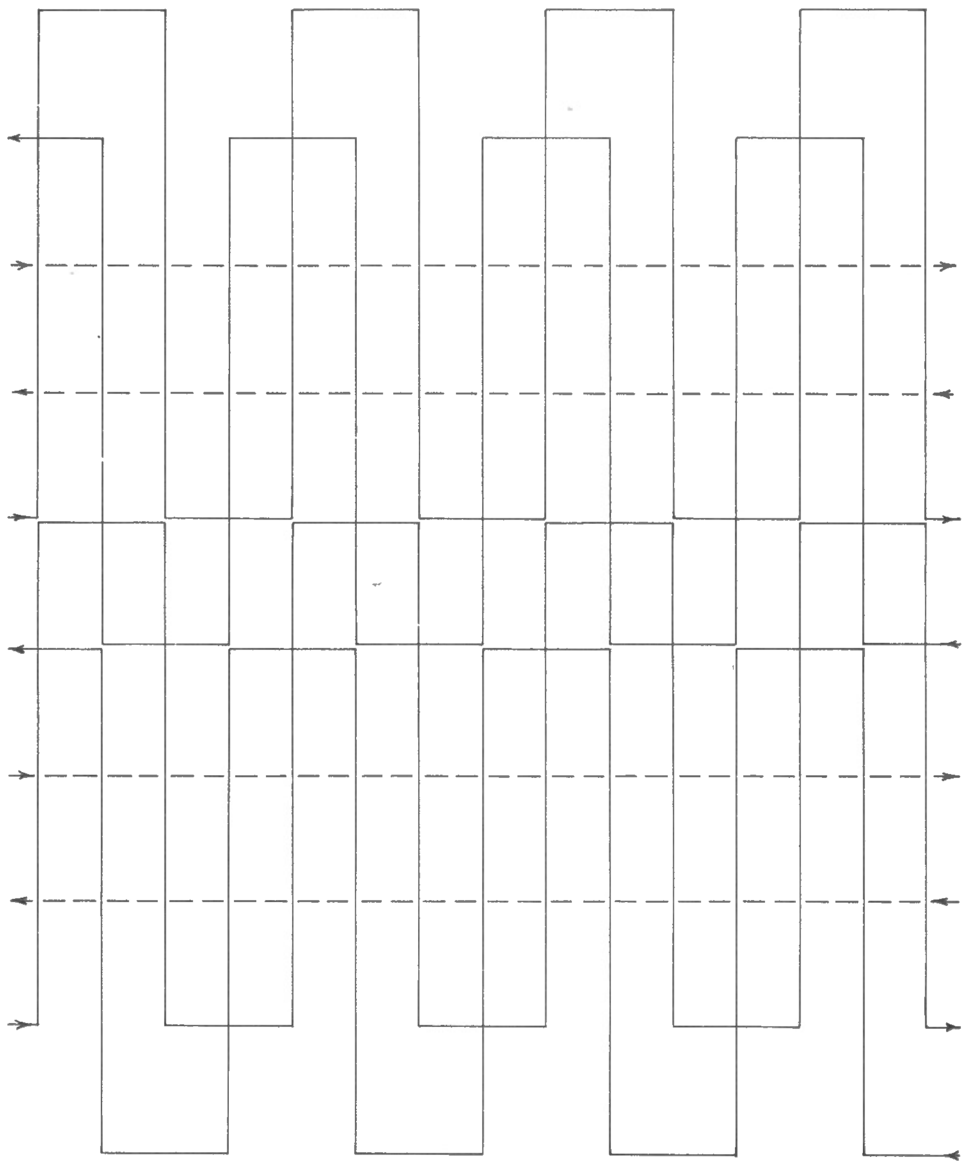


FIG. 4 SURVEY COVERAGE RESULTING FROM THE SQUARE WAVE PATTERN

— — — SHIP'S COURSE

——— FLIGHT PATH

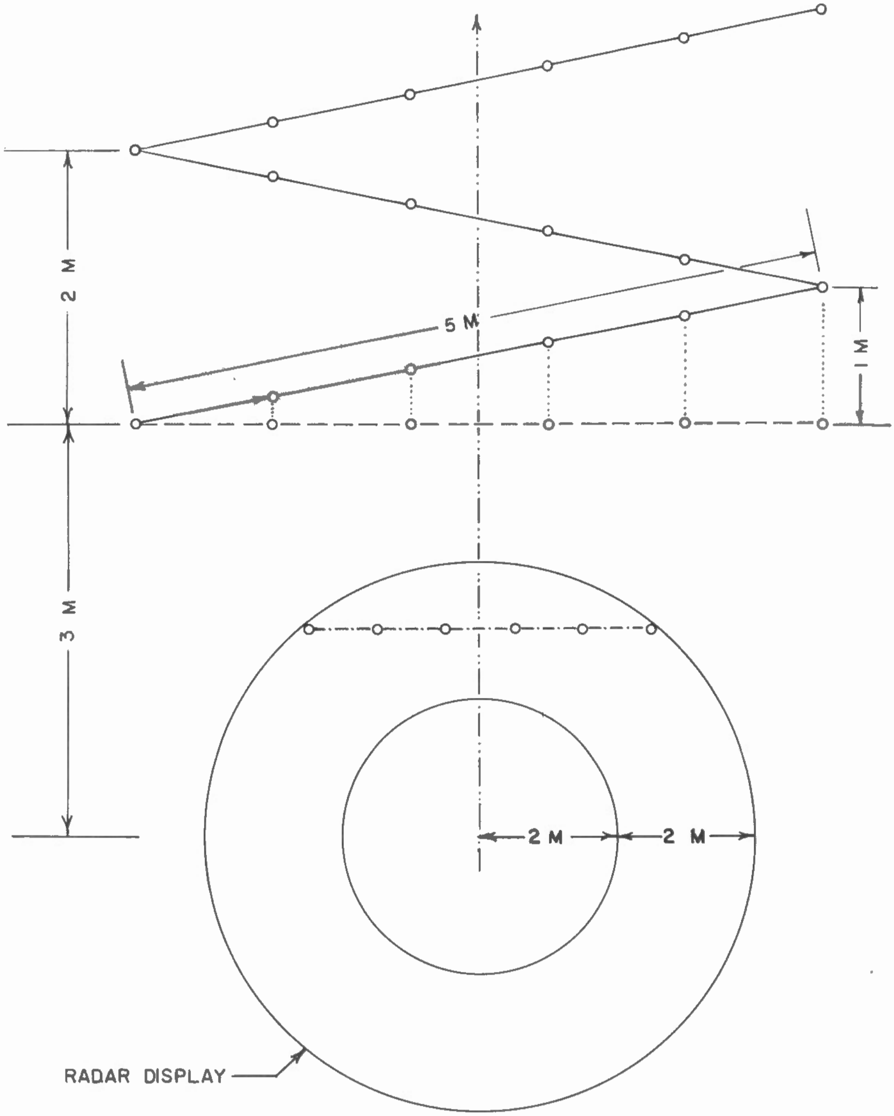


FIG. 5 ZIG ZAG PATTERN, AND HOW IT APPEARED ON THE RADAR SCREEN

—··—··— PATH OF THE SURVEY SHIP

——— ACTUAL FLIGHT PATH OF THE AIRCRAFT

— — — — THE FLIGHT PATH AS IT WOULD APPEAR DUE TO THE RELATIVE MOTION BETWEEN THE SHIP AND THE AIRCRAFT

—·—·—· THE FLIGHT PATH AS SEEN ON THE RADAR SCREEN.

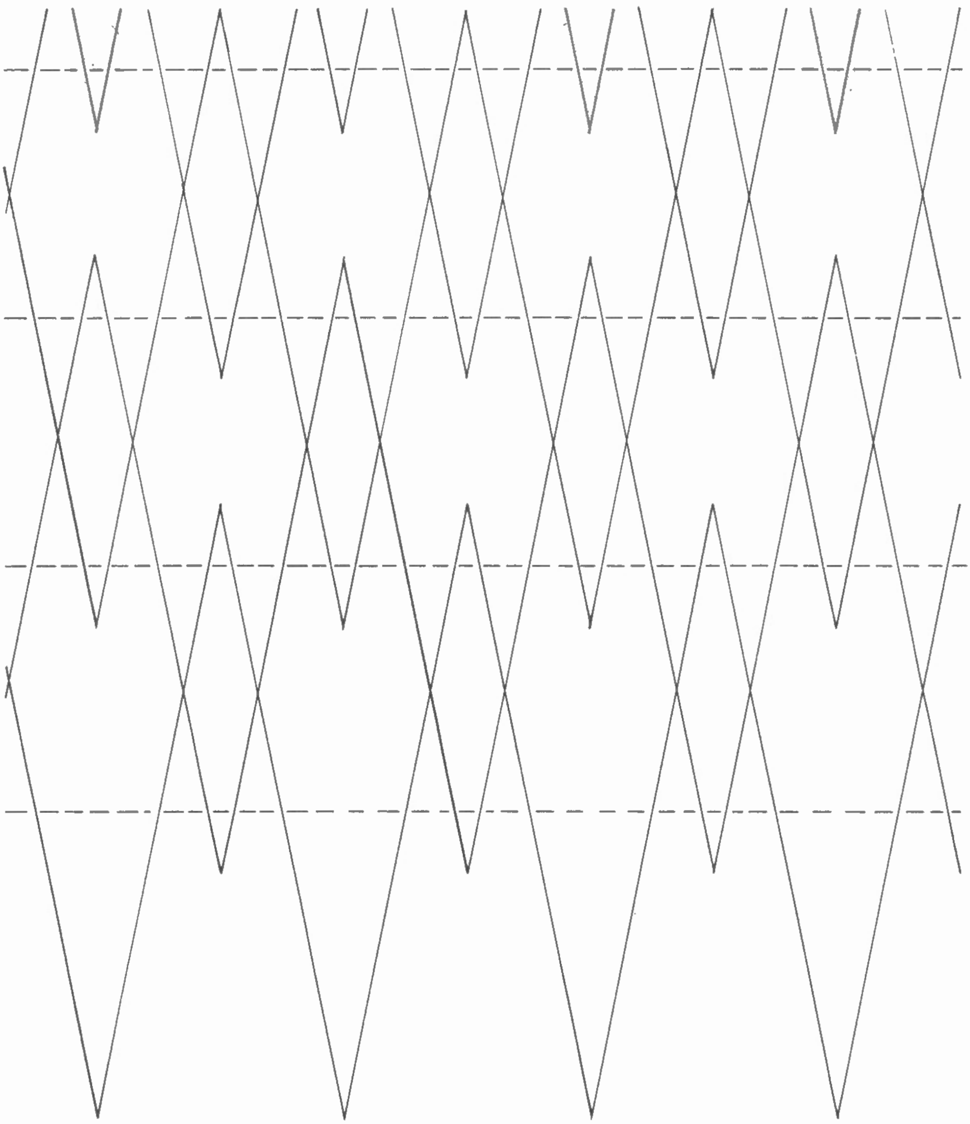


FIG. 6 SURVEY COVERAGE RESULTING FROM THE ZIG ZAG PATTERN
— — — SHIP'S COURSE
——— FLIGHT PATH

restrictions limited the useful test area ahead of the ship considerably. It was found that when the pip was lost on the Model 45 radar, it could be located without any difficulty on a newer radar, Decca Model 838.

