RESTRICTED

THE R.C.A.F.
OBSERVER

Vol 2 No 3 July 1956

Contents

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The RCAF
OBSERVER
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We received a letter the other day that warmed the cockles of our heart. It was a short letter telling us of a change of address, but it was also a warm and welcome letter for it added, "I find the Observer most interesting and informative, keeping one up to date in his branch".

We don't want you to think us vain, but such a letter does give the staff a new lease on life. Month after month the work goes on and at times we begin to wonder whether this magazine, prepared so painstakingly, is of any benefit to our readers.

A little encouragement goes a long way, but more than that we are always interested in hearing from our readers, be it complimentary or adverse. If we don't hear from you we can only assume that our publication meets with your approval.

It is very easy for you, as a reader, to sit back and say"This article isn't of much use to me,why don't they publish what I want to know?" It is something else again to sit down and write us a letter telling us what you want to know!

In closing, we could not do better than to quote Abraham Lincoln when he said, "He has the right to criticize who has the heart to help".

OBSERVERS

Past & Present

By Squadron Leader C.L. Heide, DFC, CD,
Air Force Headquarters

PART TWO

The era between the World Wars was the golden age of aircraft pioneering and the Observer or Navigator - both names were used and were generally synonymous - played his full part. The 1914-1918 War had shown, to those who wished to see, that there was no limit to the range and altitude to which future aircraft could be flown, and that the potentials of civil and military flying were fields waiting to be exploited. There was no lack of men with the vision and foresight to attempt the hitherto impossible in aircraft that demanded the utmost in fortitude.

In June, 1919, Alcock and Brown took off on their historic transatlantic flight from St. Johns, Newfoundland, to Ireland in a Vickers Vimy. Brown, the navigator, had decided on a direct heading across the ocean. As navigation aids he had a bubble sextant, a driftmeter, and a radio set the generator for which was driven by a small propeller fixed to the wing. Although good weather had been forecast they ran into dense fog almost immediately after take-off. Then the radio went dead. Brown climbed out of his seat and on to the wing to look at the radio propeller which he found to be irreparably broken. He was forced to navigate solely by dead reckoning. The weather continued to get worse; fog snow, and sleet held until near dawn. Several times Brown had to crawl out on to the fuselage during the storm to clear the glace face of the gasoline overflow gauge. Shortly before dawn the weather cleared and the navigator was able to get a fix on Vega and Polaris which showed that a southerly correction was necessary. Just after eight o'clock in the morning the aviators landed in an Irish bog to complete, in sixteen hours, the first non-stop transatlantic flight.

In the decade following the First World War the pioneering flights in aviation were nearly all made by civilians. The rush for disarmament depleted the air forces of the United States and Great Britain to the point where they were barely subsisting, having neither the manpower nor material to undertake any record-breaking flights.

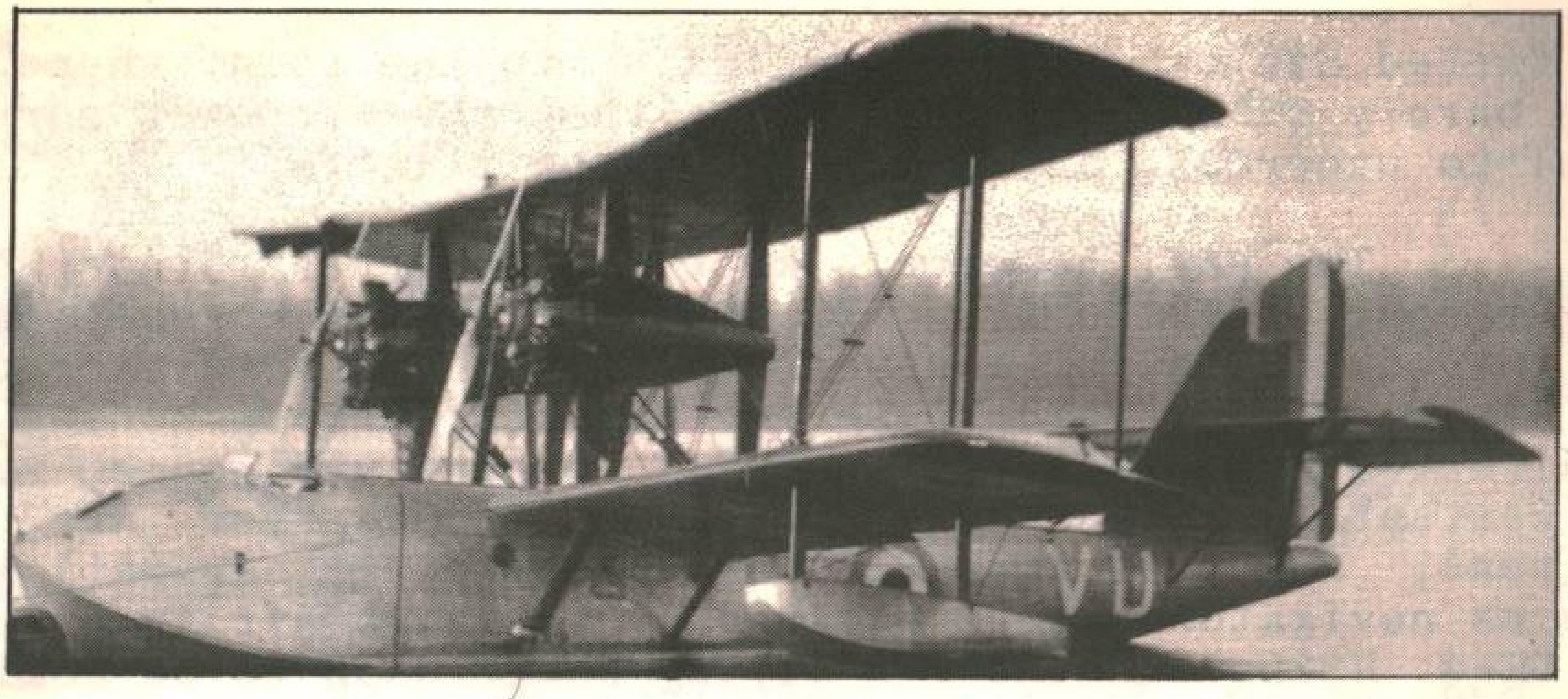
The RAF, however, kept the Observer trade advancing steadily if slowly. In 1925 the Hawker Horsely bomber was introduced,having a speed of 126 mph and a service ceiling of 15,000 feet. The Observer had his dead reckoning plus an airspeed indicator, altimeter, temperature gauge, radio, and sextant. In the RCAF the trade of Observer was non-existent; a few of the pilots specialized in navigation and flew as navigators when required. The aircraft in use were the DH-4, HS2L, and the F-3 flying boat, soon to be followed by the Vickers Vancouver flying boat.

Two United States Army Air Force aviators made the first flight from the USA to Hawaii in 1927. In a single-engine Fokker C-2 Lt. Maitland, with Lt. Hegenberger as navigator, took twenty-six hours to cover the 2,418 miles. Radio beacons had been set up in California and Hawaii beamed to meet over the ocean and coded with "A" on one side and "N" on the other. These were the forerunner of our present L/F Radio Ranges. Needless to say, Hegenberger's radio set did not work for the majority of the flight. Skilful use of the sun, driftmeter, and dead reckoning brought the Fokker directly into Hawaii.

The following year the famous Australian aviator, C. Kingsford-Smith, in a tri-motor Fokker navigated by Henry Lyon, an American, made a complete transpacific crossing. The "Southern Cross" flew from California to Honolulu;thence an unprecedented flight of 3,000 miles to Suva in the Fiji Islands; and finally to Brisbane, Australia.

It was only natural that the transoceanic crossings should be followed by round-the-world flights. The first of these was made in a single-engine Lockheed, the "Winnie Mae", piloted by Wily Post and navigated by Harold Gatty, one of the foremost pioneers in the art of navigation. In 1931, in just over eight and one half days,they flew from

DH-4



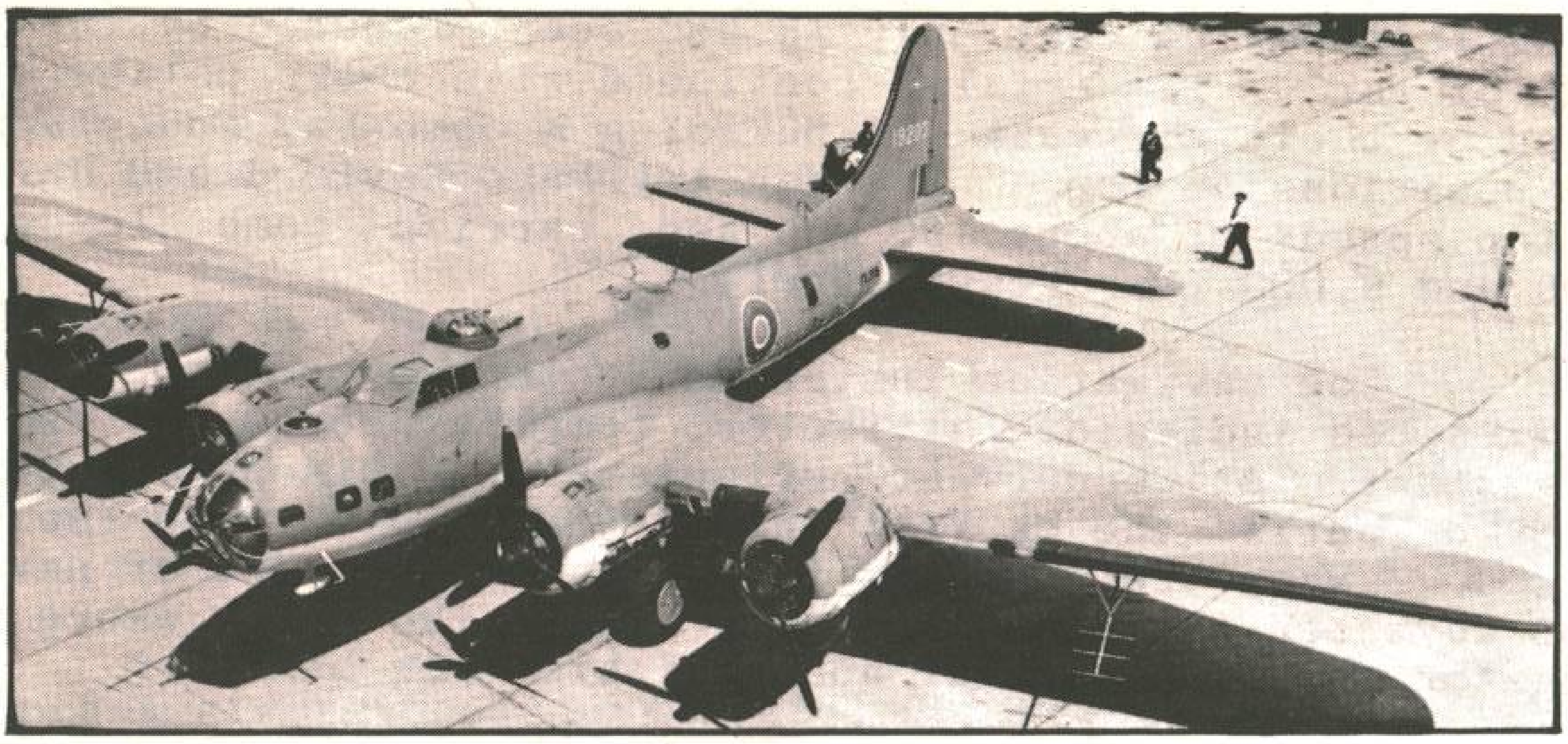
VICKERS VANCOUVER

New York to Newfoundland, to England, to Berlin, then to Moscow, across the USSR, to Alaska, and back to New York.

During the same year Herndon, with Clyde Pangborn as navigator, made the first crossing of the Pacific from Japan to the USA. Their Ballanca was loaded with fuel tanks in every conceivable location. The fixed landing gear was removed on the ground and bolted on with wires leading to the cockpit. After take-off the wires were pulled and the gear dropped. The aircraft ran into a thick storm, picking up heavy ice which made the fuel consumption dangerously high. In this storm, at 17,000 feet, Pangborn climbed out on to the wing, clung on with one hand and patiently unscrewed the remaining struts of the landing gear allowing them to drop into the sea. The Ballanca carried no radio, no dinghy, and only rudimentary navigation equipment. During the early days of World War II the writer was fortunate enough to fly with Clyde Pangborn on the Transatlantic Ferry Command, and asked him how he navigated on this historic flight. His answer: "We pointed her nose and let her go". They crash-landed at Wenatchee, Washington.

The decade following 1930 saw rapid advancement in the performance of aircraft, although generally the civil aeroplanes outpaced those of the military. The science of navigation progressed very slowly. Not until the stimulus provided by the outbreak of another war, combined with the invention of radar, did navigation make the giant strides that allowed it to advance to the state we know it today. However, as far back as 1926 Commander Byrd's tri-motor Fokker which flew over the North Pole for the first time carried three types of compasses: two magnetic compasses, an earth induction compass, and a Bumstead Sun Compass.

The USAAF introduced the B-10 bomber in 1932. With a top speed of 207 mph, service ceiling of 24,000 feet, and bomb capacity of 4,000 lbs., this was a definite advancement in the bomber field. Fast, single-engine aircraft were show-



BOEING B-17

ing great improvements in speed. A Supermarine seaplane, flown by J. Boothman, won the Schneider Trophy race in 1931 with an average speed of 340 mph.

The operation of aircraft at very high altitudes was demonstrated most effectively in 1933 when a single-engine Houston-Westland, flown by S/L The Marquess of Clydesdale with L.V. Blacker as observer, took aerial photographs of Mount Everest. The primary occupation of the observer was the operation of the cameras. Clothed in electrically heated suits, with boots, gloves, and goggles, the aviators left the ground in prodigious perspiration, cooling gradually as they climbed until they were working under the most intense cold in the open cockpits.

Blacker states: "On we went up to 31,000 feet, the mountain getting ever closer, and now I started busily taking oblique photographs of these unexplored declivities, ridges, and ranges which run south-west from Everest. This was indeed to be the main prize of our flight, because it is precisely these aspects of the massif that are unknown to science. ...my own task kept me hard at work indeed, panting for breath and racking my lungs to fill them with oxygen ... Meanwhile the mountain came ever closer, bare and clear in the wonderful atmosphere and free from cloud, except for its great plume, now bigger than ever. In the crystal clear weather I was delighted with the view over great Khumbu glacier and the terrific ridges which bound it. ...although without oxygen till 18,000 feet, neither of us felt any ill effects. We feel that we have accomplished our task - to demonstrate that inaccessible country may be photographed from the air at extreme heights."[1]

The famous USAAF bomber of the Second World War - the B-17 - first flew in 1935. It speaks volumes for the air policy of those guiding military thinking in the USA during this period that only 13 had been produced by the outbreak of war. The British continued with their policy - as stated by their aircrews -of building a bomb-bay and placing crew positions on top. The Handley-Page Heyford and Harrow had top speeds of about 190 mph and carried bomb loads of 7,000 and 9,000 lbs. respectively.

The navigation instruments in use continued to be the airspeed indicator, altimeter, temperature gauge, radio, and sextant. All underwent refinement with time. Sextants improved until the Mk VIII which was in use when the war started. Many refinements in the theory and art of navigation advanced its speed and accuracy to the point where the navigator was an essential and reliable crew member.

Air Chief Marshal Sir Philip Joubert's recollections of 1937 may sound familiar to many observers today: "On the flight from Marseilles to Malta I saw, for the first time, how a good navigator goes about his business. In this region weather conditions lead to many changes of wind, and young Dunne, our expert, was the busiest man I have ever seen in a lifetime. During the seven hours of the flight he was never still. At one moment he would be in the foreward gunner's position taking a drift with his bombsight. At the next he was aft, throwing out a sea marker on which to take a tail drift with a hand compass. Then to his chart table, where he would make his calculations. The Captain of the aircraft sat peacefully, keeping a mild eye on the working of the automatic pilot, while the crew...were reading, gossiping, or sleeping off the effects of the previous night's party."[2]

The USSR was not inactive during this period, especially in the art of polar navigation. In 1937 a single-engine Ant 25, piloted by V. Chkaloff and navigated by A. Beliakoff, made a transpolar flight from Moscow to Vancouver

WAPITI

Washington. Their aircraft had a speed of about 125 mph, carried a radio, and was equipped with oil anti-ice defrosters on the wings and propeller.