Another problem concerning radar was due to interference. When two radar units were operated simultaneously on the same ship, radio energy from one antenna would be picked up by the other. This created ever changing interference patterns that made it even more difficult to find and follow the small pip representing the helicopter.

The interference problem could be eliminated relatively easily by operating two repeater units from one high quality master unit. The master unit could be located on the bridge thus permitting the ship's officers to use the radar whenever they desired. One repeater could be used by the aircraft controller and the other could be photographed to obtain the required record of the flight path of the aircraft.

Radio

During the course of the experiment it was found that the radio equipment used to control the flight path of the helicopter should be of a high quality. The equipment available was of the amplitude modulated type and rather prone to interference, and as a result the instructions given to the pilot were not always understood. A test was conducted using the VHF equipment, normally used to telemeter the precession signal from the aircraft to the ship, and excellent results were obtained. Unfortunately the latter equipment was not available for aircraft control work while the survey was in progress.

The effect of winds, tides and ship traffic

The tests were conducted in the Bay of Fundy during August 1964. Ships and fishing boats were encountered in large numbers. To avoid collisions the ship's speed was often varied or other evasive action taken. This, coupled with strong tides that acted on the ship, and winds of varying velocities that tended to alter the speed and direction of the helicopter, had to be taken into account by the aircraft controller when attempting to guide the aircraft along a predetermined course. Experience in coping with these problems would most likely be the best remedy.

Accuracy

The ship's position could be determined to a high degree of accuracy but the exact location of the helicopter with respect to the ship however was a little more doubtful for the simple reason that during the interval of about three seconds (the time required to obtain a photograph) the helicopter moved a distance of nearly six hundred feet. Figure 7 shows a plot of the helicopter's track while attempting to fly the zig-zag pattern. It certainly is not the smooth pattern shown in Figure 5. The positions shown were obtained by plotting the helicopter's position at 72 second intervals, points 4460 to 4660, and at 36 second intervals, points 4660 to 4840. To determine the reliability of these points, other points were chosen which should fall half way between

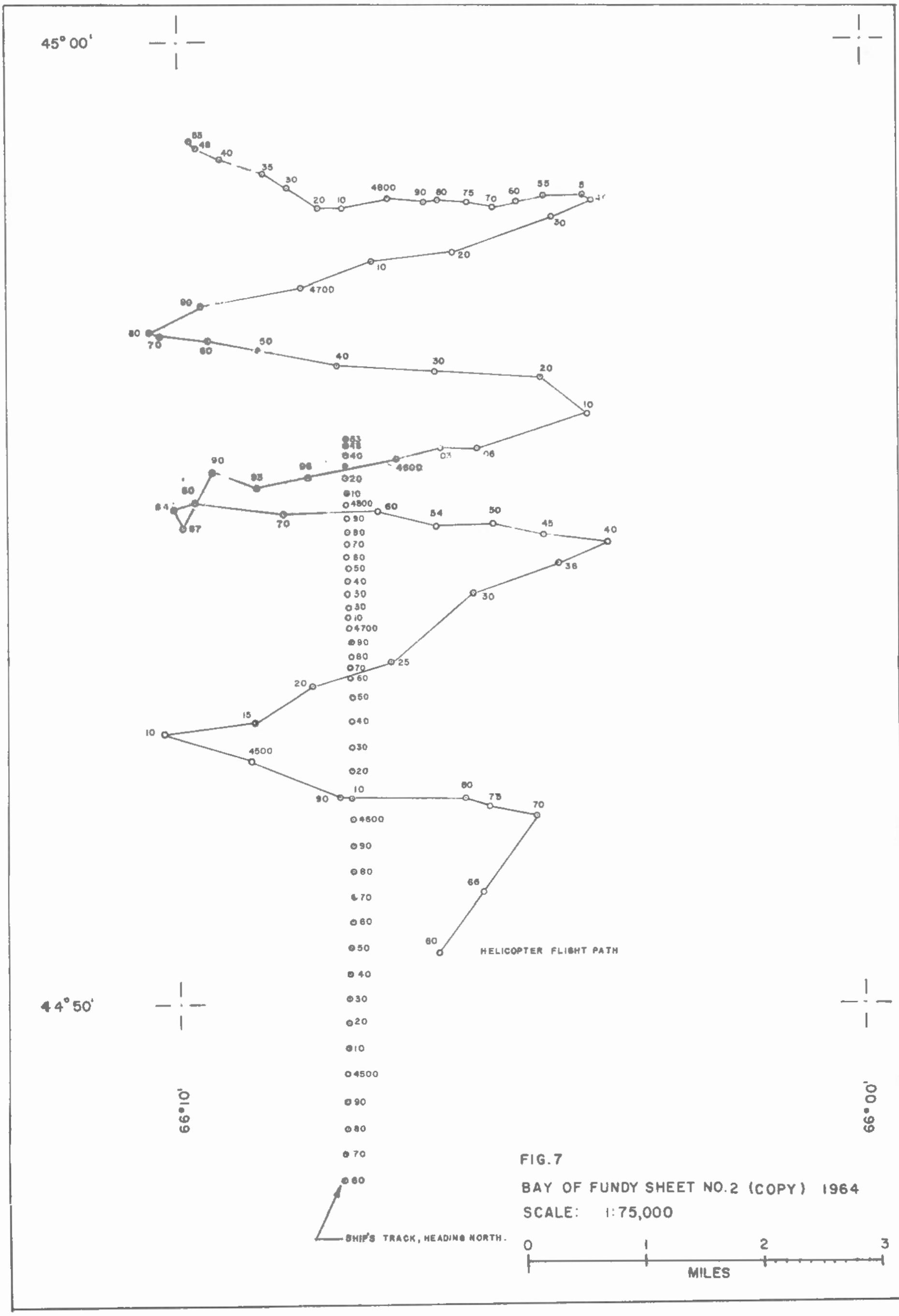


FIG. 7

BAY OF FUNDY SHEET NO. 2 (COPY) 1964

SCALE: 1:75,000

those points that had been plotted initially. In the majority of cases the positions were more or less where expected thus indicating that the original plot was not entirely in error.

The fastest sampling rate was 3.6 seconds. Attempts were made to transfer the information from each exposure or frame. For a helicopter speed of 90 knots, the helicopter would have moved a distance of 547 feet or a little more than 1/6 of a nautical mile. This distance was not difficult to measure on a map with a scale of 1:75,000. To determine the helicopter's position the ship's position had to be plotted first and in 3.6 seconds the ship when steaming at 10 knots, would have advanced only 61 feet or about 1/100 of a nautical mile. This latter distance was found to be rather difficult to measure accurately on the chart that was used for the survey work. The number of helicopter positions which were plotted was dependent upon the number of ship's positions that could be physically plotted on a line of a given length.

Detailed Description of the Equipment and its Functions

Special equipment designed and built for the ship

When photographing the radar display and other instruments it was necessary to make provision for the control of the light intensities on the various pieces of equipment. All lights used for this purpose were operated from 28 vdc, the same power source required to operate the camera. Two lamps per instrument were used for increased reliability. To reduce blurring to a minimum due to the motion of the hands on the decometers and watch, the lights illuminating them were flashed at the instant the camera shutter was first opened. Figure 8 shows the circuitry that accomplished this.

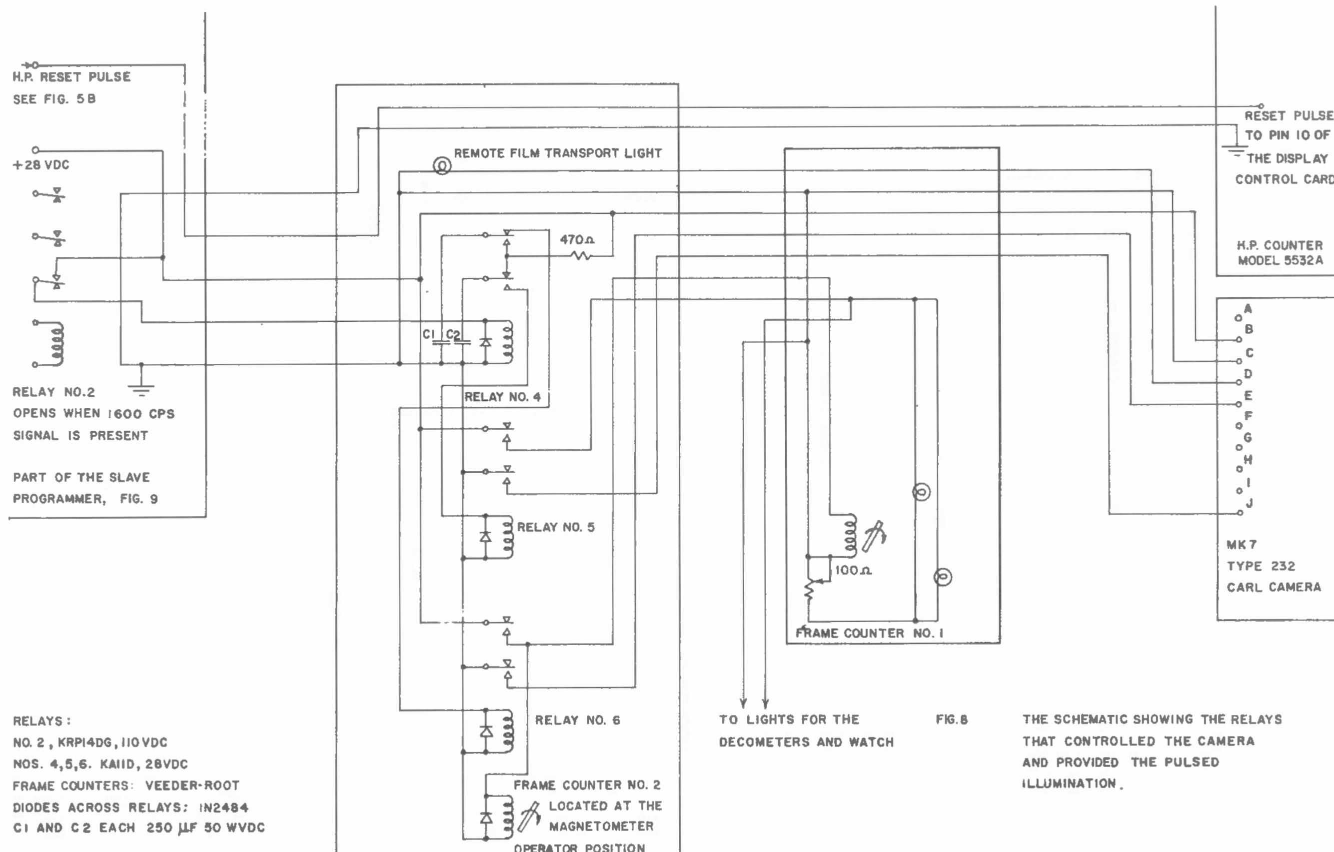
The function of the various relays shown in Figure 8 may be explained as follows, from left to right.