During the late 1930's the RCAF was flying such aircraft as the Wapiti, Shark, Avro 626, Fleet, Delta, and Fairchild. The pilots continued to take supplementary courses in navigation, wireless, and armament. There was no other aircrew trade until shortly before the war when that of Air Gunner was introduced. The gunners were not commissioned and wore a silver bullet with wings on the sleeve.

On the outbreak of the Second World War the RCAF claimed a strength of just over 4,000 personnel and 270 aircraft. This was soon to change drastically as plans for the British Commonwealth Air Training Plan were drawn up which called for 10 Air Observer Schools, 10 Bombing and Gunnery Schools, 2 Air Navigation Schools, and 2 Wireless Schools to be in operation by April of 1942.

In the concluding article of this series we shall attempt to trace the impact of war and its aftermath on the history of the Observer.

1 - First Over Everest - PFM Fellowes, Lane and Head, London 1933.

2 - The Fated Sky - A/C/M Sir Philip Joubert, Hutchinson, London, 1952

ANSWERS TO NAV QUIZ

1 W/V of 270/50 is affecting both aircraft. Plot your TH and TAS and from the air positions at 1513 and 1529. Lay off the relative bearings and distances of the other aircraft, giving a TH of 005T and TAS of 244K. Tolerance of ±5 on each.

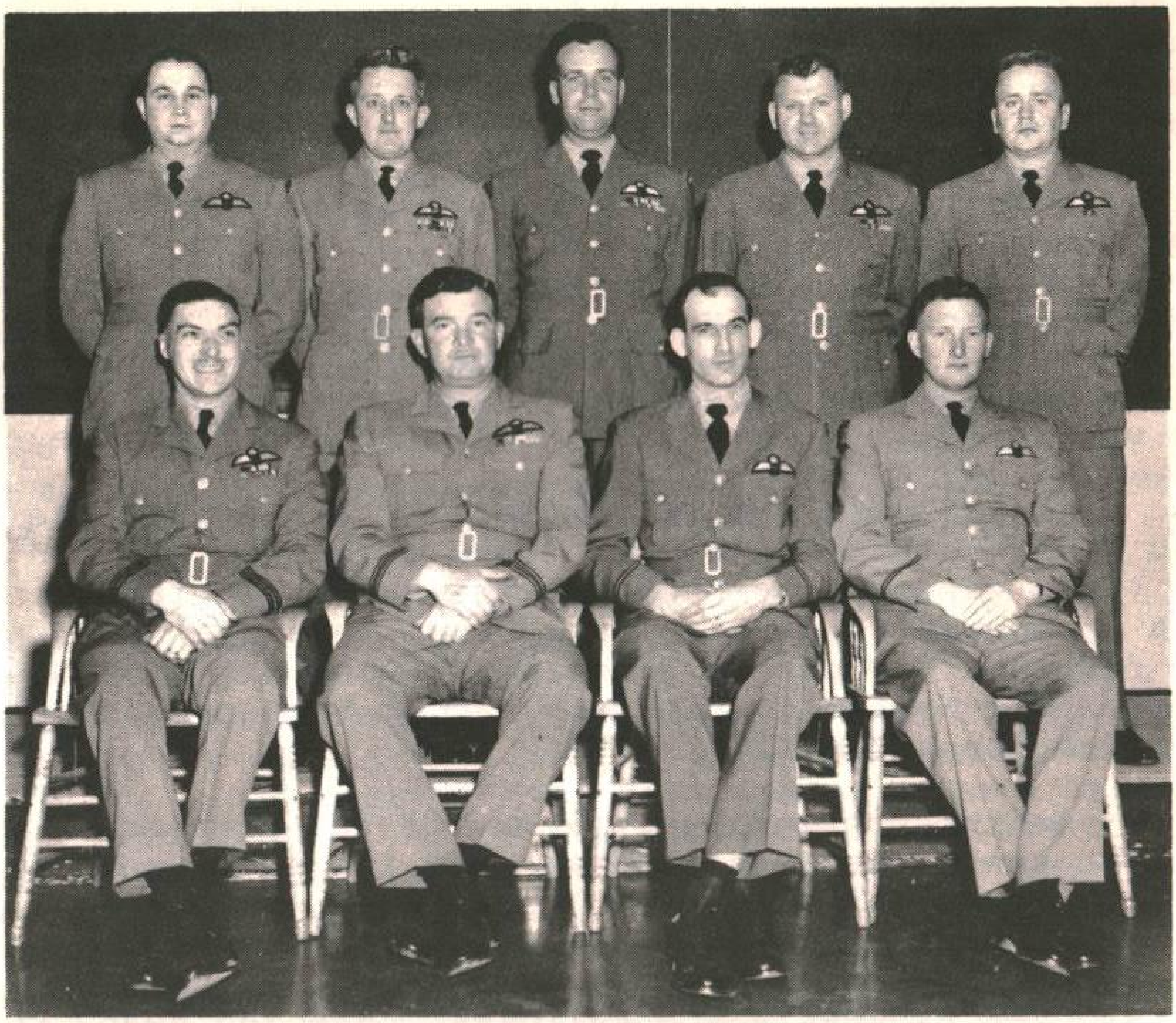
2 $\frac{\text{New Deviation}}{\text{Old Deviation}} = \frac{\text{Old Distance}^3}{\text{New Distance}^3}$ $\therefore$ New Deviation $= \frac{8 \times 5^3}{10^3} = 1°$

3 Sucker Question. Critical mach number remains constant. Therefore the answer is .75!!

4 Ch Long $= \frac{MC}{\eta} = \frac{34}{.64} = 53°$E. $\therefore$ Ref. Mer. $= 75+53 = 128°$W.

5 MC $= \eta \times$ CH Long
$= .6304 \times 63$
$= 39.715°$

6 15.04 x Sin Lat/Hr
15.04 x .707 = 10.633°
15.04 x .866 = 13.024°
23.657°



13 SROI COURSE

13 February 1956 - 8 June 1956

Back Row

F/O KA MacKay F/L JLJ Fontaine F/L AR Westgate F/L D Porayko
F/L AA Pulfer

Front Row

F/L WD Lyall F/L ADJ Delmotte F/O EE Haenni F/O DHG Rowden

Transistors

By Flight Lieutenant H. A. Llewellyn,
Central Navigation School

The most outstanding development in the science of electronics since the end of World War II has been that of the transistor. The transistor has progressed in the short period of seven or eight years, from an interesting laboratory toy with recognized possibilities to a real threat to the very existence of vacuum tubes. If the present rate of development of transistors continues, it is predicted that within two or three years all receiving-type tubes and low-powered transmitting-type tubes will be replaced in all new equipment by transistors.

A transistor is an amplifying device, similar to a vacuum tube. However, don't expect to buy transistors to replace the notorious, power-consuming vacuum tubes in your present receiver - the two are not compatible. The principles of operation are different - a vacuum tube is dependent upon voltages and voltage changes for operation whereas a transistor is dependent upon current and current changes. Generally speaking only transistor amplifier circuits and vacuum tube amplifier circuits are similar.

The purpose of this article is to outline briefly the action of a transistor and to point out some of the advantages and limitations of these devices. The significance of these characteristics should be of interest to all aircrew for the use of transistors in airborne electronic installations will make no small contribution to increased performance and capabilities of modern aircraft.

To save space in this article, it is assumed that the reader has a basic understanding of the structure of matter, electric charges, conductors and insulators, and the operation of the vacuum tube.

TRANSISTOR OPERATION

Semi-Conductor Materials

Certain crystalline substances, notably germanium and silicon are classified as semi-conductors of electricity; that is, they are neither good conductors nor good insulators. In the copper atom there is one electron in the outermost orbit which is outside a complete orbit of 18 electrons. This single electron is called a 'free electron' and may be removed from the atom with relative ease. The free electrons available in a copper wire make it the second best conductor of electricity - only silver is better. Insulators on the other hand have nearly a complete outer orbit of electrons and hence will not give any free electrons. The semi-conductors, germanium and silicon, lie midway between conductors and insulators, having four electrons in their outer orbit.

Most atoms 'like' to have eight electrons associated with their outer orbits. To reach this condition they will either give up one or two electrons or accept one or two electrons and thus enter into chemical combination with other atoms. Pure germanium or silicon also have this 'desire' but instead of actually 'capturing' or 'releasing' four electrons they share four electrons with four neighbouring germanium or silicon atoms and build up a crystal lattice. The atoms are held together by the 'sharing' of electrons in the outer orbit. We may represent these electrons in the outer orbit by means of hooks and sketch a schematic diagram of a portion of a germanium crystal as is shown in Figure 1.

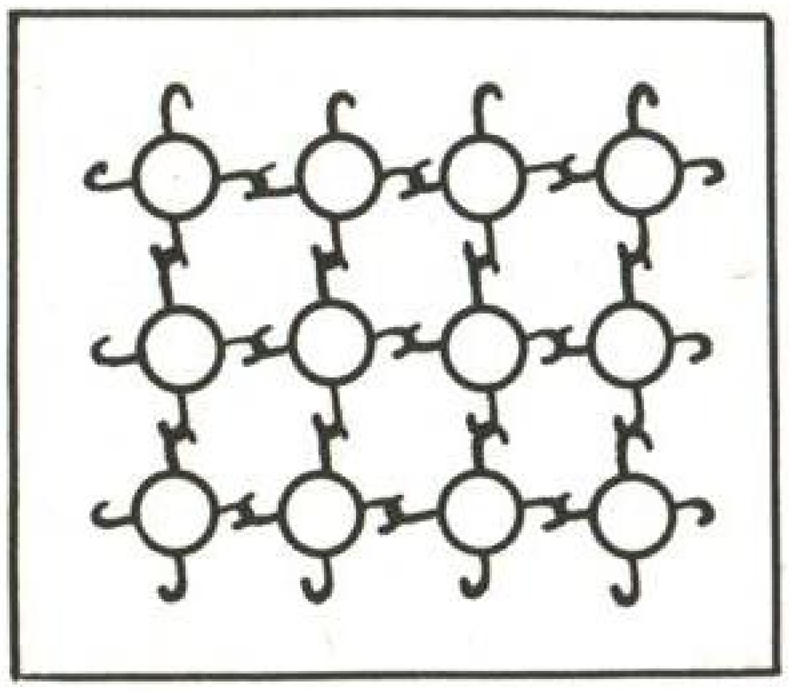


FIGURE 1

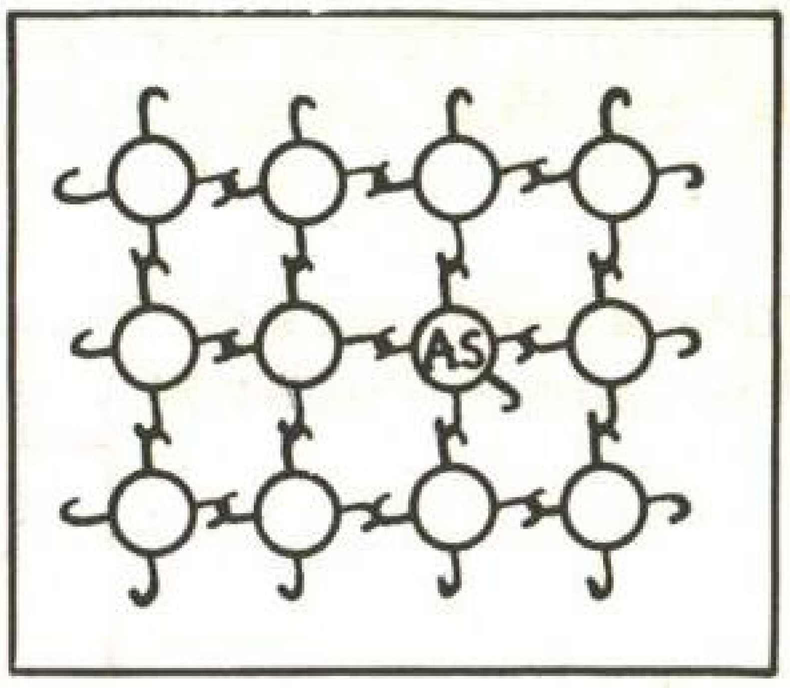
SCHEMATIC DIAGRAM OF A GERMANIUM CRYSTAL

N-Type Material. If molten germanium is mixed with a small quantity of arsenic (which has five electrons in its outer orbit) the arsenic enters into the lattice structure when the mixture is crystallized. In this case, however, there is still a spare electron from each arsenic atom which is not shared in the structure so in effect, we have free electrons in the germanium-arsenic mixture. (Figure 2).

The germanium - arsenic combination is called N-type or 'negative' type material because of the surplus electrons or negative charges. Sometimes the N-type impurity is called a 'donor' because its atom donates an electron for current carrying qualities through the semi-conductor.

FIGURE 2

SCHEMATIC DIAGRAM OF A GERMANIUM CRYSTAL CONTAINING ARSENIC IMPURITY



P-Type Material. If, instead of mixing arsenic with the germanium, indium or boron is added the resulting material is classified as P-type. The outer orbit of indium or boron contains only three electrons, hence when the crystal is formed one of the germanium atoms has only three electrons to share in its outer orbit. The deficiency of the electron is referred to as a 'hole' for, indeed, it is a hole in the crystal lattice structure. (Figure 3)

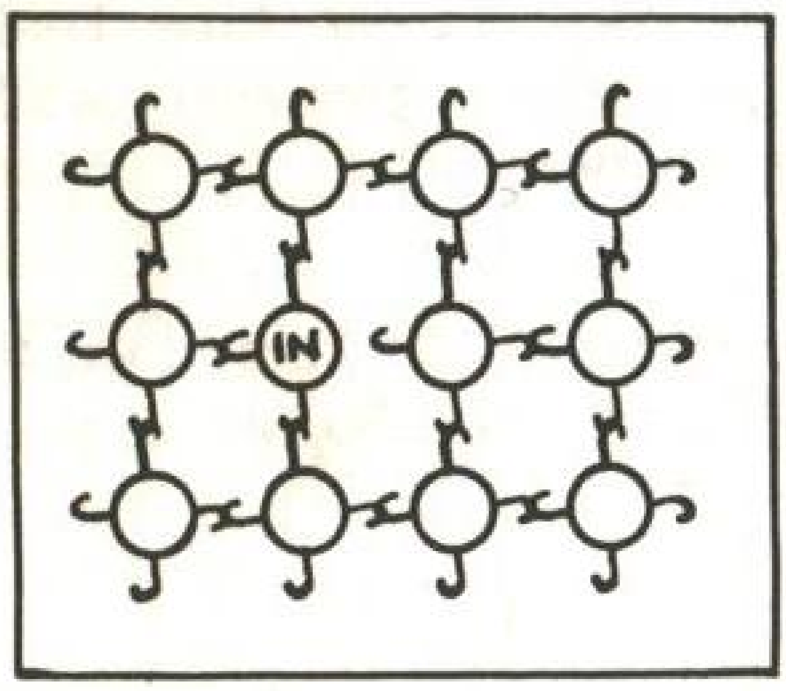


FIGURE 3

SCHEMATIC DIAGRAM OF A GERMANIUM CRYSTAL CONTAINING INDIUM IMPURITY

The holes in the P-type material act much like the electrons in the N-type material. An electron can be 'borrowed' temporarily to fill in the hole causing a temporary hole elsewhere in the lattice.

The PN Diode Junction

If a block of P-type material is fused to a block of N-type material a PN junction, which has characteristics similar to a diode, is formed. If the P-type material is connected to a positive polarity and the N-type material is connected to a negative polarity, then the 'carriers' (electrons in the N-type and holes in the P-type) are repelled toward the boundary between the materials. (Figure 4)

With the forward voltage applied, the different carriers were repelled to the junction where the holes accept electrons and the electrons readily fill in the holes. This upsets the equilibrium inside the crystal as far as the individual atoms are concerned, so the battery must draw off extra electrons from the P-type material (i.e. restore the number of holes) and additional electrons must be supplied to the N-type material to make up for those which were captured by the holes at the junction. The battery removes electrons from one side of the junction and supplies electrons to the other side, hence current flows.

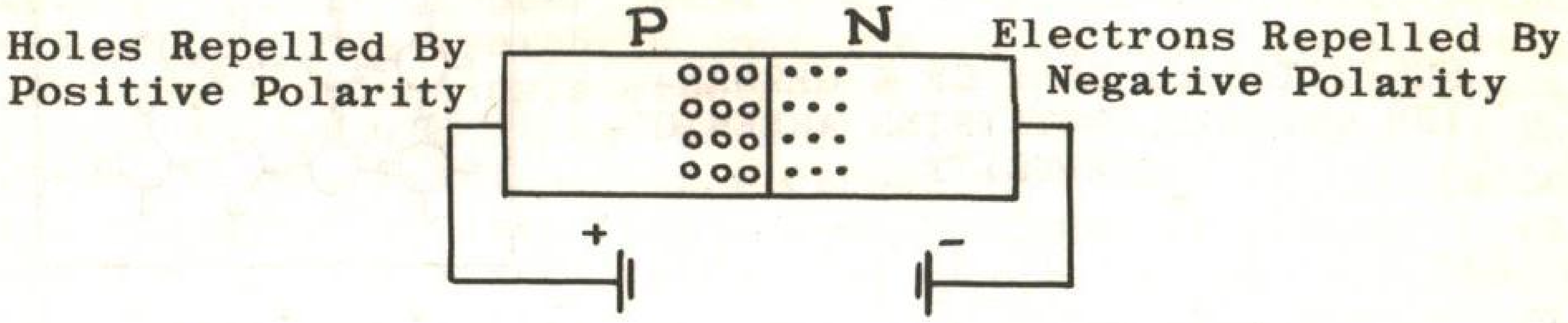


FIGURE 4 CONDITIONS EXISTING IN A P - N DIODE WITH A FORWARD VOLTAGE APPLIED

If the connections are reversed the negative potential applied to the P-type material draws the holes away from the junction and similarly the electrons are drawn away from the junction in the N-type material. Thus there is no opportunity for the holes and electrons to meet and hence, for all practical purposes, no current flows from the battery. (Figure 5). (Actually a small inverse current will flow but for practical purposes it can be ignored.)

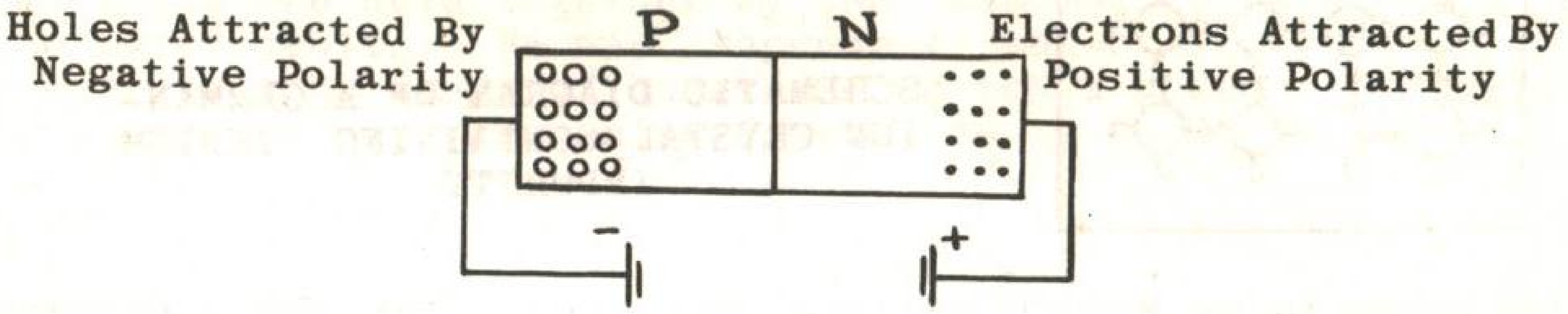


FIGURE 5 CONDITIONS EXISTING IN A P - N DIODE WITH AN INVERSE VOLTAGE APPLIED

From the above reasoning, it is plain to see that the single PN junction acts just like a thermionic diode - it permits current flow in one direction but prevents it in the opposite direction. This principle is used quite extensively in modern crystal detectors.

The 'Triode' Transistor

As is the case with the thermionic diode, the 'PN' diode produces no amplification. However, if the thermionic diode is modified by placing a wire mesh or 'grid' between cathode and plate it becomes a thermionic triode and a voltage applied between cathode and grid can then control the electron flow to the plate. A relatively small grid voltage change has an effect on the plate current equal to that produced by a very large change of plate voltage. Thus the thermionic triode is able to amplify small changes of grid voltages into much larger changes of plate voltage (if there is a load impedance in the plate circuit).

Similarly, to produce an amplifier using semiconductors, three sections are required in the transistor. The transistor may be made of a sandwich of two blocks of P-type material separated by a thin wafer, (.001" or less) of N-type material or vice versa. These may be referred to as a PNP transistor or an NPN transistor respectively (Figure 6).

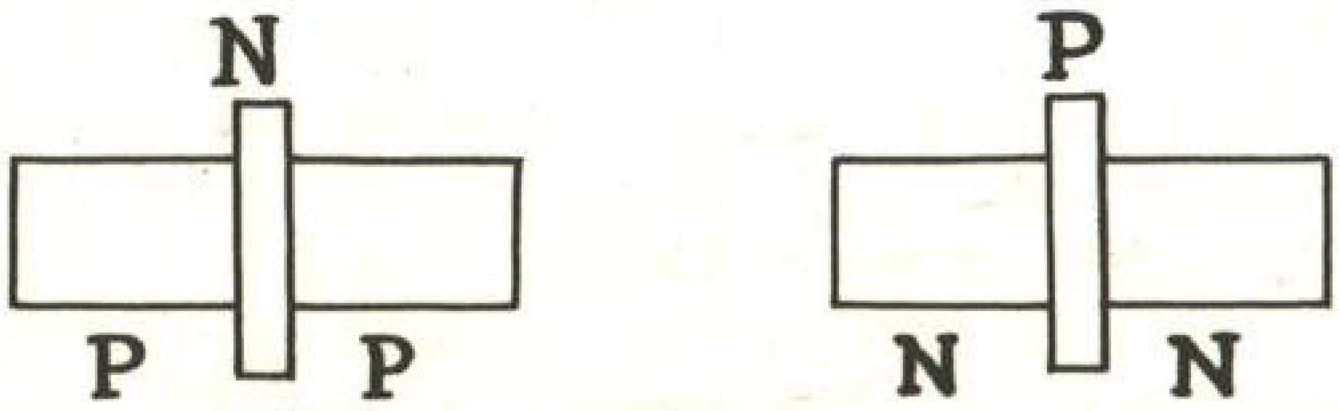


FIGURE 6 CONSTRUCTION OF PNP AND NPN TRANSISTORS

Action of the Transistor

In the transistor there are two junctions within the sandwich. One of these junctions is biased in the forward and the other is biased in the inverse direction. The biasing arrangement of a PNP junction transistor is shown in Figure 7.

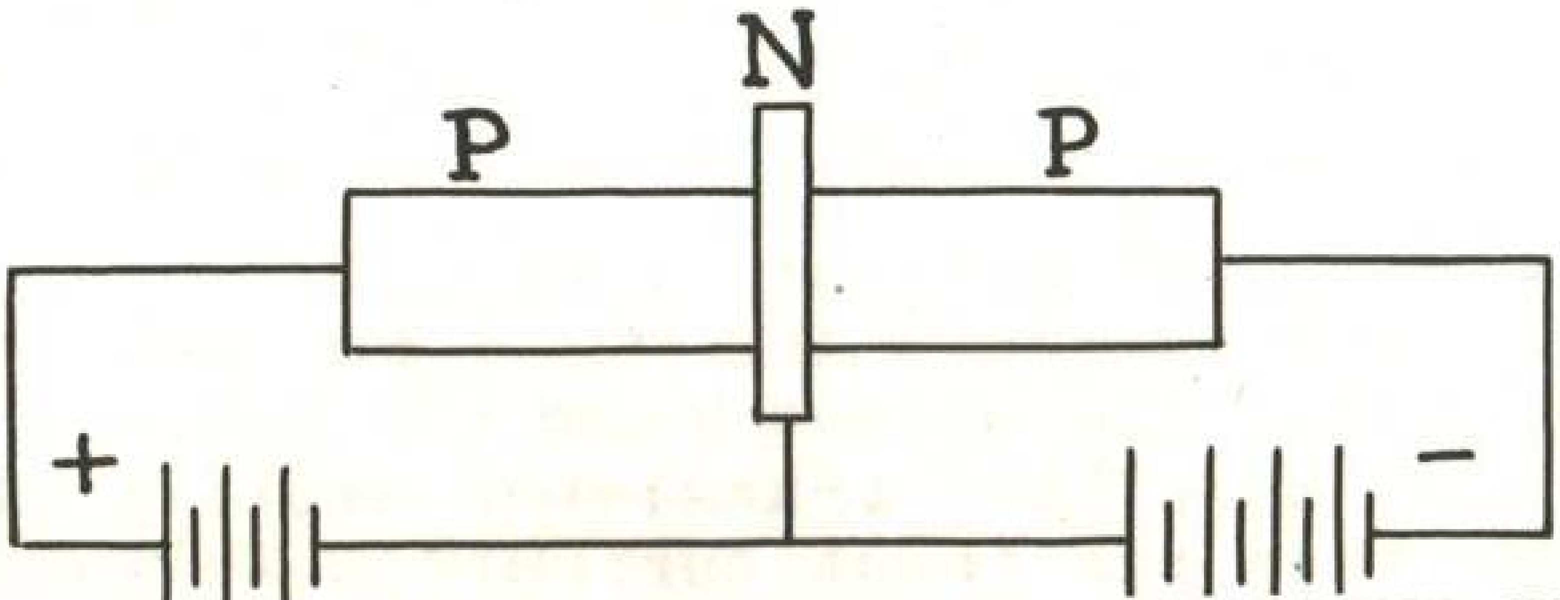


FIGURE 7 BIASING ARRANGEMENT OF A PNP TRANSISTOR

In figure 7 the left junction is biased in the forward direction and hence the holes in the P-type material are repelled toward the junction. Similarly, the electrons in the N-type wafer are repelled toward the junction. With the P-type material 'doped' more heavily than the N-type material, there just aren't enough electrons available to satisfy all the holes coming from the P-type material. It must be remembered that the N type wafer is extremely thin, and so any holes entering the N-type material soon drift into close proximity to the second junction.

The second junction is biased in the inverse direction (ie all the holes in the material are drawn away from the junction). However, the heavy concentration of holes in the N-type material permits many of these holes to cross the junction into the second block of P-type material in exchange for electrons.

Before going any further, we should name the components of the transistor. From the above description it is seen that the P-type material biased in the forward direction provides holes to the N-type material, hence it is called the 'emitter'. It emits (or sends) holes to the N-type material. The middle component of the sandwich is, for some reason or other called the 'base'. Since in our discussion of the PNP transistor, the surplus holes in the base went to the other junction we call this second junction the 'collector' junction and its associated block of P-type material is called the collector. These three transistor components are analagous to the cathode, grid and plate respectively of a triode vacuum tube.

In operation, the relationships of base current, emitter current and collector current might be as shown in figure 8. The arrows represent electron flow.

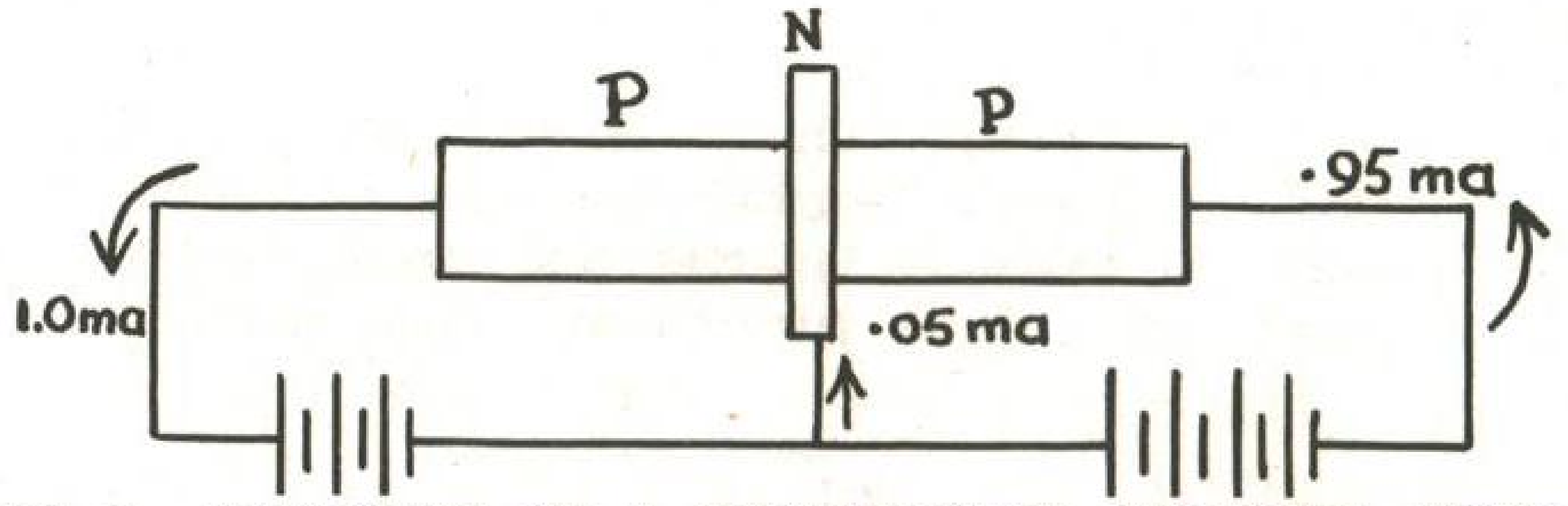


FIGURE 8 DIAGRAM OF A TRANSISTOR SHOWING COMPONENT CURRENTS

The emitter current is equal to the sum of the base and collector currents and so if we feed the input to the emitter and take the output from the collector the question arises, 'How does the transistor amplify if the output current is less than the input current?' The answer is relatively simple.

The emitter junction is biased in the forward and hence has very little resistance to current flow (say, for example, 500 ohms). The collector junction is biased in the inverse direction and hence has relatively more resistance (say, for example, 10,000 ohms). If the emitter current is changed by .1 MA it will require a change of .05 volts (500 x .1 MA = .05 volt) to accomplish this. This change of .1 MA in the emitter current will cause a change of .095 MA in the collector current. This change of current through the collector junction will cause a change of voltage of .95 volts (10,000 x .095 MA = .95 volts) across the collector junction if a suitable impedance exists in the collector circuit. Thus a change of .05 volts applied to the emitter causes a change of .95 volts in the collector circuit and amplification is accomplished.

The Significance of Transistors

The discussion of the action of the transistor has been simplified and limited to the junction type transistor. Also the concept of transistor circuit design has not been discussed so as to keep this article reasonably short. The only thing left to do now is to discuss the advantages and disadvantages of using transistors in airborne electronic systems.

It might be best to list the important characteristics of transistors and then to expand on the significance of these characteristics in the airborne application. The characteristics are rather loosely divided into two categories; electrical characteristics and physical characteristics.

Electrical Characteristics. There are six important electrical characteristics of transistors which might be listed as follows:

- Transistors require no heater power to 'boil' electrons off a cathode.
- Transistors generally operate on low voltages from 1 or 2 volts DC to about 50 volts DC.
- Power handling capabilities are measured in terms of milliwatts for signal amplifying transistors to tens of watts for power transistors.
- The frequency-power spectra of transistors in existence today is limited approximately as shown in Figure 9.