1. The source of the HP counter reset pulse, and below it a relay that responded to a 1600 cps signal, transmitted from the survey aircraft.

2. The presence of a 1600 cps signal opened the above noted relay No. 2. Tracing the circuit to the right, it will be seen that this caused relay No. 4 to close. In the rest position of this relay capacitor, C_2, was permitted to charge to + 28 vdc. Upon being closed, C_2 discharged through relay No. 5, thus closing it for 1/20 of a second.

3. While relay No. 4 was closed, C_1 charged toward + 28 vdc. When the contacts were made at relay No. 5, the lower contact produced a short grounding pulse that went to pin J of the camera, required to open the shutter. The top contact of relay No. 5 turned on the lamps by momentarily connecting them to + 28 vdc, thus illuminating the instruments shown in Figure 2.

4. At the end of the 1600 cps signal, relay No. 4 opened again. This permitted the charge accumulated by C_1 to close relay No. 6 momentarily, thus producing pulses of



RELAYS:
NO. 2, KRP14DG, 110 VDC
NOS. 4,5,6. KA11D, 28VDC
FRAME COUNTERS: VEEDER-ROOT
DIODES ACROSS RELAYS: 1N2484
C1 AND C2 EACH 250 μF 50 WVDC

FIG. 8 THE SCHEMATIC SHOWING THE RELAYS THAT CONTROLLED THE CAMERA AND PROVIDED THE PULSED ILLUMINATION.

1/20 second duration from both contacts. The top contact of relay No. 6 energized two frame counters, one at the operator's position and the other beside the radar screen; the latter being photographed. The bottom contact of relay No. 6 provided a negative pulse to pin E of the camera, required to close the shutter and advance the film.

From Figure 1 it may be seen that the precession signal and the 1600 cps were transmitted from the helicopter to the ship via a 164.01 MC transmitter. The output from the radio receiver on the ship was fed to a slave programmer (Fig. 4) that consisted of two tuneable amplifiers. One was tuned to the precession frequency and the other to 1600 cps.

Associated with each amplifier in the slave programmer was a relay circuit, operated through a vacuum tube. The presence of a signal of the proper frequency biased the tube to the "off" state. This in turn allowed the relay associated with it to open. Relay No. 1 (Figs. 9 and 10B) was used to reset the Beckman and HP counters. Relay No. 2 (Figs. 9 and 2) was used to control the camera, fiducial counters and lights as described above.

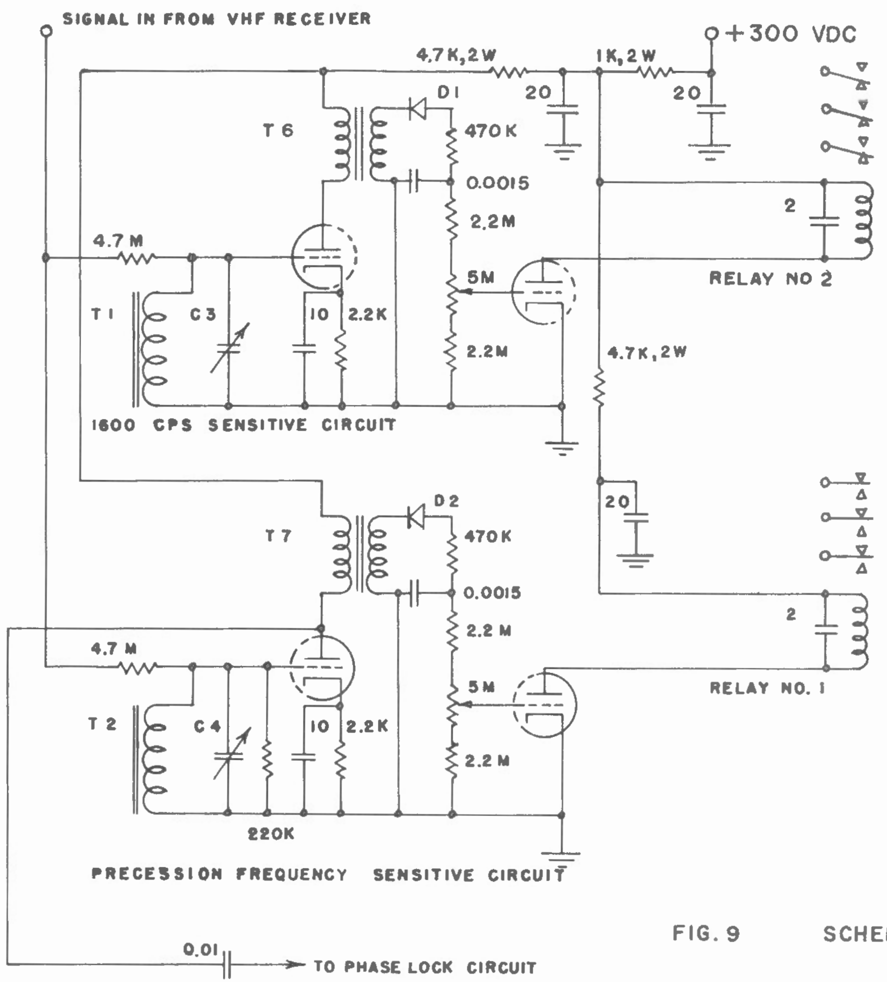
The output of the precession frequency amplifier, associated with the slave programmer was fed to the phase lock (Fig. 11) whose output was fed to the Beckman counter, from where the HP counter received its pulses. The display of the Beckman counter was recorded by means of a Beckman printer, and the display on the HP counter was photographed (Fig. 2).

As both counters were to display the same data it was necessary to reset both counters simultaneously. This was accomplished by the circuit shown in Figure 10B. The HP counter required a negative pulse of a few milliseconds duration. The Beckman counter required a grounding pulse to reset it. Both conditions were met by the circuit shown in the above mentioned diagram.

The HP counter, model 5532A did not have a variable gate such as the Beckman counter and one was furnished or supplied indirectly. The counting period required by both counters for a direct reading output of the magnetic field was 0.7340 second (Collett and Sawatzky, 1966). In order that the HP counter might count for this interval, the variable gate of the Beckman counter was set to 0.7340 second. The HP counter was set to count any incoming signal connected to its input for a period of one second after the counter had been reset.

The output of the first decimal counting unit (DCU) in the Beckman counter was tapped and fed to the input of the HP counter (Fig. 10A). The Beckman counter presented the total intensity of the earth's field to an accuracy of a tenth of a gamma. The HP counter therefore displayed the same value, but reduced by one tenth, that is, the least significant digit was $\pm$ 1 gamma instead of $\pm$ 0.1 gamma. The HP counter was thus forced to count for an interval of 0.7340 second, because at the end of that period no more pulses arrived from the Beckman counter.

With the equipment arranged as described above, it was possible to print out every reading of the Beckman counter. The display of the instruments (Fig. 2)



T1,T2 — MQ85 (UTC)
T6,T7 — NO. 832 (HAMMOND)
C3,C4 — CAPACITANCE DECADE SWITCHES
D1,D2 — IN459A
CAPACITORS IN μF
RESISTORS: 1/2 W UNLESS OTHERWISE SPECIFIED

FIG. 9 SCHEMATIC OF THE SLAVE PROGRAMMER.

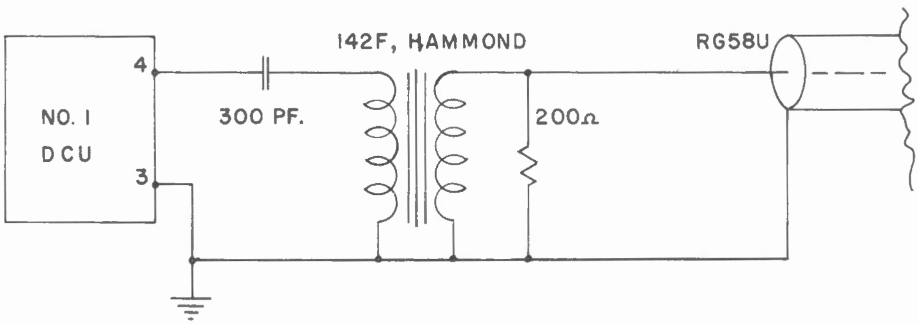


FIG.10A THE METHOD USED TO TAKE OUT THE SIGNAL FROM THE BECKMAN COUNTER FOR THE HEWLETT-PACKARD COUNTER.
BECKMAN MODEL 7361
H.P. MODEL 5532A

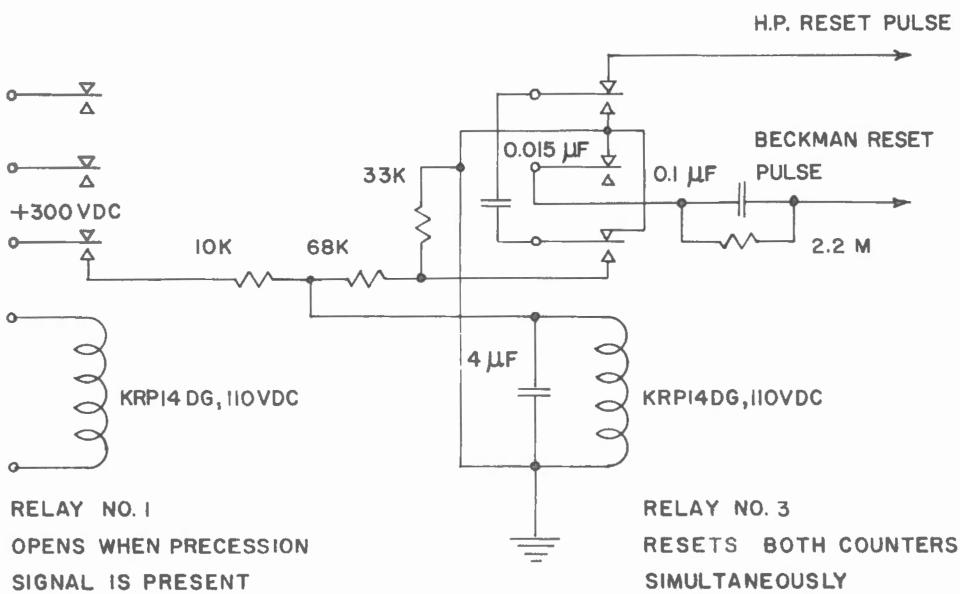


FIG.10B THE CIRCUIT USED TO OBTAIN THE PROPER RESET PULSES FOR BOTH COUNTERS AT THE SAME INSTANT.