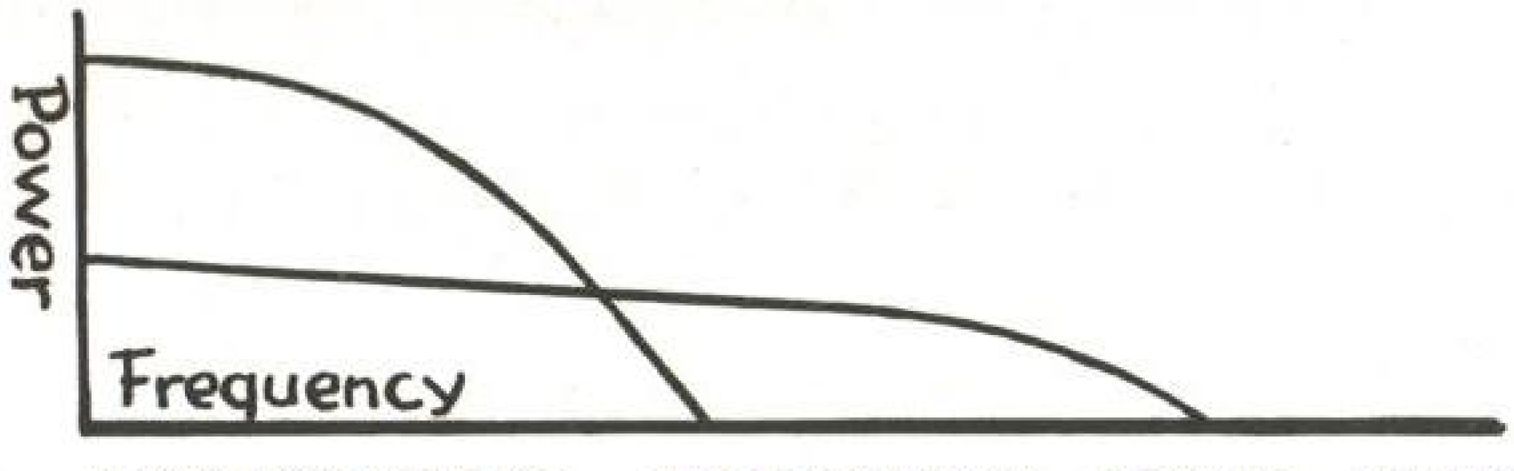


FIGURE 9 APPROXIMATE FREQUENCY POWER SPECTRUM OF EXISTING TRANSISTORS

- The operating temperature of transistors is quite critical. Germanium transistors can operate within the range of about 20°C to 65° C. At temperatures about 65°C the leakage current increases very rapidly for a small increase in temperature. In some cases, the transistor may destroy itself because increasing leakage current increases the temperature which in turn increases the leakage current and so on. Silicon has superior thermal characteristics but inferior electrical characteristics to germanium. However a 3 per cent silicon-germanium transistor permits an operating temperature range of 18° C to 95°C and has almost identical electrical characteristics to the pure germanium transsistor.

- The average life of a transistor is at least 10,000 hours with 70,000 hours (8 years of continuous operation) entirely possible.

Physical Characteristics. There are three important physical characteristics of transistors, two of which are extremely important when considering airborne electronic equipment for modern military aircraft. These three characteristics are:

- Transistors are very small - signal amplifying transistors are smaller than miniature and some subminiature tubes. Figure 10 shows the relative sizes of some signal amplifying and power transistors.

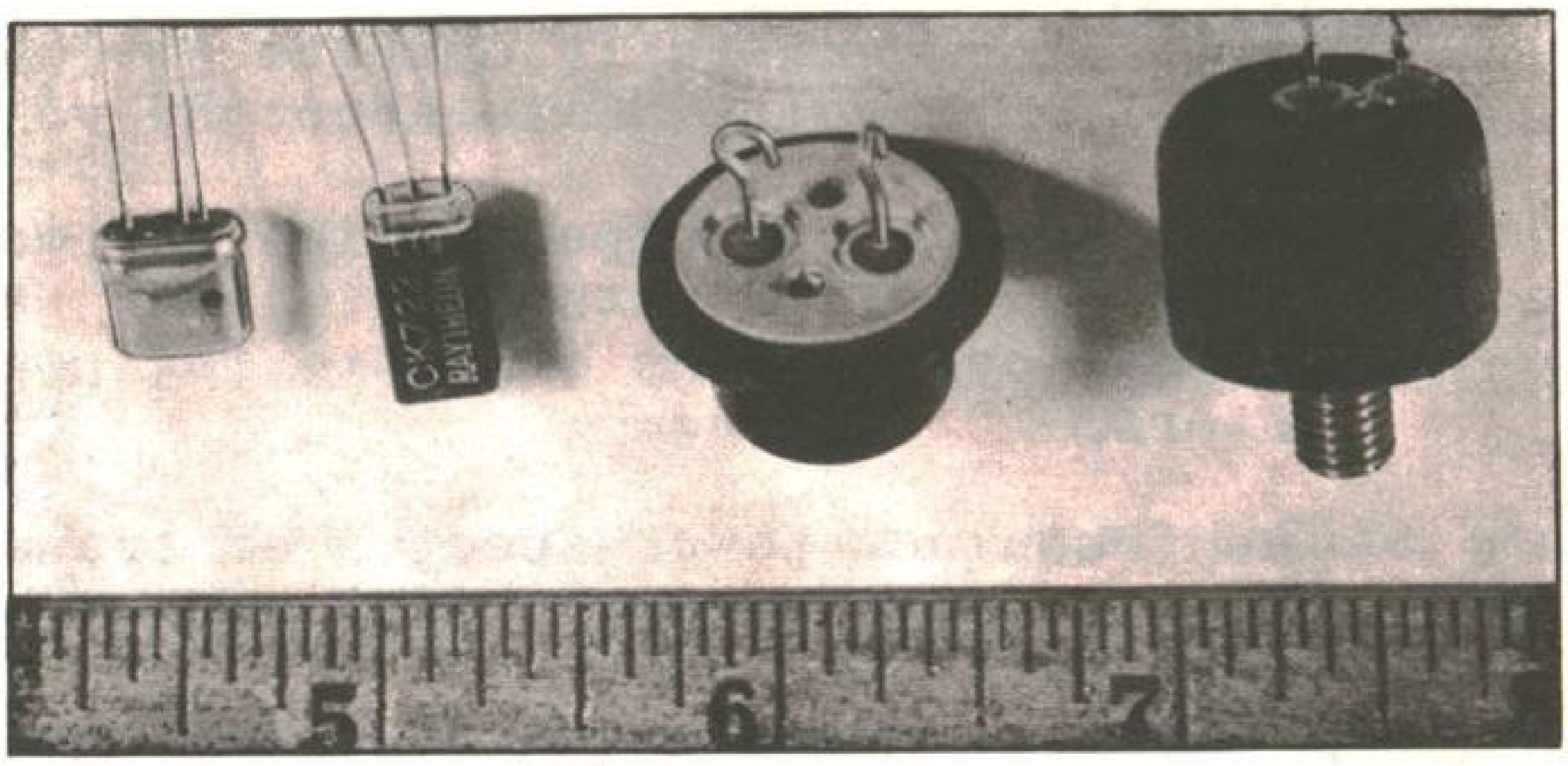


FIGURE 10 TYPICAL TRANSISTORS. THE TWO LARGE SPECIMENS ARE POWER TRANSISTORS

- Transistors have no delicate grid and cathode structures which must be protected from mechanical vibration and other acceleration.

- Transistors must be hermetically sealed in metal cases to prevent crystal contamination by moisture.

It is impossible to consider the characteristics of transistors individually when discussing their application to modern airborne equipment because in equipment design one characteristic may be complementary with or contrary to another characteristic.

The most important problem in airborne equipment is that of space and weight. Modern military aircraft are extremely limited in space available because of the large volume required for jet fuel and vital equipment. In addition, the 1 in 10 rule quoted by designers applies. The 1 in 10 rule implies that for each one pound of equipment added the gross weight of the aircraft will be increased by 10 pounds because of the heavier airframe construction necessary to accommodate the extra weight and the additional fuel required to give the heavier aircraft nearly the same range and speed performance. Transistors can help alleviate these problems in several ways.

First of all, the small size of transistors allow the equipment to be made physically smaller. In addition, the low power levels at which they operate permit the use of physically smaller components (ie one quarter watt resistors compared with one, two or five watt sizes required by existing vacuum tube circuits). In turn however,the use of low voltages means that large capacity capacitors must be used for inter-stage coupling. A completely new type of low-voltage, high-capacity capacitor of small physical size had to be designed and put into production. The use of these capacitors necessitates the design of new capacitor checking equipment because the high testing voltage used in existing designs will damage these low voltage capacitors. The small size of the transistors and associated components is most adaptable to encapsulated construction where all components are cast into a resin or plastic block. This method of construction protects the components from physical shock but it complicates the cooling problem.

Secondly, in terms of weight saving the transistor has several points in its favour. Since it operates on low voltage direct current it can use the aircraft primary power supply directly. This eliminates the need for heavy dynamotors to provide the high voltage DC necessary for vacuum tubes. With smaller and lighter components and power supplies, more circuitry for the same weight and hence greater capabilities are possible or the same capabilities may be had for much less weight.

A very dramatic illustration of the space-weight saving achieved by using transistor amplifiers is that found in a certain aircraft having 12 interphone stations with an amplifier at each station. Each transistorized amplifier weighs 11 ounces and the weight saving achieved by replacing the vacuum tube amplifiers was in excess of 100 pounds. Figure 11 is a photograph showing the relative sizes of the old vacuum tube amplifier and the new transistor amplifier which does exactly the same job.

Equipment reliability is an extremely vital problem in military aviation. Airborne electronic systems are be-coming increasingly complicated because of increasing capabilities and accuracies demanded of them. In modern navigation and bombing systems the relatively low reliability of vacuum tubes has been the major cause of unserviceabilities. Tracing one faulty vacuum tube in 200 or 300 becomes quite a task. By using transistors with an average life of 70,000 hours the equipment reliability will increase considerably. In addition component life would be of the same order in well designed encapsulated construction so it will be more economical to discard unserviceable modules than to attempt to repair them. Greater reliability has far reaching effects because fewer spares have to be bought and stored, fewer technicians are required for maintenance and a higher percentage of aircraft can be in operation at one time.

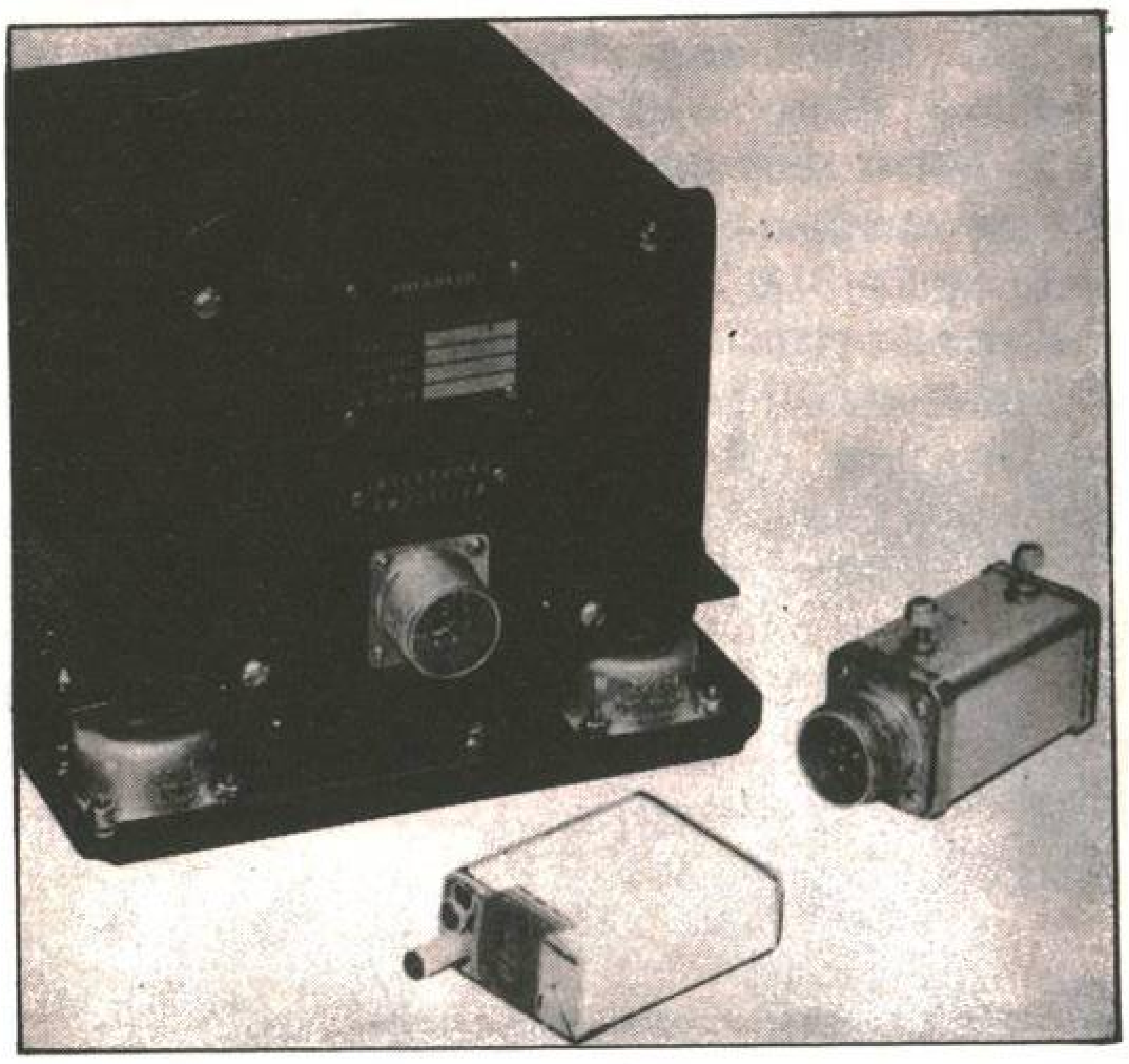


FIGURE 11 EXAMPLE OF THE RELATIVE SIZES OF A VACUUM TUBE INTERPHONE AMPLIFIER AND THE EQUIVALENT TRANSISTOR AMPLIFIER

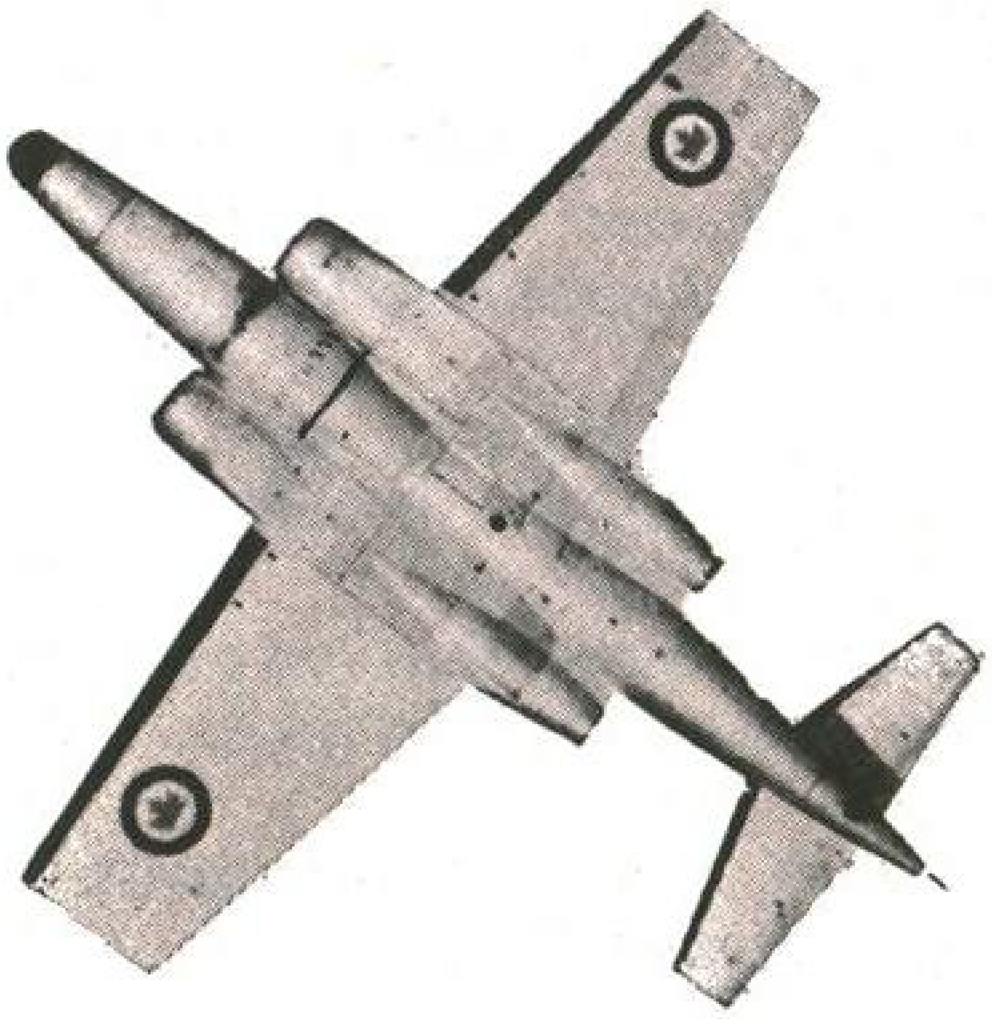
A problem of considerable magnitude which is really a factor in equipment reliability is one of cooling. The power required to heat the vacuum tube cathodes for thermionic emission also heats up the interior of the equipment. If this heat is not removed component ageing is accelerated (causing premature malfunctioning) and sufficiently high temperatures may be reached to cause softening of the glass envelopes of vacuum tubes permitting air to displace the vacuum. In present day equipment the problem is so acute that systems have had to be built around a liquid cooled 'cold-plate' in order to keep temperatures within reasonable limits. Flying at high altitudes makes the cooling problem even more acute, for although the air temperatures are lower, the density and specific heat of the air and hence thermal capacity are much lower than at lower altitudes. Therefore a larger volume of air is required to produce the same cooling effect. Compressibility heating must be considered at high speeds as well.

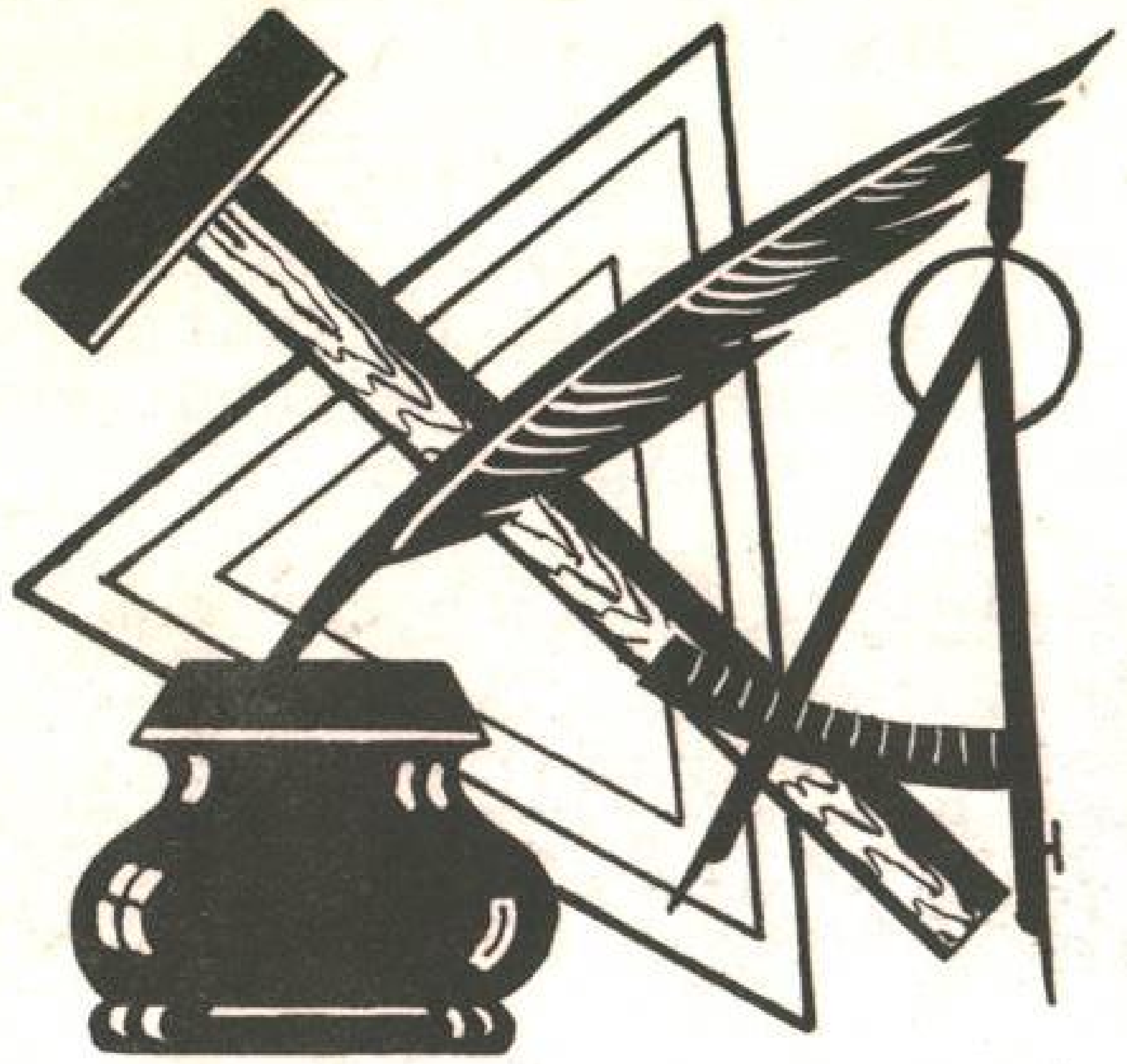
The transistor does not do much to help in the solution of the cooling problem. The transistor will work in a limited range of temperatures only and although the transistor requires no cathode heating and operates at lower power levels than the vacuum tube, miniaturized and encapsulated construction has caused the heat density (watts of wasted power per cubic foot of equipment) to be about the same in both transistor and vacuum tube equipments.

The significance of transistors in airborne equipment can be summarized as follows:

- Transistor equipment can be more compact because of the small physical size of the transistors and their circuit components.
- Transistor equipment can be made lighter because the 28 Volt DC primary power can be used directly eliminating the need for dynamotors and other power converting devices.
- Equipment can be made more reliable because of the transistors' immunity to physical shock and its inherent long life.
- Unless high temperature transistors (capable of operation at 100°C to 200°C) are developed, the cooling problem associated with aircraft equipment will become acute.

In this article, two things have been attempted. Firstly a brief description of the operation of the junction box transistor; and secondly, an insight into the problems facing the 'boffins' who design airborne equipment with emphasis on how the use of the transistor might help reduce these problems.





The Ten COMMANDMENTS of

Technical writing

I Thou shalt remember thy readers all the days of thy life; for without readers thy words are as naught.

II Thou shalt not forsake the time-honoured virtue of simplicity.

III Thou shalt not abuse the third person passive.

IV Thou shalt not dangle thy participles; neither shalt thou misplace thy modifiers.

V Thou shalt not commit monotony.

VI Thou shalt not cloud thy message with a miasma of technical jargon.

VII Thou shalt not hide the fruits of thy research beneath excess verbiage; neither shalt thou obscure thy conclusions with vague generalities.

VIII Thou shalt not resent helpful advice from thy editors reviewers, and critics.

IX Thou shalt consider also the views of the layman, for his is an insight often unknown to technocrats.

X Thou shalt write and rewrite without tiring, for such is the key to improvement.

W. W. Shaw

Good instruction

I Thou shalt be dynamically alive, but not emotionally overwrought.

II Thou shalt attain scholarship, but not be absorbed in the abstract.

III Thou shalt achieve practical wisdom,but not be utilitarian.

IV Thou shalt be imbued with idealism, but not be a visionary.

V Thou shalt be sympathetic, but not credulous.

VI Thou shalt be self-analytical, but not an introvert.

VII Thou shalt be responsible to suggestions, but not vacillating in principles.

VIII Thou shalt cherish humor, but not display ridicule.

IX Thou shalt cultivate charm, but not display affectation.

X Thou shalt absorb culture, but not affect it.

('Decalogue' DeBruile)

Observer Training in the RCAF

(CONCLUSION)

Once Observers have been awarded their "wings"they are assigned to an operational command for crew or combat operation training at an Opertaional Training Unit (OTU). There are three of these units of interest to Observers: Observers (AI) are assigned to the All-weather Fighter OTU while Observers(NAV) and Observers(RAD)are assigned to either the Maritime or Transport OTUs. At these units they are trained to the operational requirements of the particular command.

All-Weather Fighter OTU

At the All-Weather (AW) Fighter OTU Observers (AI) are given 12 weeks of intensive training and instruction in Airborne Interception techniques and the peculiarities and problems of high-speed, high-altitude jet operations.

Shortly after his arrival at the OTU the Observer is "married" to a pilot. From this point on they train as a crew, and in all probability they will remain together throughout their tour with an All-Weather Interceptor squadron.

The academic syllabus at the AW OTU for both crew members includes such subjects as:

AI Techniques and Equipment

Navigation Procedures

Meteorology

Ground Controlled Interception

Aircraft Regulations

Air Regulation

Jet Let-down Procedures

Airmanship

Aeromedical

Armament

The flying syllabus at the AW OTU includes exercises in Mitchell,T-33, and CF-100 aircraft.On these flights the student crews practice interceptions, tactics, navigation, and instrument flying.

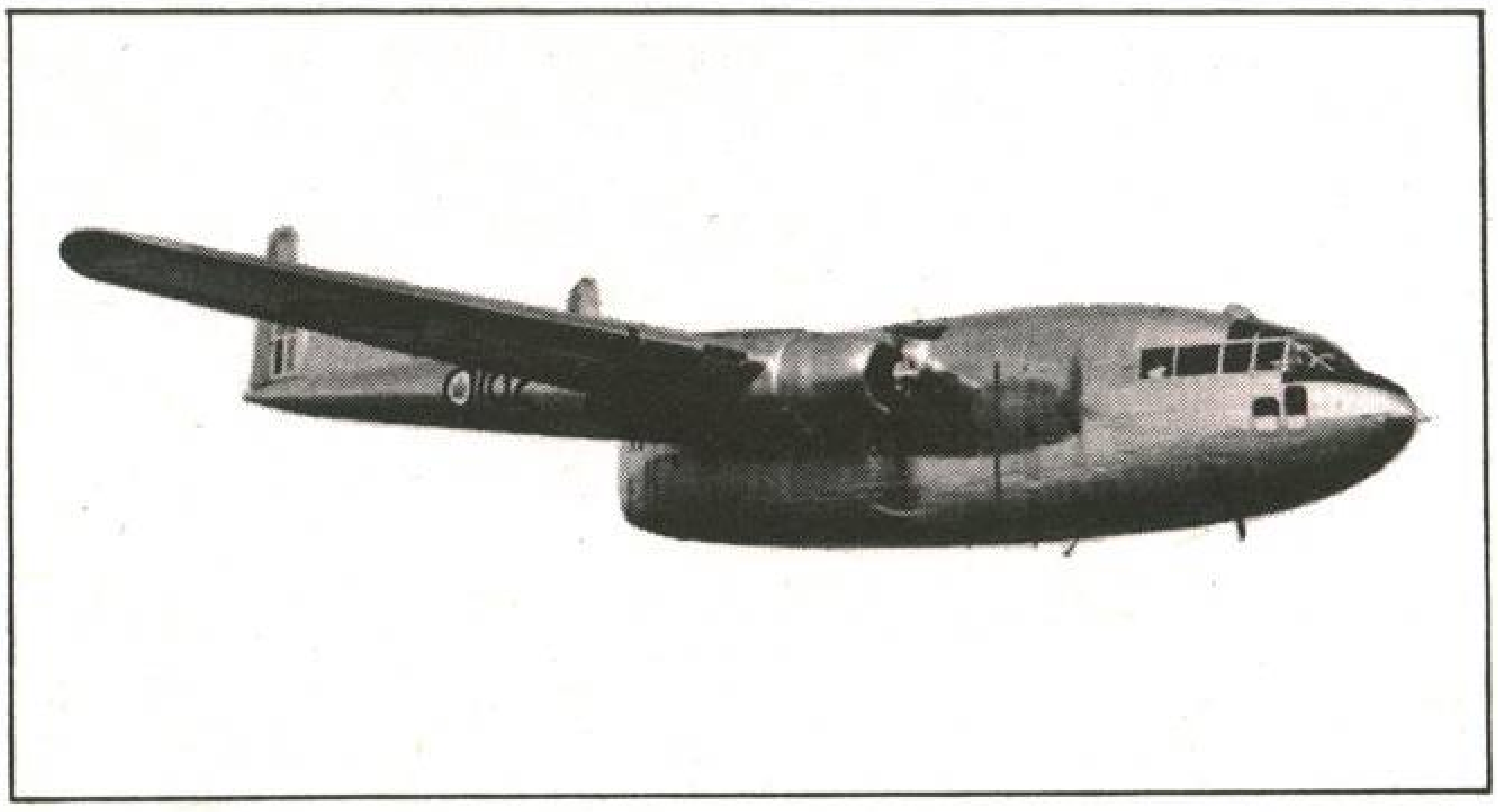
Maritime OTU

The Maritime OTU training course is of 20 weeks duration and is divided into two phases: a four week conversion phase and a sixteen week operational phase. In the conversion phase the Observer (NAV) reviews basic navigation procedures and navigation instruments while the Observer (RAD) reviews electronic equipment,communications and morse. In the operational phase the entire crew receives instruction in maritime tactics, bombing, air weapons, convoy escort and anti-submarine search.

The academic syllabus is designed to prepare the student crews for the bombing and navigation flights where simulated "area sweep" and convoy escort exercises are practiced. The final exercise, known as "Operation Iceberg" is the high point of the course. It consists of a maritime exercise to Bermuda and return.

Transport OTU

The Transport OTU training syllabus is of sixteen weeks duration and is designed to familiarize student crews with long-range transport procedures. The academic syllabus consists of additional instruction in flight planning, navigation aids (which includes radio and radar aids)



C-119 PACKET - USED BY AIR TRANSPORT
COMMAND AND TACTICAL AIR COMMAND

NORTH STAR - LONG RANGE CARRIER OF AIR TRANSPORT COMMAND

navigation techniques (which includes basic DR, grid, and pressure pattern), meteorology, celestial and airmanship. The flying exercises, consist of long-range transport flights where the student crews become familiar with techniques and facilities on Transport Command routes.

Squadron Training

All flying units of the RCAF conduct training programs to ensure that their personnel maintain a high degree of proficiency in their respective trades. In addition, the squadron training programs serve to give the graduates of the OTUs the squadron experience they need to round out their professional knowledge for the particular role.

Cross Training

Up to this point we have been referring to the newly graduated Observer; however, it is worth mentioning that some cross-training of experienced Observers is conducted. For instance, an Observer (NAV) or Observer (RAD) may be selected for further training as an Observer (AI). In which case they are returned to 2 AOS for the Basic AI course. Similarly, an Observer (AI) may receive further training as an Observer (NAV). Thus some Observers eventually become qualified in all three Observer specialties.

POST-GRADUATE OBSERVER TRAINING

Once an Observer has completed a flying tour in an operational capacity and has demonstrated above average ability in his trade he may be selected for one of the post-graduate courses offered by the RCAF. Normally, graduates of these courses will be employed as instructors at various schools and OTUs. The courses themselves are all conducted at the Central Navigation School (CNS) located at Winnipeg.