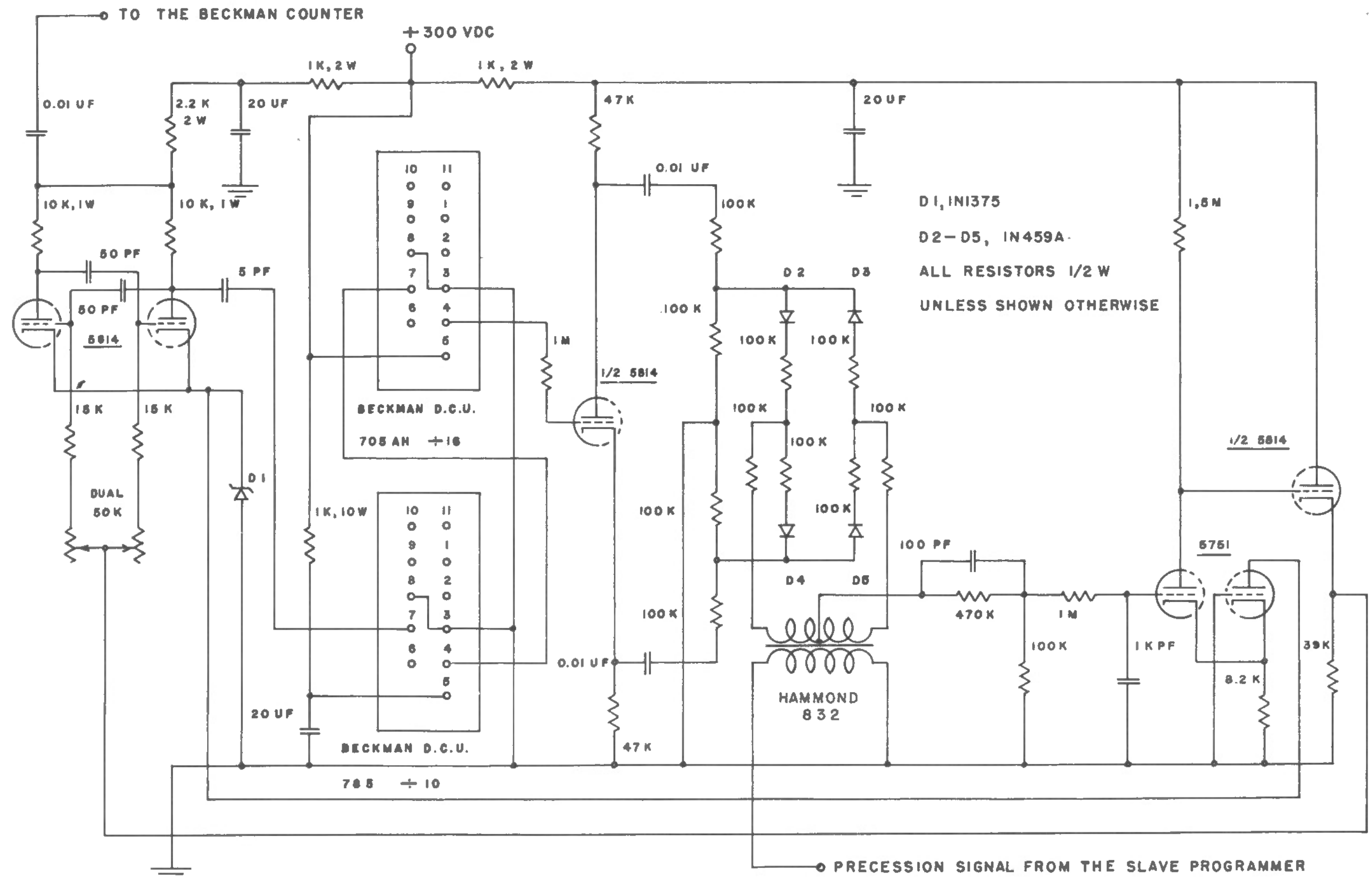


FIG.11 PHASE LOCK CIRCUIT.

was photographed only on command from the aircraft where the master programmer and pulse integrator were located. The command pulse could be selected to occur automatically after every second, fourth, fifth, tenth or twentieth "read" interval. The reason for this was to determine the number of exposures required to recover the flight path of the helicopter. From experience it was found that exposures every 20 seconds were adequate to recover the flight path.

In order that the magnetic values which were photographed could be matched more easily to those that were printed, a two colour ribbon, red and black, was used in the printer. The pulse that initiated the command to open the camera shutter also caused the printer to print the same number in red as was being photographed. The operator (see Pl. 4 and 5) then could mark an occasional number, printed in red, with the frame number displayed in front of him.

The Carl Mark 7, Type 232, 35 mm camera

The camera, mounted on the end of the wooden box (Pl. 6, 7, 8 and 9) was modified to take time exposures. The exposed film area was 25 mm by 36 mm and was obtained by installing this type of picture format. In addition the shutter had to be modified. The shutter that came with the camera was in the form of a disk with an opening of 33°. Under normal survey conditions the shutter disk rotated once per frame, and the opening was just large enough to produce an exposure time lasting 1/100 of a second. However during a time exposure the opening in the disk remained opposite the lens until the close pulse arrived. The 33° opening was not large enough for the above noted format, and it was necessary to make a new shutter with a larger opening of 70° and install it in the camera.

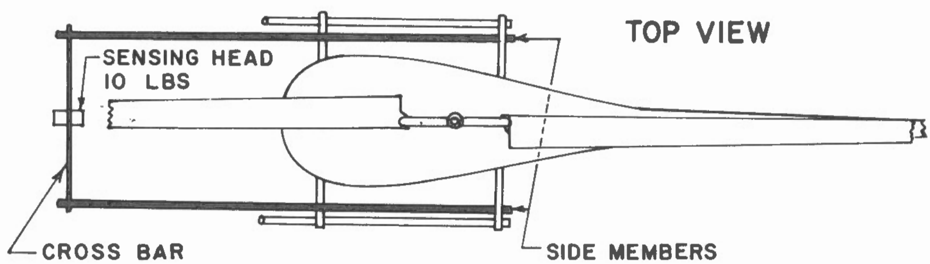
Special equipment designed and built for the helicopter

During a previous magnetometer survey, where a helicopter had been used, the sensing head had been towed at the end of a 100 foot cable (Washkurak and Sawatzky, 1966). This worked very well, but it was decided that a sensing head, mounted in a fixed position would be safer to fly from a ship. The helicopter contains a considerable amount of steel and for this reason the sensing head had to be mounted a sufficient distance from the machine, so that the magnetic gradients were low enough to obtain a precession signal. Tests were conducted, and it was found that a sensing head mounted on a boom eight feet in front of the machine produced good results.

Plans were drawn (Fig. 12), which show the side members curved slightly upwards to obtain enough clearance on take off and landing for a machine equipped with skids. This was found to be unnecessary as may be seen from (Pl. 2 and 3), due to the added height gained by placing the helicopter on floats. Supports, or braces were added to prevent vibration and flexing of the side members (see Pl. 2 and 3). A weight provided by the manufacturers of the helicopter was attached to the tail boom to restore the proper balance to the helicopter. This method of mounting the sensing head was found to be satisfactory.

METHOD OF MOUNTING A SENSING HEAD FOR A PRECESSION MAGNETOMETER ON A HELICOPTER

MATERIAL:	SIDE MEMBERS, ALUMINUM TUBING
	CROSS BAR, WOOD OR FIBERGLASS
CONSTRUCTION:	BOLTED AND CLAMPED TO LANDING GEAR
SCALE:	NOT DRAWN TO SCALE
DATE:	2-4-64



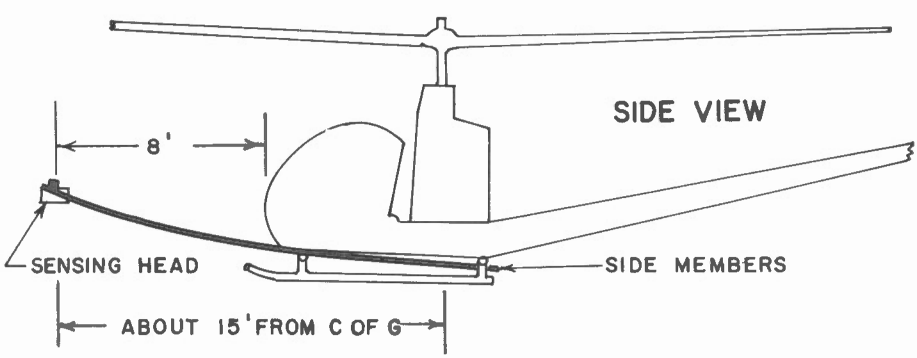


FIG. 12

A special rack was also built to hold the telemetering magnetometer (Fig. 13). The finished product complete with instruments and installed in the helicopter is shown in Plates 10, 11 and 12. Several units were built especially for this rack, and all were mounted in such a way that they could be replaced in a matter of seconds if required. As the helicopter would have to be shared with others, the instrument rack and boom to which the sensing head was attached could also be removed completely in a matter of minutes.

The telemetering magnetometer

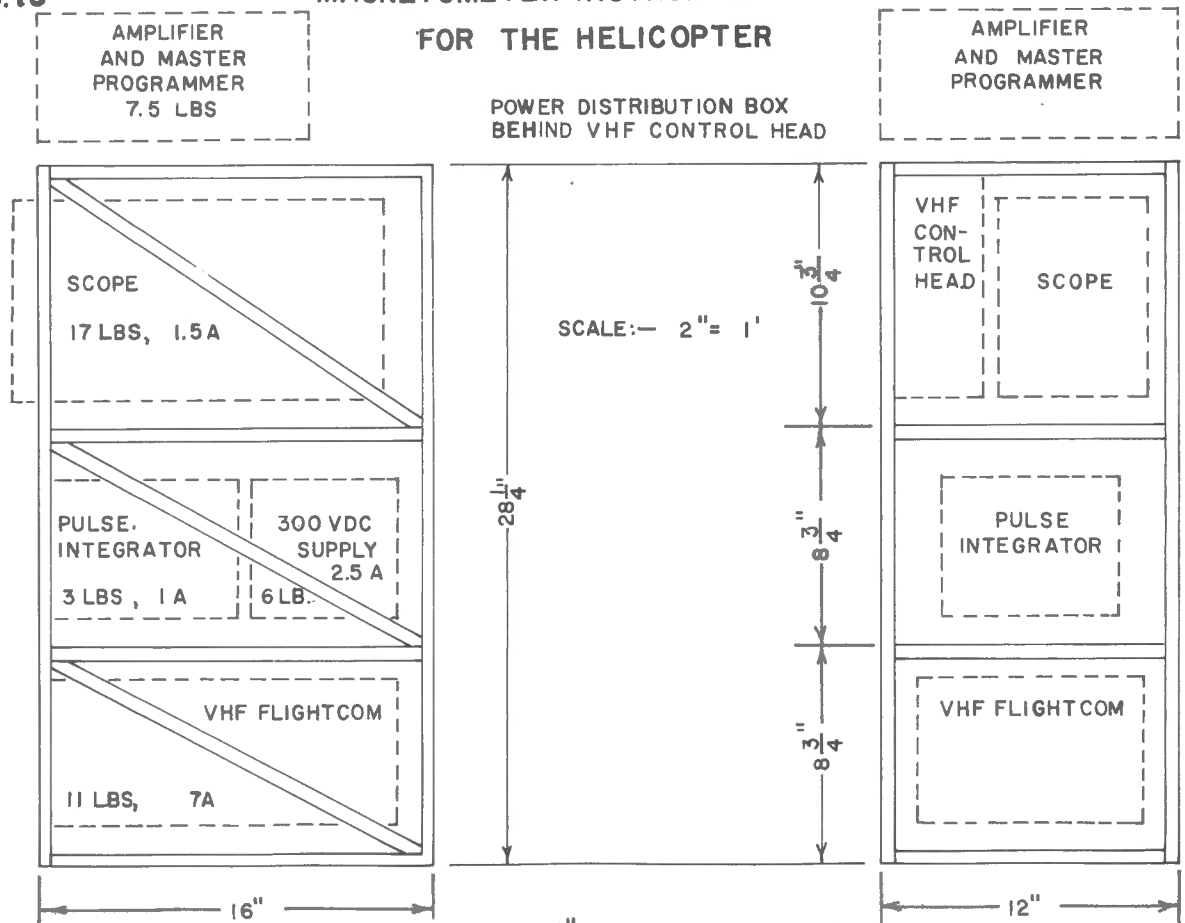
Figure 13 and Plates 10 and 11 show the actual placement of the telemetering magnetometer components in the instrument rack, each being individually shock-mounted.