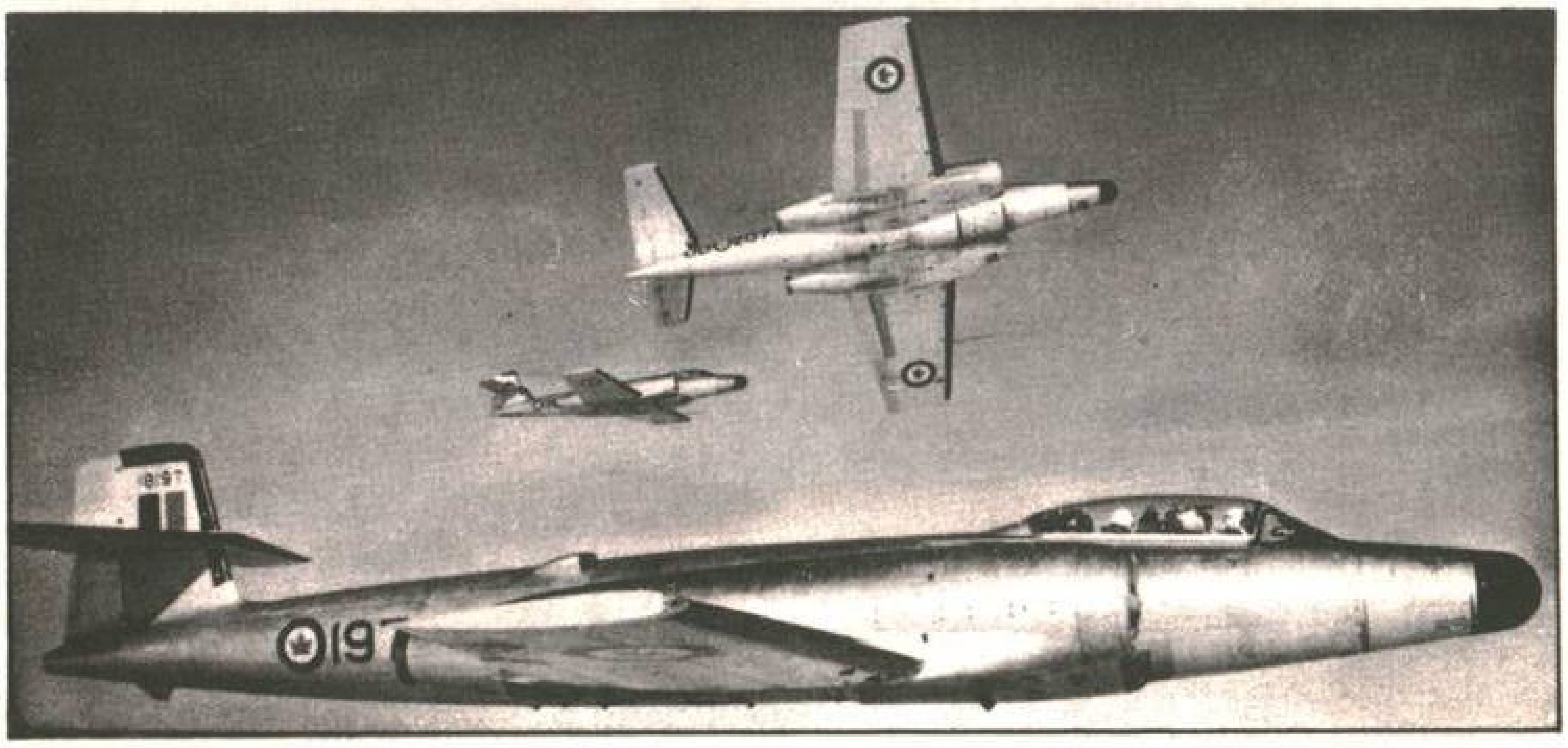
Staff Navigation Instructor - Navigator Course

The Staff Navigation Instructor - Navigator (SNIN) Course is designed to qualify selected candidates as instructors and to provide them with a knowledge of navigation and allied subjects so that they may be better qualified to assume staff appointments on squadrons, at OTUs and at group and command headquarters. The course is of 17 weeks duration, the first two weeks of which are spent at the School of Instructional Technique (SIT), Trenton.

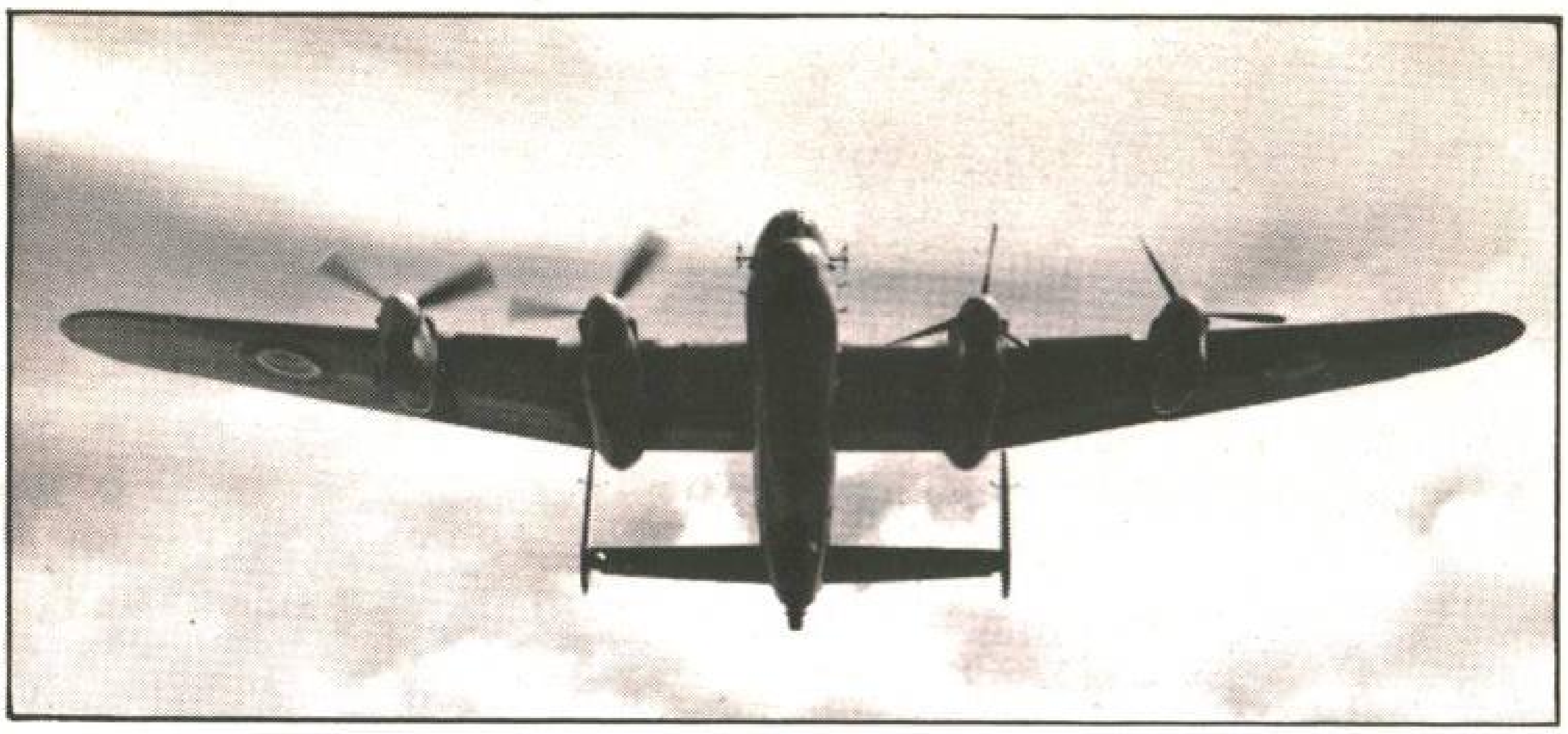
The academic syllabus and the time allotted to each subject is as follows:

Applied Navigation	- 75 hours
Aerodynamics	- 35 hours
Instruments	- 29 hours
Compasses	- 23 hours
Astronomical Navigation	- 36 hours
Map Projections	- 21 hours
Electronics	- 103 hours
Mathematics	- 40 hours
Meteorology	- 32 hours
Instructor Training (80 hours at SIT)	-143 hours

This course provides the SNIN student with a detailed knowledge of the subjects in the various navigation syllabi, and gives him an excellent academic background in addition to his operational experience.



CF-100 CANUCK - LONG-RANGE INTERCEPTOR
OF AIR DEFENCE COMMAND



LANCASTER - "OLD RELIABLE", BEING REPLACED IN MARITIME AIR COMMAND BY THE NEPTUNE AND BRITTANIA

A total of 40 hours is devoted to flying on the SNIN course. Of this total, ten hours are spent obtaining practice in assessing AOS students in the air. The remainder of the flying time consists of Long Range Navigation Flights to the OTUs where the SNIN students are briefed on their operation.

Staff Radio Officer Instructor Course

The Staff Radio Officer - Instructor (SROI) Course is designed to fulfil a function similar to that of the SNIN Course in providing the students with the necessary academic background to fill positions as electronic instructors or junior staff radio officers. The SROI students also take additional instruction in basic navigation to fit them for their role as Observer (RAD). The course is of 17 weeks duration and like the SNIN course includes two weeks at the SIT.

A total of 40 hours is devoted to air instruction on the SROI course. This is designed:

- to familiarize the student with the methods of air instruction and assessment;
- to provide the student with practical navigation experience; and
- to provide the student with practical experience in operating airborne communications and radar equipment.

The exercises include navigation flights, radio - radar flights, and flights to assess basic Observer (RAD) students.

The academic syllabus and the time allotted for each subject is as follows:

Applied Navigation	- 60 hours
Electronic Theory	-120 hours
Electronic Equipment	- 66 hours
Mathematics	- 32 hours
Meteorology	- 32 hours
Aerodynamics	- 30 hours
Morse	- 20 hours
Radio Trainers	- 4 hours
Procedure and Operational Organization	- 20 hours
Instructor Training (including 80 hours at SIT)	-130 hours

Like the SNIN Course, the SROI Course provides the students with an academic background which coupled with their operational experience, provides them the means to become good instructors and staff officers.

Specialist Navigation Course

The third post-graduate course available to Observers is the Specialist Navigation (SpecN) Course. It is designed to qualify general list and aircrew officers for any senior navigation staff position in the RCAF. The course is of 40 weeks duration and is conducted once a year. Each course normally has nine students: seven RCAF Observers, one RCAF Pilot and one USAF Observer or Pilot.

BRITTANIA - A MODIFIED VERSION OF THIS AIRCRAFT WILL SOON BE IN USE WITH MARITIME AIR COMMAND

The main objectives of the SpecN course are as follows:

- To familiarize the students with all aspects of air navigation and allied subjects.
- To present the students with a picture of navigation in its widest sense, the problems to be faced, and the development trends along which the solution to these problems is likely to be found.
- To provide the students with the opportunity of visiting training, operational, experimental and manufacturing establishments in Canada USA and UK.
- To provide a flying program which will give the student an opportunity to test and evaluate navigation equipment and techniques.

To obtain these objectives the students must be provided sufficient academic background to enable them to appreciate the material being taught and to provide a basis for future self-improvement. To this end an extensive academic syllabus forms a major portion of the course. Some of the subjects taught and the time devoted to each is as follows:

Applied Navigation	- 50 hours
Aerodynamics	- 65 hours
Mathematics	- 70 hours
Physics	- 50 hours
Meteorology	- 56 hours
Celestial Navigation	- 45 hours
Instruments	- 60 hours
Compasses	- 34 hours
Map Projections	- 45 hours
Electronic Theory	- 90 hours
Electronic Equipment	- 75 hours
Staff Duties	- 29 hours

The students posted to the SpecN course are normally highly experienced practical navigators, therefore, there is little justification in assessing their ability to navigate an aircraft over a prescribed route. However, one of the requirements of a specialist navigator is his ability to test and evaluate navigation techniques and equipment. For this purpose air exercises are flown as follows:

- Local flights are arranged as required for familiarization with equipment, assigned tasks and instrument calibration.
- Maritime flights are arranged to give the students experience in Maritime Air Operations. Over-water techniques are used throughout and interceptions, patrols and searches are practiced.
- Arctic flights are carried out to give the students practical experience in arctic flying and to carry out projects assigned by various government agencies.
- On each of the flights to visit Canada, USA and UK establishments the students are assigned navigational tasks to carry out enroute.

The object of the visits included in the SpecN course is to give the students an opportunity to observe methods and techniques used in the RCAF, the USAF and the RAF; and to examine the latest developments in navigation instruments and electronic aids to navigation. Thus the graduate SpecN has a thorough back-ground of information on existing equipment, present development, and future trends in the field of Military Aviation.

Conclusion

In this series of articles we have outlined the present methods of Observer Training in the RCAF. We have not indicated what changes may take place in the future, but we can be sure that changes must and will take place to keep abreast of the current trends of military thinking. In any case, we hope we have managed to enlighten our readers, particularly those not directly connected with Observer training.


North
TACAN
BEARING TO STATION 120°
DISTANCE
184 MILES
NORTH
184
DISTANCE
NAUTICAL MILES
RADIO
BEARING
33 0 3 6 9 12 15 18 21 24 27 30
BEARING TO
AIRPLANE 300°
T
CHAN
NAV
T/R
REC
OFF
VOL
TACAN
GROUND STATION

One of the latest additions to the ever increasing list of automatic electronic aids to air navigation is TACAN (TACtical Air Navigation). Recently removed from the classified list when it was accepted by the civil authorities in the USA for use in civilian aircraft, TACAN is being hailed by many as the answer to the problems of high speed, short range navigation and aircraft control.

Using a single ground station, TACAN provides a continuous airborne indication of range and bearing to the ground station at line-of-sight ranges up to 200 nm. The bearing information is accurate to within 0.9 degrees, and the range counters will show slant range with an error varying between 200 yards and 1000 yards. The airborne equipment, consisting of a transceiver, a control box, a bearing indicator, and a range indicator, is extremely simple to operate and almost fail-safe in its accurate indications. Thus far, only military specification models of the equipment (AN/ARN-21) have been produced in quantity, but less expensive, smaller, and less sophisticated sets are under development for civil airlines and private fliers.

Principle

Bearing information is obtained in basically the same manner as in the Omni-directional range. Range information is obtained using interrogator/responder principles worked in with the normal bearing transmissions.

The ground antenna system consists of a stationary central fed conductor, with 10 parasitic elements on a rotating base around the central conductor. The effect of the nine outer parasites causes a nine lobed radiation pattern as shown in Figure 1. The effect of the single inner parasite is to offset the nine-lobed pattern in the direction away from the inner parasite as shown in Figure 2.