The low noise amplifier, Figure 14, was similar in its basic design to that used in an earlier survey conducted with a helicopter with some modifications. In order that the signal to noise ratio might be improved, the amplifier tubes were mounted on a small aluminum plate, which in turn was shock-mounted with foam rubber on the main chassis. The relays of the master programmer (Fig. 15) were also shock-mounted in a similar manner to eliminate relay contact bounce and chatter created by the vibrations in the helicopter.

In order that the equipment on the ship and in the helicopter might be synchronized, the programmer in the helicopter indirectly controlled the equipment mounted on board the ship. This was accomplished by means of the Pulse Integrator (Fig. 16). Figures 15 and 16 show that when the relay on the left of Figure 15 was in the open state, relay No. 4 of Figure 16 was closed. This was termed the "read" part of the cycle, because at this time the precession signal was transmitted to the ship to be converted there into a record of the magnetic field value equivalent to the precession signal. During the "polarize" part of the cycle, relay No. 4 of Figure 16 was open. This permitted relay No. 1 of Figure 16 to advance the wiper of the stepper switch to the next contact. With S1 of Figure 16, set as shown, on the fifth such movement of the stepper switch, relay No. 2 would close during the polarize period of the cycle. This in turn would permit a 1600 cps signal to be transmitted. On board the ship, the slave programmer (Fig. 9) reacted to these signals as described previously. Relays 3 and 5 of Figure 16 were not used during the summer's operation, and were installed in case it should have been necessary to operate a survey camera in the helicopter.

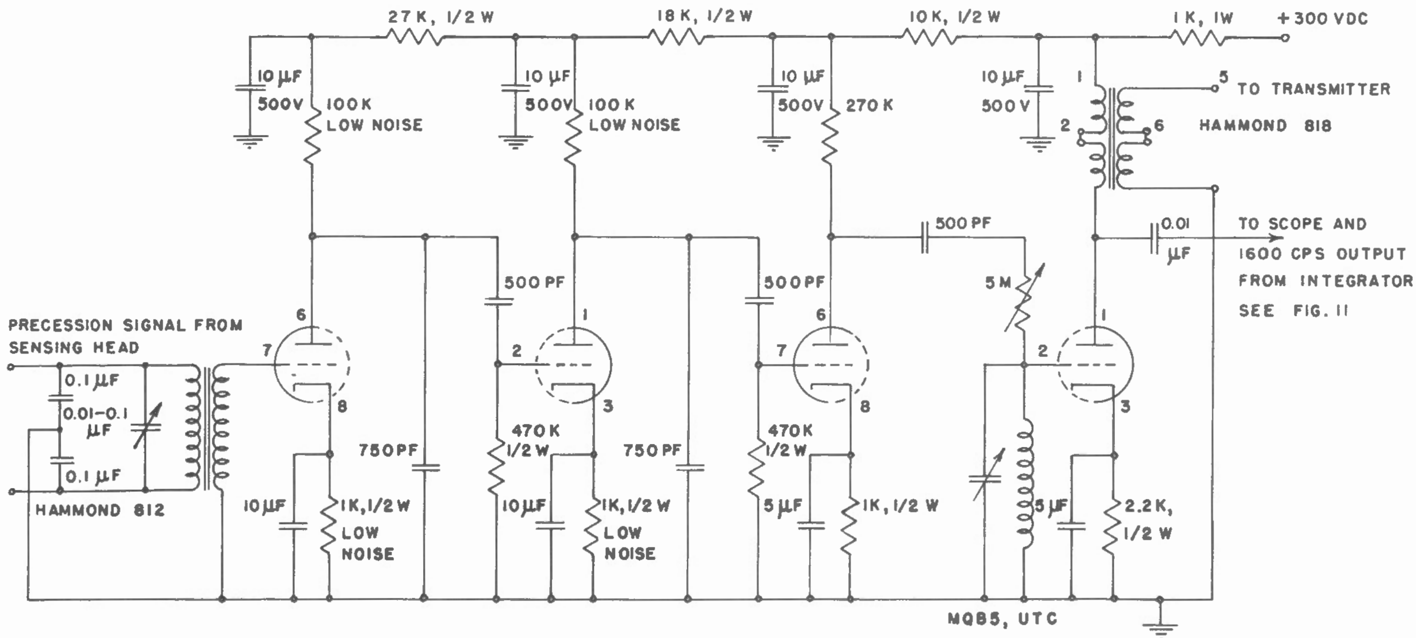
The distribution box (Fig. 17) obtained its power in such a manner that the aircraft master switch also automatically turned off the power to the magnetometer and associated equipment thus eliminating the possibility of draining the helicopter battery accidentally. In addition to each piece of equipment being fused, the power lead to each piece of equipment had its own circuit breaker. The 1 mh choke in the supply line to the VHF Transmitter Receiver prevented the switching spikes from its transistorized power supply from reaching the other equipment. The R. F. choke was added to further filter the supply and prevent interference from entering or leaving the distribution box.

FIG. 13 MAGNETOMETER INSTRUMENT RACK FOR THE HELICOPTER



MATERIAL:— 41–30, 1/2" SQUARE, STEEL TUBING

NOTE: ALL LEADS ENTERING AND LEAVING THE AMPLIFIER AND MASTER PROGRAMMER CHASSIS WERE SHIELDED AGAINST R.F. INTERFERENCE. ADDITIONAL R.F. SUPPRESSION WAS USED ON THE TUBE FILAMENTS. FOR DETAILS SEE CHAPTER 23 OF THE RADIO AMATEURS HANDBOOK.



TUBES 5751 WA

FIG. 14 LOW NOISE AMPLIFIER

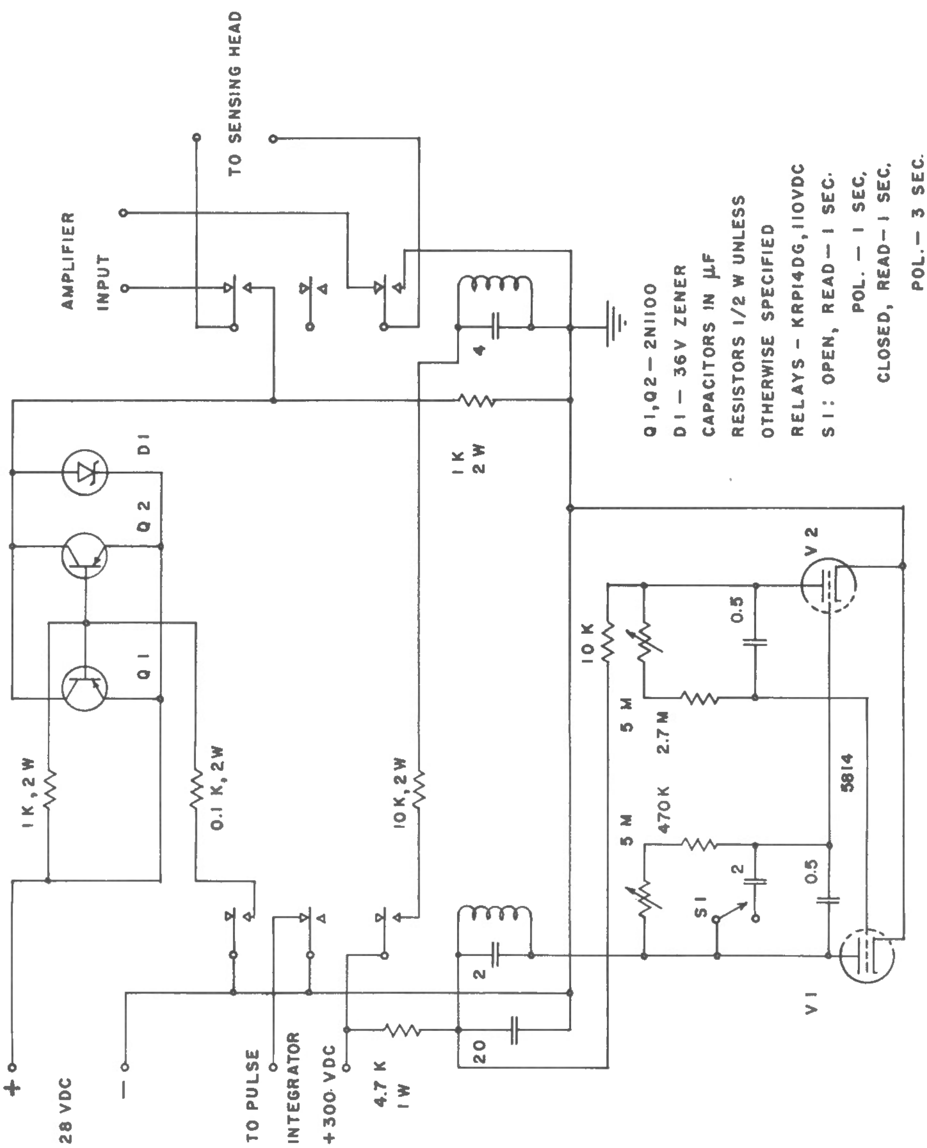
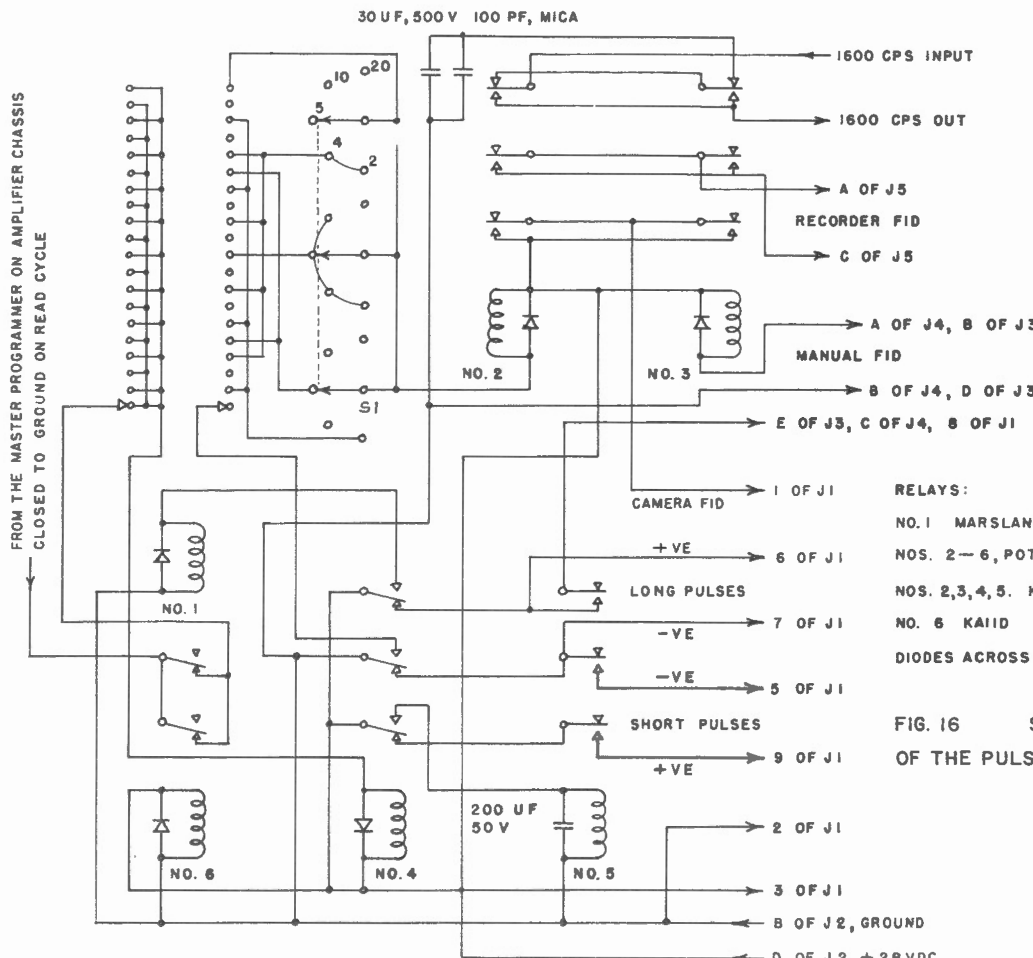


FIG. 15 MASTER PROGRAMMER IN THE AIRCRAFT



RELAYS:

NO. 1 MARSLAND, 250-514-204

NOS. 2 — 6, POTTER-BROMFIELD

NOS. 2,3,4,5. KA14D

NO. 6 KA11D

DIODES ACROSS RELAYS 1N2484

FIG. 16 SCHEMATIC OF THE PULSE INTEGRATOR

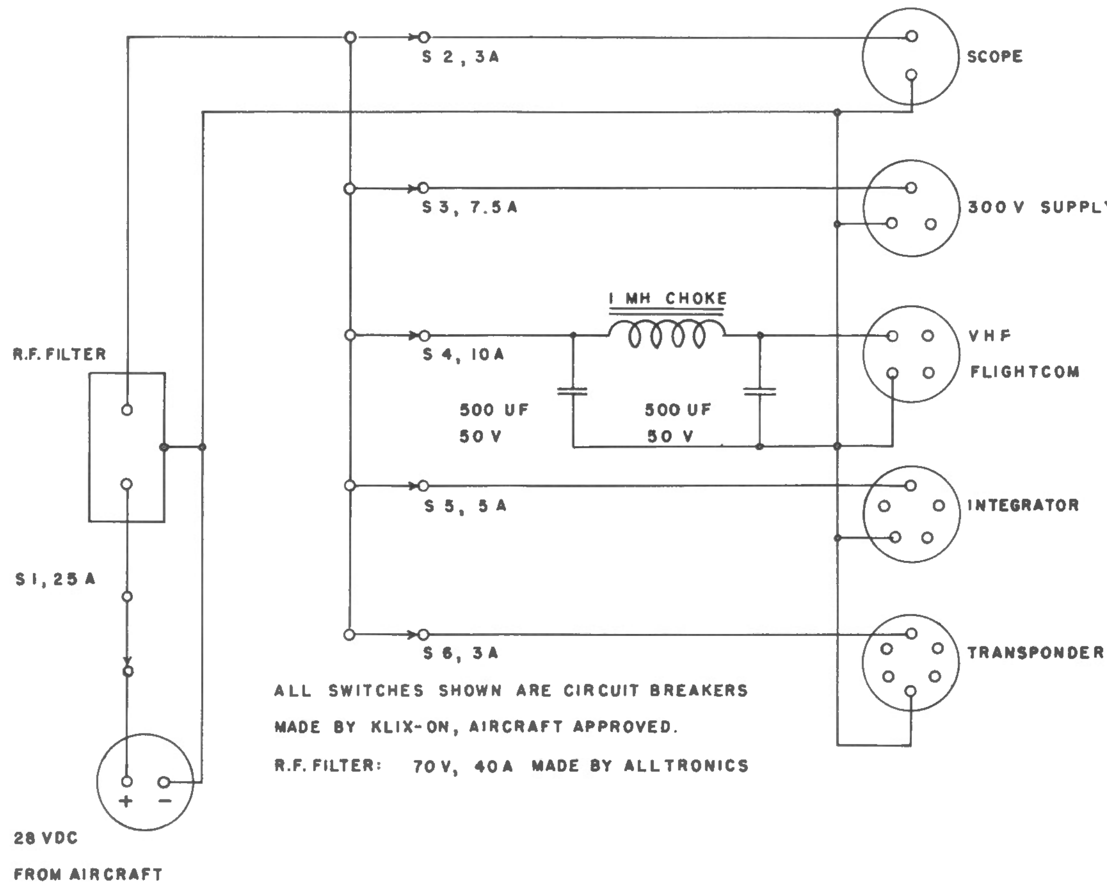


FIG. 17 SCHEMATIC OF THE POWER DISTRIBUTION BOX FOR THE AIRCRAFT.

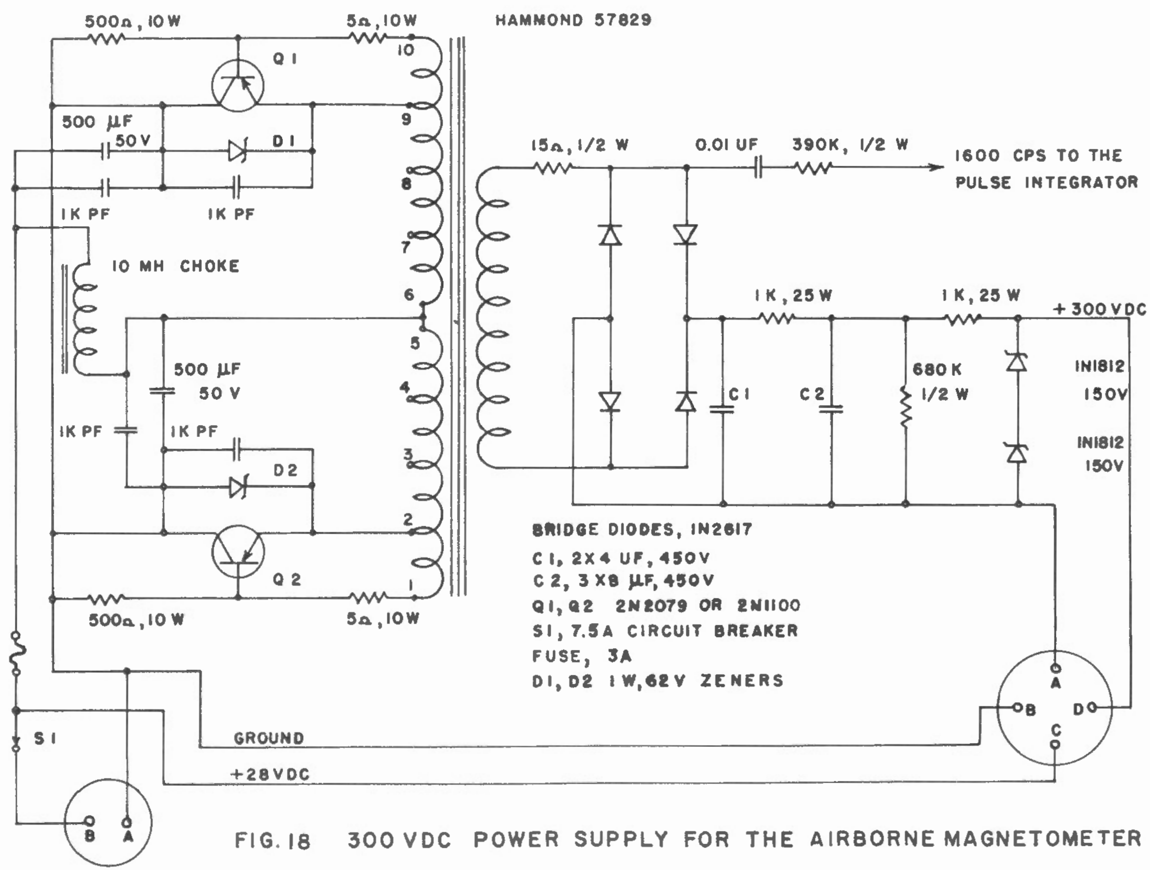


FIG. 18 300 VDC POWER SUPPLY FOR THE AIRBORNE MAGNETOMETER

The 300 vdc Power Supply (Fig. 18) was designed and built especially for the telemetering magnetometer. The transformer used was designed to obtain a switching frequency between 1600 cps and 1800 cps, the actual operating frequency was close to 1600 cps. The reason for this was that the difference between the fundamental and the second harmonic was to straddle the precession frequency which would be expected to be between 2000 and 3000 cps, the range necessary to operate in Canada. The switching frequency of the power supply would therefore not create interference. The 10 mh choke was added to prevent any switching transients from reaching the 28 vdc line.