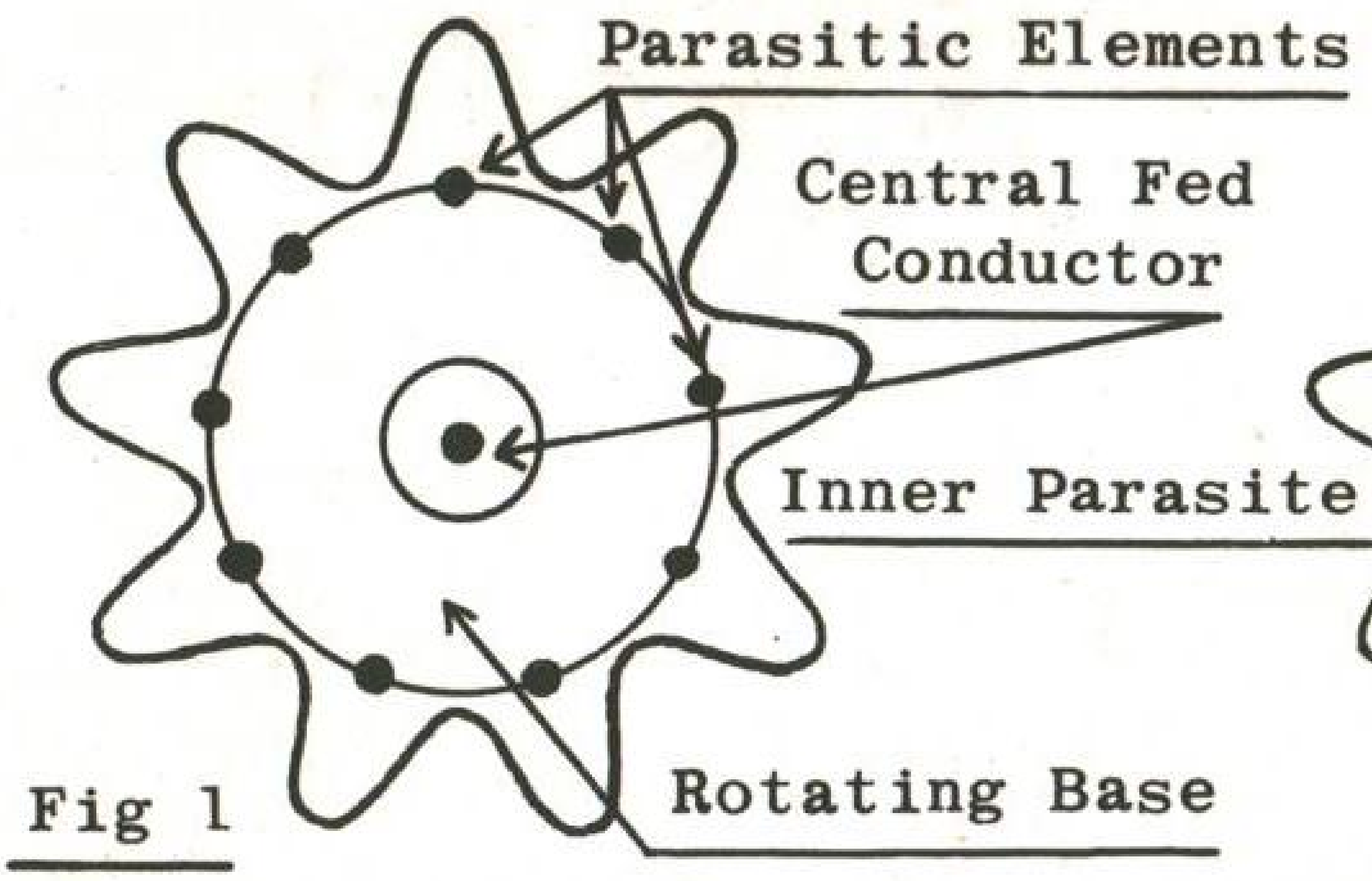


Fig 1

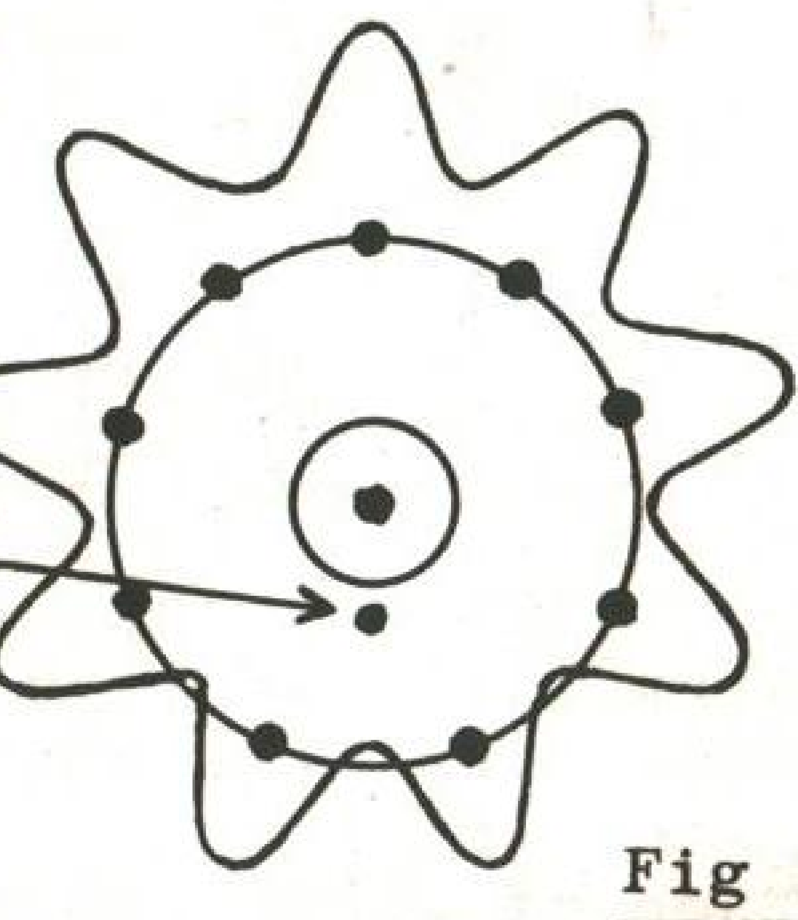


Fig 2

The rotating base carrying the 10 parasitic elements is rotated at 15 rps. The pick-up at a stationary receiver will vary as the signal strength of the rotating pattern varies, being maximum when the main lobe of the nine-lobed pattern is pointing towards the receiver. Because of the nine lobes of the radiation pattern, the received signal will also have nine minor maxima and minima in each revolution as shown in Figure 3.

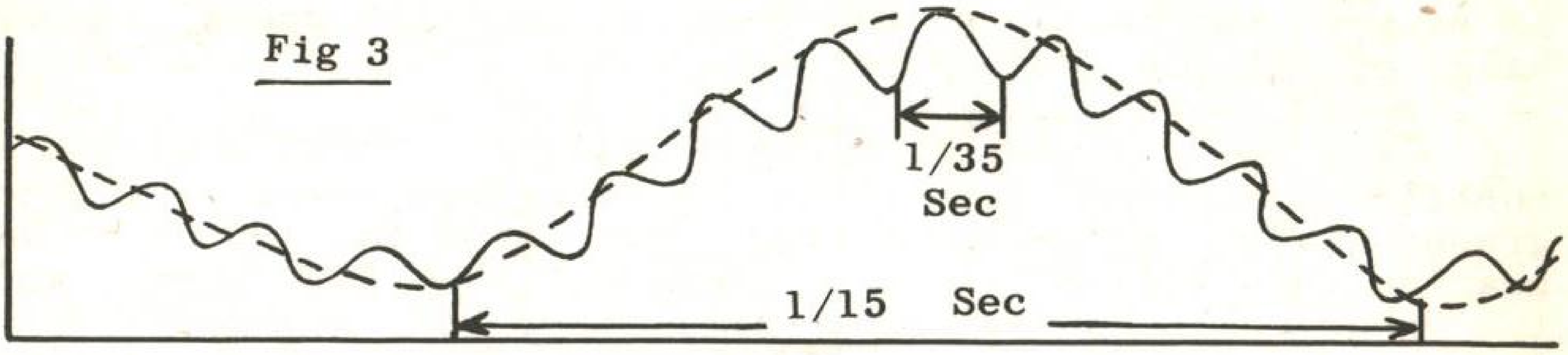


Fig 3

The RF energy emitted by the antenna system is in the form of pulse pairs. Approximately 2700 pulse pairs per second are transmitted. With such a large number of pulses the 15 cps modulation and the 135 cps modulation are carried just as accurately as if a CW emission was used.

This system is referenced to magnetic north by means of a reference pulse train instead of a separate reference signal as in VOR. When the maximum of the 15 cps modulation passes magnetic south a main reference pulse train, consisting of 12 pulse pairs with 30 μs between each pair, is transmitted. Thus an aircraft with a bearing of 000M to the station will receive the maximum amplitude of the 15 cps modulation and the main reference pulse train at the same time as shown in Figure 4. The phase difference is thus measured between the reception of the main reference pulse train and the maximum of the 15 cps modulation. If the aircraft was on 090M to the station the maximum amplitude of the 15 cps signal would occur 90 degrees of phase later than the main reference pulse train as shown in Figure 5. Thus at any magnetic bearing through 360 degrees the phase difference will be equal to the magnetic bearing to the station.

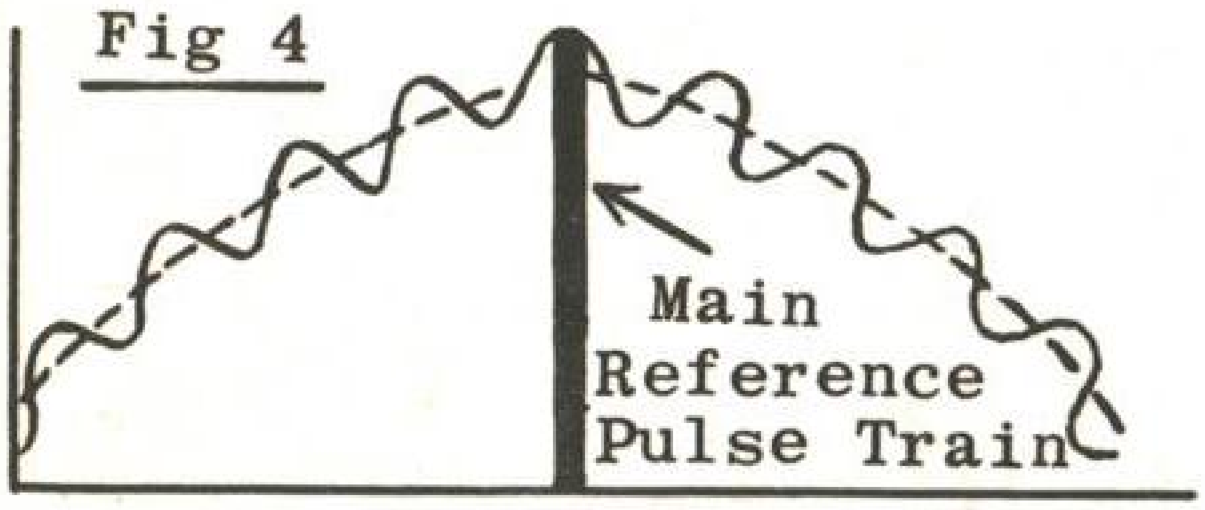


Fig 4

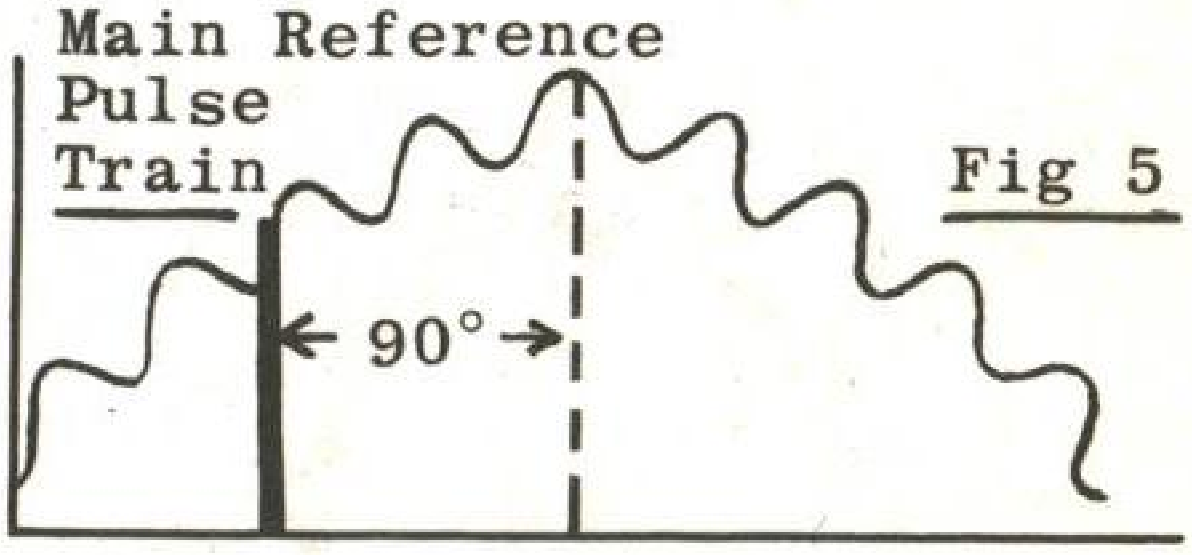
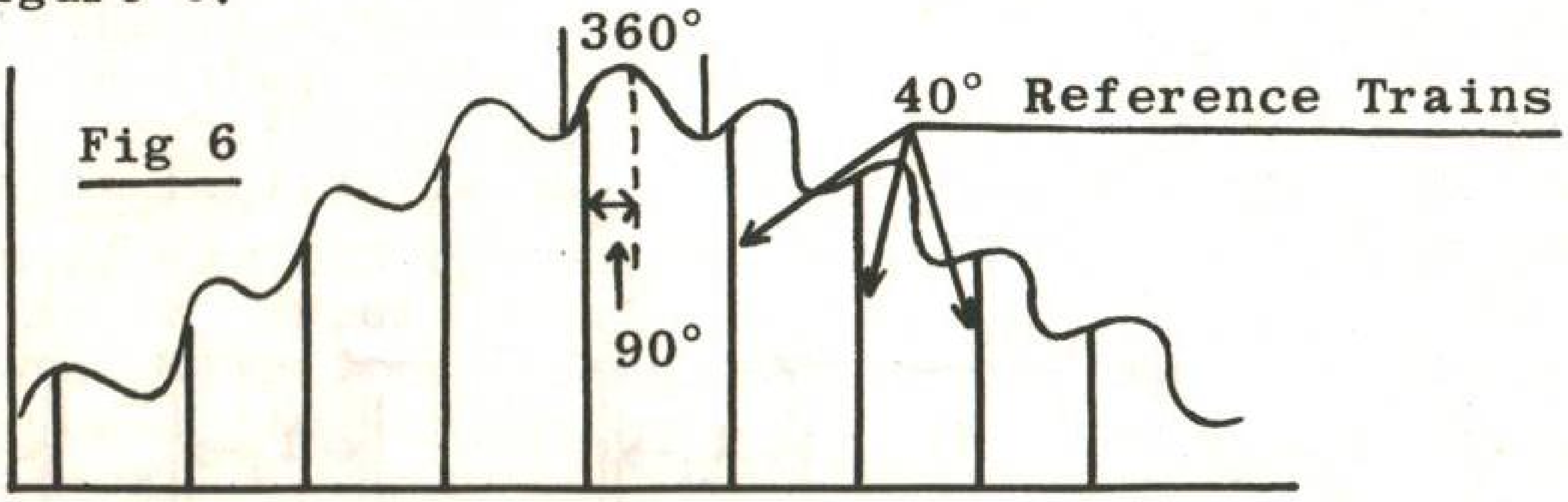


Fig 5

The 15 cps modulation and main reference pulse train are only used for coarse positioning of the bearing pointer. Fine positioning is accomplished using the 135 cps modulation of the nine small lobes. Each time the maximum amplitude of each 135 cps lobe passes magnetic south a 40 degree reference pulse train, consisting of 6 pulse pairs with 24 μs between each pair, is transmitted. The phase difference between the reception of a 40 degree reference pulse train and the maximum of a 135 cps lobe is used for fine positioning of the bearing pointer. Thus an aircraft on 090 M to the station will receive the 40 degree reference pulse trains 90 phase degrees at 135 cps (10 degrees at 15 cps) before the reception of the maximums of the 135 cps lobes as shown in Figure 6.

Fig 6



The main reference train is used to determine bearing to the nearest 20 degrees, then the 40 degree reference pulse trains are used to determnne the bearing to the nearest 0.9 degrees.