If the radar of the survey ship had been equipped with a sector scan, a device that would permit scanning of a small segment of the horizon instead of the conventional 360°, it would have been possible to photograph the radar screen during the one second normally allotted to the polarize part of the cycle described previously. However in case it proved necessary to take time exposures lasting nearly three seconds, the time required for the scanner to sweep through 360°, an additional feature was added to the master programmer. This consisted of S1 and a 2μf. capacitor, shown in Figure 15. Closing the switch produced a three second polarize pulse, long enough to photograph the radar screen for a full sweep.

The VHF Transmitter Receiver used was frequency modulated. Previous tests had shown that it was superior to amplitude modulation for this type of work. A blower was mounted above the output stage to permit continuous operation of the transmitter.

In order that the radar might show the helicopter as a strong pip, a transponder was carried on the helicopter. Plate 13 shows the transponder mounted on the right hand cargo rack of the helicopter. The transponder acted as an active radar beacon.

Acknowledgments

Thanks are extended to all those who contributed and participated directly or indirectly in developing the method of surveying described in this report. The equipment that was designed and adapted for this project was based on the work done by Dr. P. Serson of the Dominion Observatory, and on development work that had been carried out by personnel of the Geophysics division in previous years.

The following organizations contributed equipment used in the project:

The camera used to photograph the radar and associated equipment was loaned from the Royal Canadian Air Force.

The transponder, radar, and decometers mounted beside it were supplied by the Bedford Institute of Oceanography.

The Hiller 12E was chartered by the Marine Sciences Branch, and all the flying while testing the feasibility of the telemetering system at sea was under their auspices.

During the entire operation every courtesy and assistance that the ship's officers, scientific personnel, and crew could extend to the party concerned with the work described was given freely and graciously.

Conclusions

From the past summer's work it would seem that a helicopter could very well help to improve the efficiency of magnetometer surveys conducted at sea. The success of the operation would however depend to a very large extent upon the quality of the equipment used. As the system described is not completely automated, a great deal would also depend upon the skill and initiative of the personnel involved.

References

Collett, L. S., and Sawatzky, P.
1966: The Serson Direct-reading proton free precession magnetometer: Part I - Shipborne use; Geol. Surv. Can., Paper 65-31.

Washkurak, S., and Sawatzky, P.
1966: Part II - Airborne use with telemetering and automatic diurnal correction; Geol. Surv. Can., Paper 65-31.

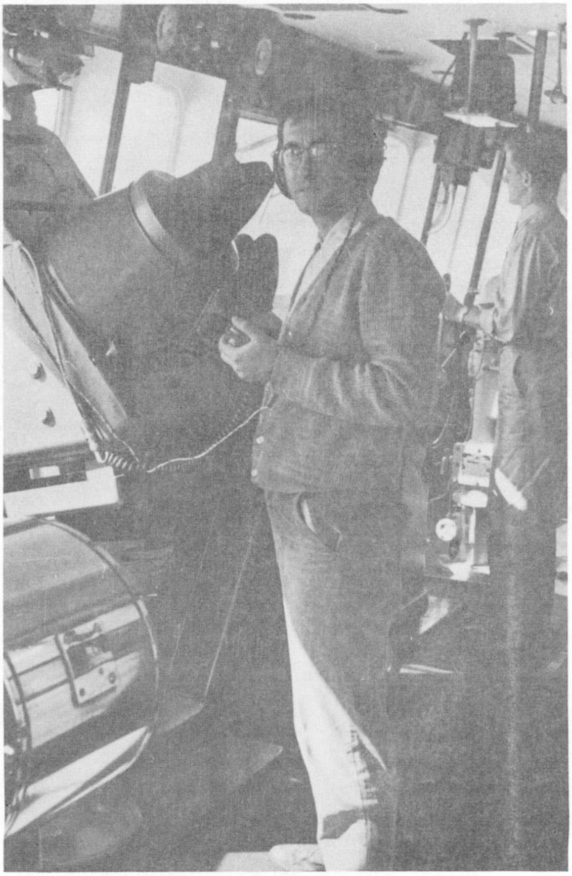


Plate 1. The model 45 Decca radar that was used to control the flight path of the helicopter

Plate 2. A front view of the helicopter showing the boom attached to the aircraft and the sensing head in the foreground

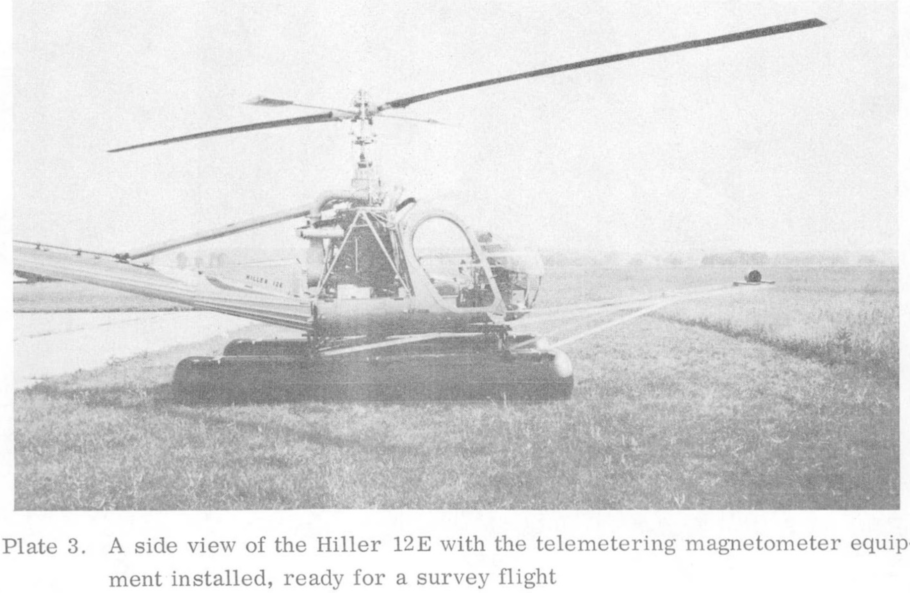


Plate 3. A side view of the Hiller 12E with the telemetering magnetometer equipment installed, ready for a survey flight

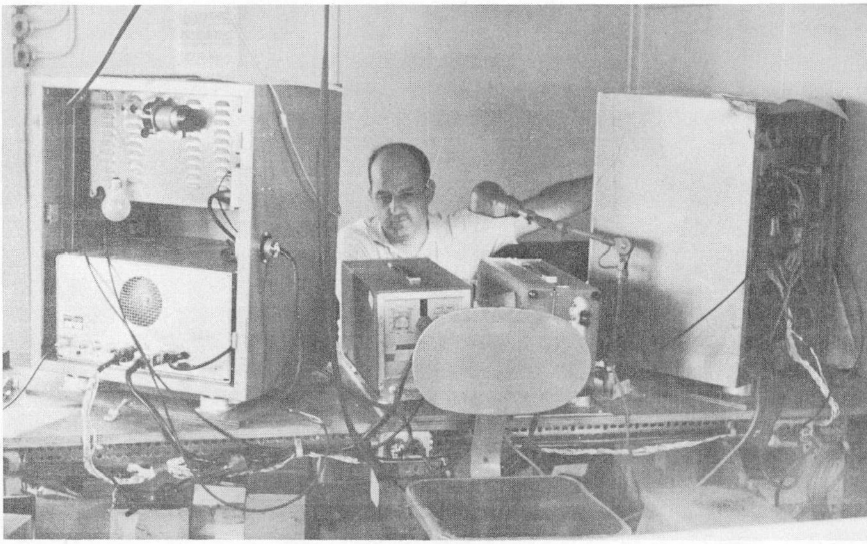


Plate 4. A rear view of the station magnetometer located on the ship

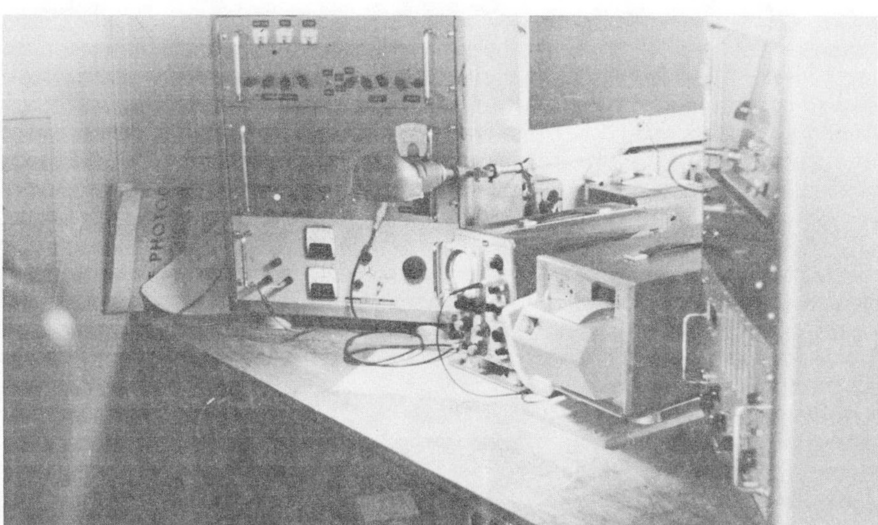


Plate 5. A front view of the station magnetometer

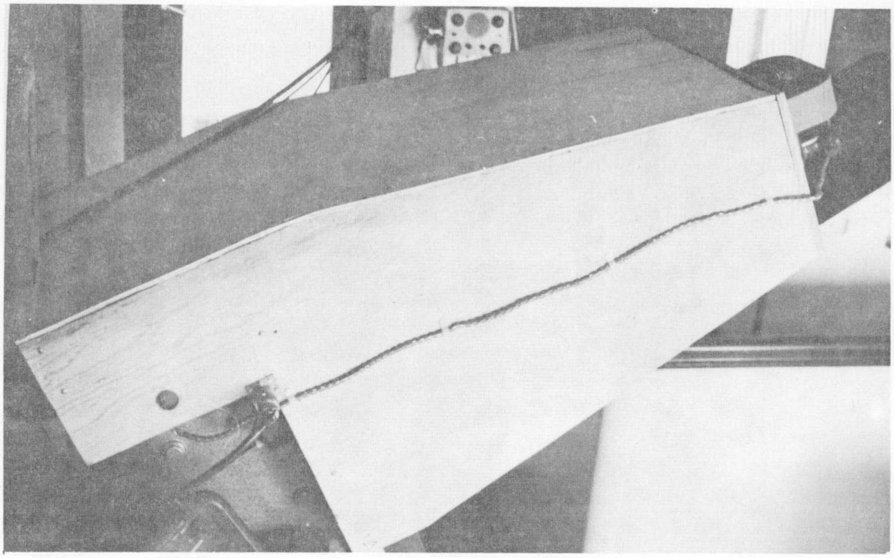


Plate 6. A top and side view of the box that enclosed the model 45 repeater radar

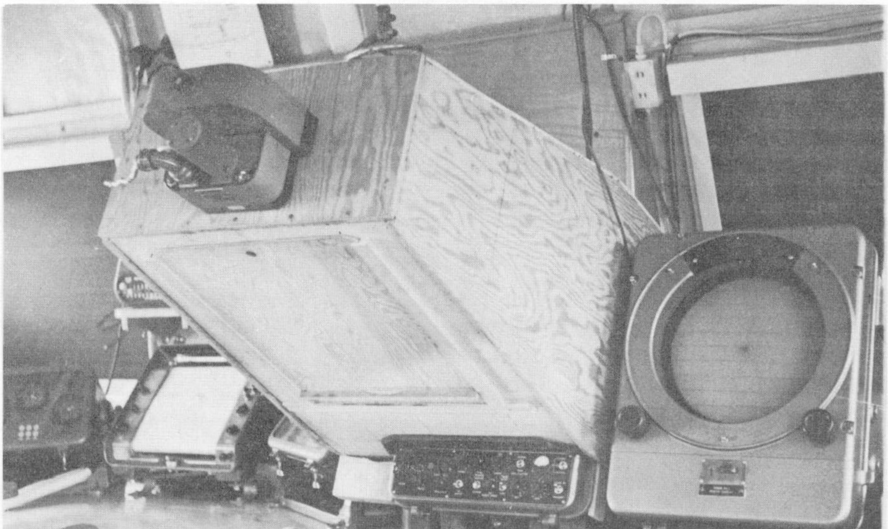


Plate 7. A front and side view of the box enclosing the model 45 repeater radar, showing the camera with the sliding hatch closed, ready for operation

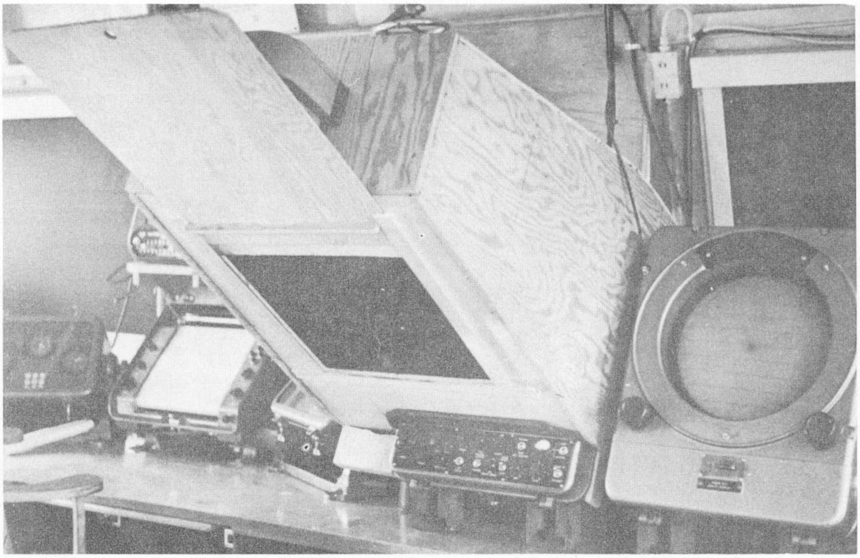


Plate 8. A front and side view of the camera installation with the sliding hatch open, required to adjust to the radar and other instruments located beside the radar screen

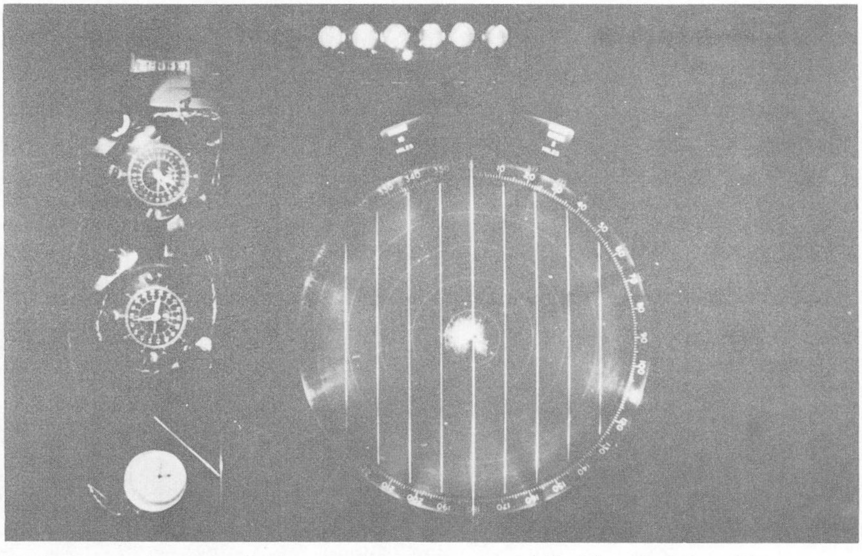


Plate 9. A photograph showing the instruments that located the ship, see Figure 1

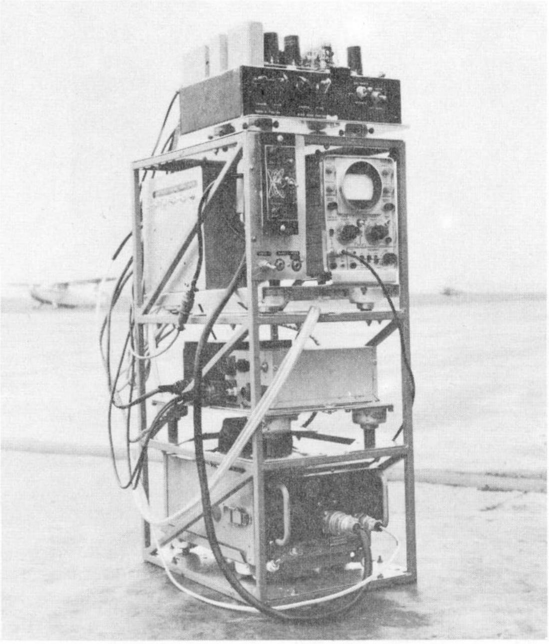


Plate 10.
A front and side view of the magnetometer rack showing the location of the various instruments

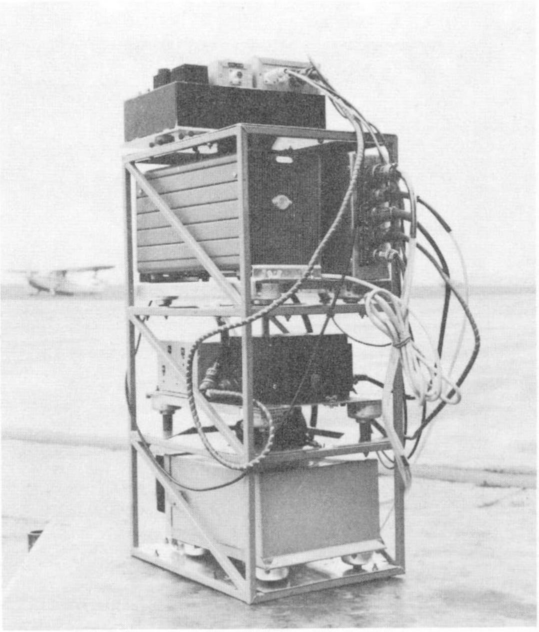


Plate 11.
A rear and left side view of the magnetometer rack

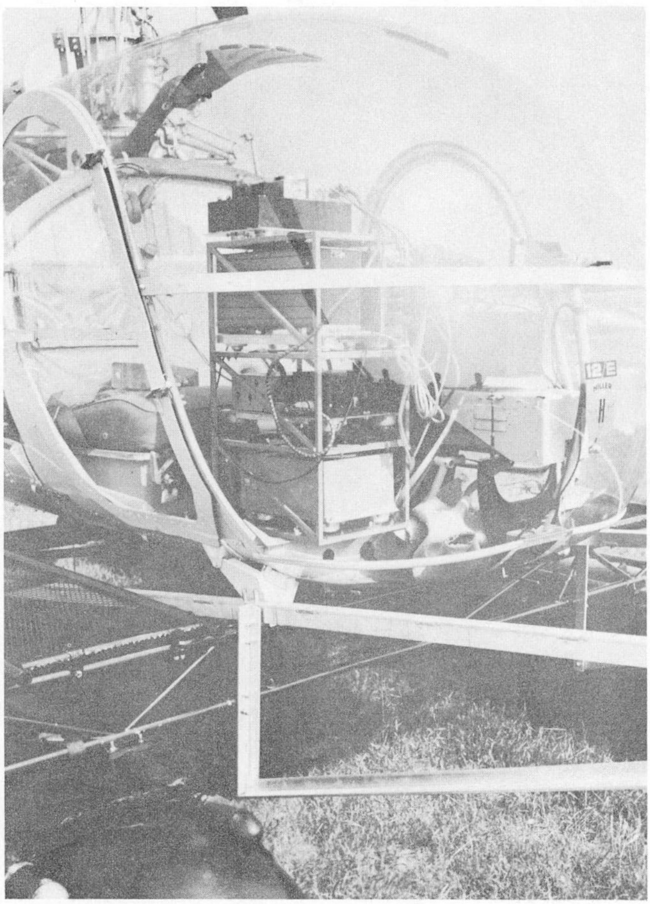


Plate 12. A close up view of the Hiller 12E showing the telemetering magnetometer rack installed in the aircraft

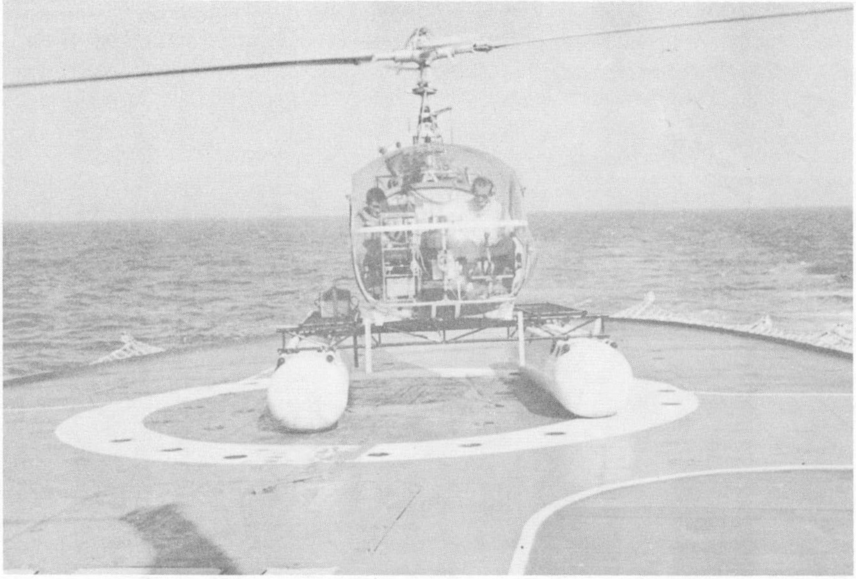


Plate 13. A view of the helicopter prior to take-off on the flight deck of the survey ship. Note the transponder mounted on the right hand cargo rack. The transponder antenna is the black tube beside the right hand float