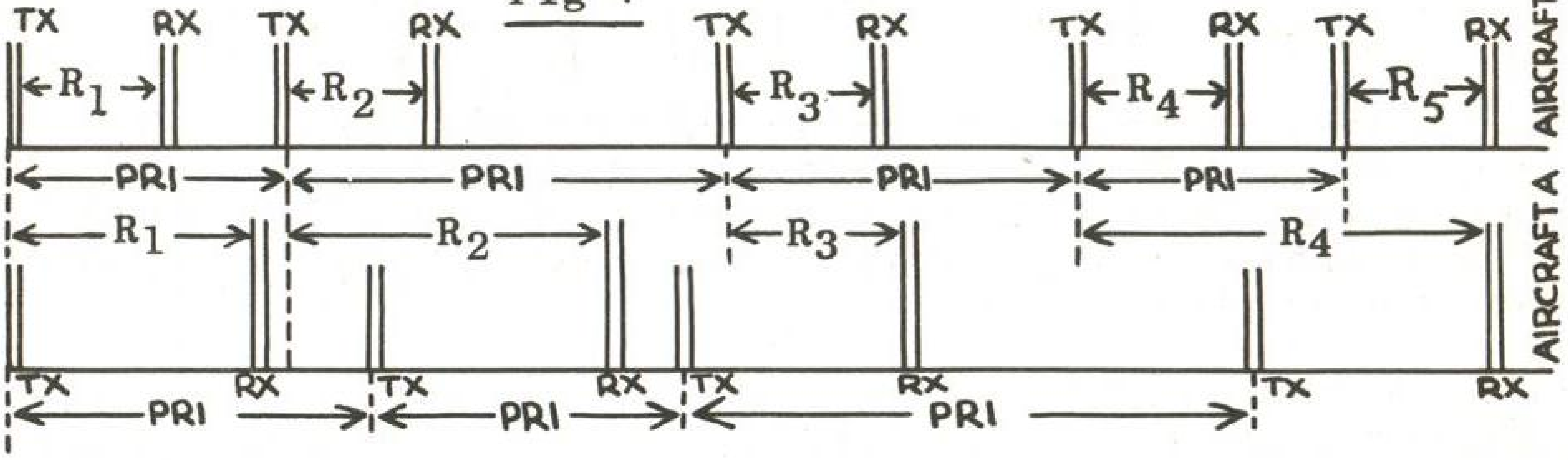
In addition to the reference pulse pairs, the transmitter also sends out approximately 2700 other pulse pairs per second. These consist of range pulse pair replies, morse code identification pulse pairs, and random spaced pulse pairs. Every pulse pair has 12 μs between the pulses in the pair so that the aircraft receiver can be set up to accept only these signals and reject any noises or spurious pulses.

Distance information is obtained in a normal DME manner. The airborne transmitter sends out interrogation pulse pairs which are received by the ground station, and 50 μs later are answered with pulse pairs. Since the spacing between pulse pairs will not affect the 15 cps and 135 cps modulations, the pulse pair spacing can be used for distance measurement without interfering with the bearing information. Similarly, in the circuits where the pulse spacing is being detected for distance measurement, the amplitude modulation of the pulse can be removed by clipping the pulses at a fixed level, so that the bearing information will not affect the distance measuring circuits.

While the airborne transmitter is sending out interrogation pulse pairs, the airborne receiver searches for reply pulse pairs that are always occurring with the same delay after the interrogation pulse pairs. When the correct return pulse pairs are found, the receiver locks on and measures the time delay which in turn is used to show range on counters. As long as interrogation pulse pairs are being sent and received the receiver will stay locked on and continuously indicate range.

To prevent the receiver from locking on returns initiated by another aircraft in the area, the interrogation pulse pairs are sent out at random intervals. While on search about 150 pulse pairs per second are sent out, and on track about 24 to 30 pulse pairs per second are sent out. The receiver will only track reply pulse pairs that always occur with the same delay after the interrogating pulse pairs, without regard to the time between replies. No two interrogators will be putting out pulse pairs with the same varying intervals between pulse pairs. Figure 7 shows an example of two aircraft sending out an initial interrogating pulse pair at the same time.

Fig 7



Airborne Equipment

The AN/ARN-21 airborne UHF transmitter-receiver is designed to pick up the pulse pairs and amplitude modulations and translate this information into measurements of bearing and range. Figure 8 shows a block diagram of the receiver and associated equipment. As shown, the input pulse pairs are fed to five different detectors as follows:

- The envelope detector picks off the composite 15 cps and 135 cps amplitude modulations.
- The main reference pulse detector picks off only the pulse trains of 12 pulse pairs 30 μs apart.
- The 40 degree reference pulse detector picks off only the pulse trains of 6 pulse pairs 24 μs apart.
- The range pulse detector picks off all pulse pairs occuring with the same delay after interrogating pulse pairs.
- The beacon identification pulse detector picks off especially arranged pulse pairs which give a morse code identification signal

The signal from the envelope detector is passed through a high pass filter and a low pass filter for separation into a 15 cps component and a 135 cps component. The 15 cps azimuth circuits detect the phase difference between the reception of the main reference pulse train and the maximum of the 15 cps signal. This phase difference is fed as an error signal to the azimuth servo which drives a phase shifter to shift the phase of the 15 cps signal to eliminate the phase difference. At the same time the servo positions the bearing pointer within a 40 degree sector no more than 20 degrees from the correct bearing.

The 135 cps azimuth circuits now detect the phase difference between the 40 degree reference pulse train and the maximum of the 135 cps signal. This phase difference is also fed as an error signal to the azimuth servo which drives the phase shifter to eliminate the phase difference and at the same time positions the bearing pointer to the correct bearing.

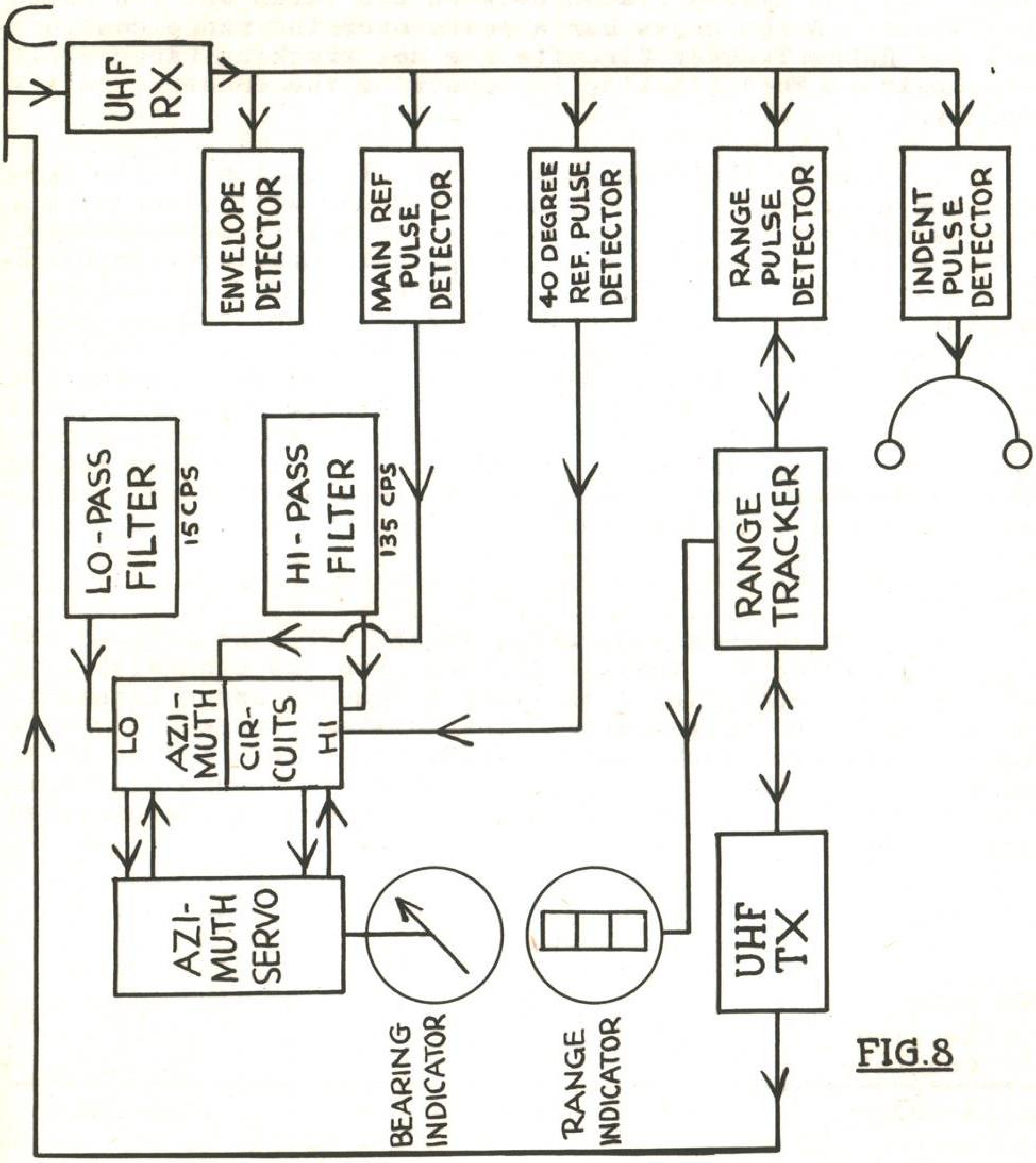


FIG.8

When the equipment is not receiving a beacon signal, or is not receiving a strong enough signal, the bearing pointer will spin, so that a reading cannot be taken.

The bearing information can be displayed on any type of synchro bearing indicator such as the RMI type. A special phase detecting network can be used to cause the bearing information to operate the vertical cross pointer and ambiguity meter of the normal Course Deviation Indication.

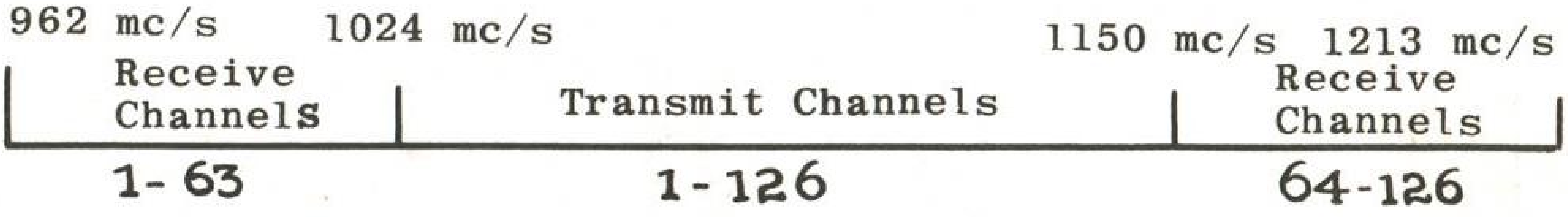
As discussed previously the range information is determined separately from the range pulse pairs in the Range Tracker Circuits. The range counters indicate slant range from the ground beacon between 200 yards and 195 nautical miles. A red cross bar appears over the range counters when the Range Tracker Circuits are not tracking range reply pulse pairs. When tracking is occurring the counters rotate rapidly.

Due to the propagation characteristics of the frequencies used, fading of the beacon signal will often occur, especially when flying over water. For this reason, memory circuits are included in the range and bearing circuits. When the signal is lost, the bearing circuit memory will maintain the last bearing on the indicator pointer for about 3 seconds, after which the bearing pointer will begin to spin. The range memory circuit will continue tracking for about 10 seconds before the red bar will drop over the counters. If the signal re-appears within the memory times, there will be no apparent interruption: but if either memory time is exceeded, the search circuit will again have to find the signal for that function.

Frequencies

The system operates in the UHF band between 962 mc/s and 1213 mc/s. This is divided into 126 channels, with each channel containing a receiver frequency and a transmitter frequency 63 mc/s apart. Channels are spaced one mc/s apart. The frequency band is subdivided into two receiver bands and a transmitter band as shown in Figure 9. This arrangement permits all channels to be crystal controlled with the use of only 43 crystals.

FIG. 9



NAV QUIZ

Judging from some of the comments we have received our last quiz was far too easy. So, for those of you who like to work out your problems we have collected a few problem-type questions. Answers on page 95.

1 You are the navigator of an aircraft on a TH of 239T. Your TAS is 270K and the W/V is 270/50. At 1513 you get a radar bearing on another aircraft which bears 345 relative at a distance of 70 NM. At 1529 the same aircraft bears 140 relative at a distance of 55 NM. What is the TH and TAS of the other aircraft?

2 A Dakota transporting an aircraft engine had an extra compass deviation of 8° when the engine was five feet from the compass. During flight, while in cloud, the engine had to be moved a further five feet from the compass. What would you expect the new deviation to be?

3 If the critical mach number of an aircraft is .75 at 3500 feet when the temperature is -15°C, what will its critical mach number be at 55,000 feet when the temperature is -50°C and the pressure is equal to an altitude of 57,000 feet in the standard atmosphere?

4 On a Lambert Conformal Grid North lies 40° to the east of True North at 75° West longitude. Constant of the cone (η) = .64. What is the longitude of the reference meridian?

5 On a Lambert Conformal whose reference meridian is 0° longitude and η = .6304, what is Map Convergency at 63° West?

6 A Gyro was corrected for drift due to wander at 45° North. If the gyro was moved to 60° South what would the error per hour be?

Hint: Sin 45 = .707
Sin 60 = .866

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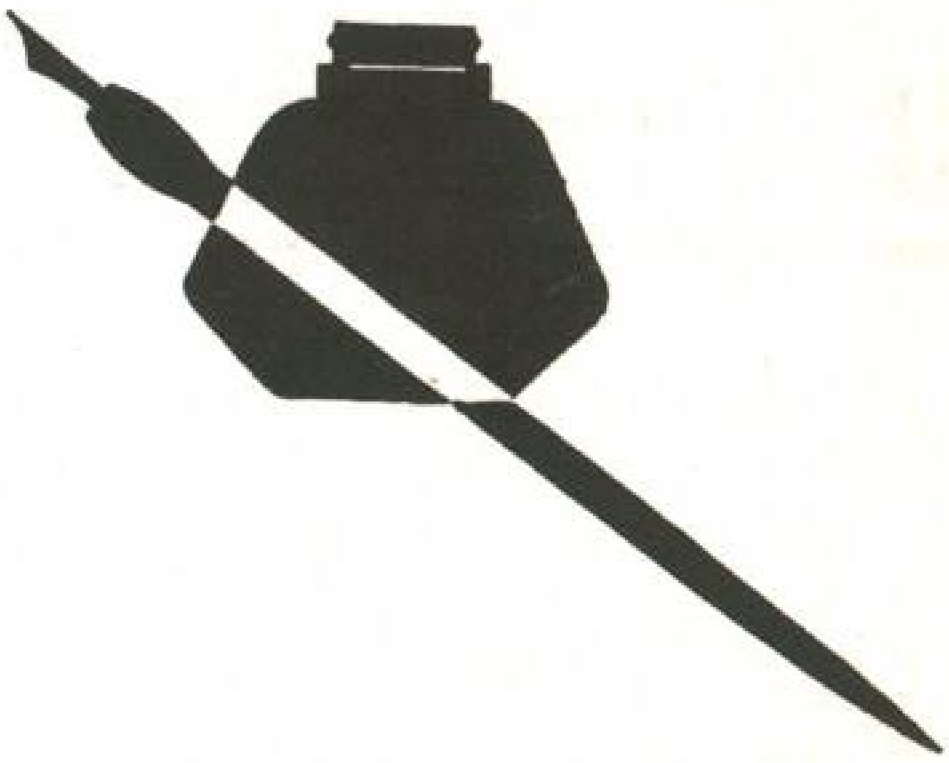
Letters *to the Editor*



The Editor,
The RCAF Observer,
RCAF Station Winnipeg,
Stevenson Field,
Winnipeg, Manitoba.

I believe that the following information and attached graph would be of sufficient interest to RCAF Navigators to be published in the OBSERVER.

The graph on heading errors applies to a periscopic sextant such as the Kollsman. It shows the maximum and probable heading errors that are introduced when the vertical alignment with the celestial body is in error. For example, the maximum error in the heading observation is 0.5° and the probable error is 0.3° when a body with an altitude of 45° is used when the vertical error is 30'. For a given vertical error, the error in the heading observation increases without limit as the altitude of the body is increased. However, regardless of the size of the vertical error, the error in the heading observation is zero when using bodies on the horizon. Since a vertical error of 30' is common under average flight conditions only bodies with an altitude under 40° should be used for checking heading.

When using bodies with relative bearings of 090 and 270 to check heading, vertical errors caused by autopilot altitude hunting and changes in airspeed introduce azimuth errors, while a false vertical caused by a change in heading will introduce a large error when sighting on a body ahead or behind the aircraft.

It should be remembered that these conditions are reversed when observing the altitude of a body for a position line. When sighting on a body ahead or behind the aircraft, the accuracy of the H_s is affected by vertical errors caused by altitude hunting and changes in airspeed, while changes in heading will introduce vertical errors that will affect the accuracy of sights on the beam.

I realize that there are a good many navigators who believe it is possible to obtain consistently single shot astro observations with an accuracy better than 30'. My experience has been that this claim will not stand up under test, and therefore, when checking the heading using the periscopic sextant, bodies under 40° should be used, thus reducing the effect of vertical error.

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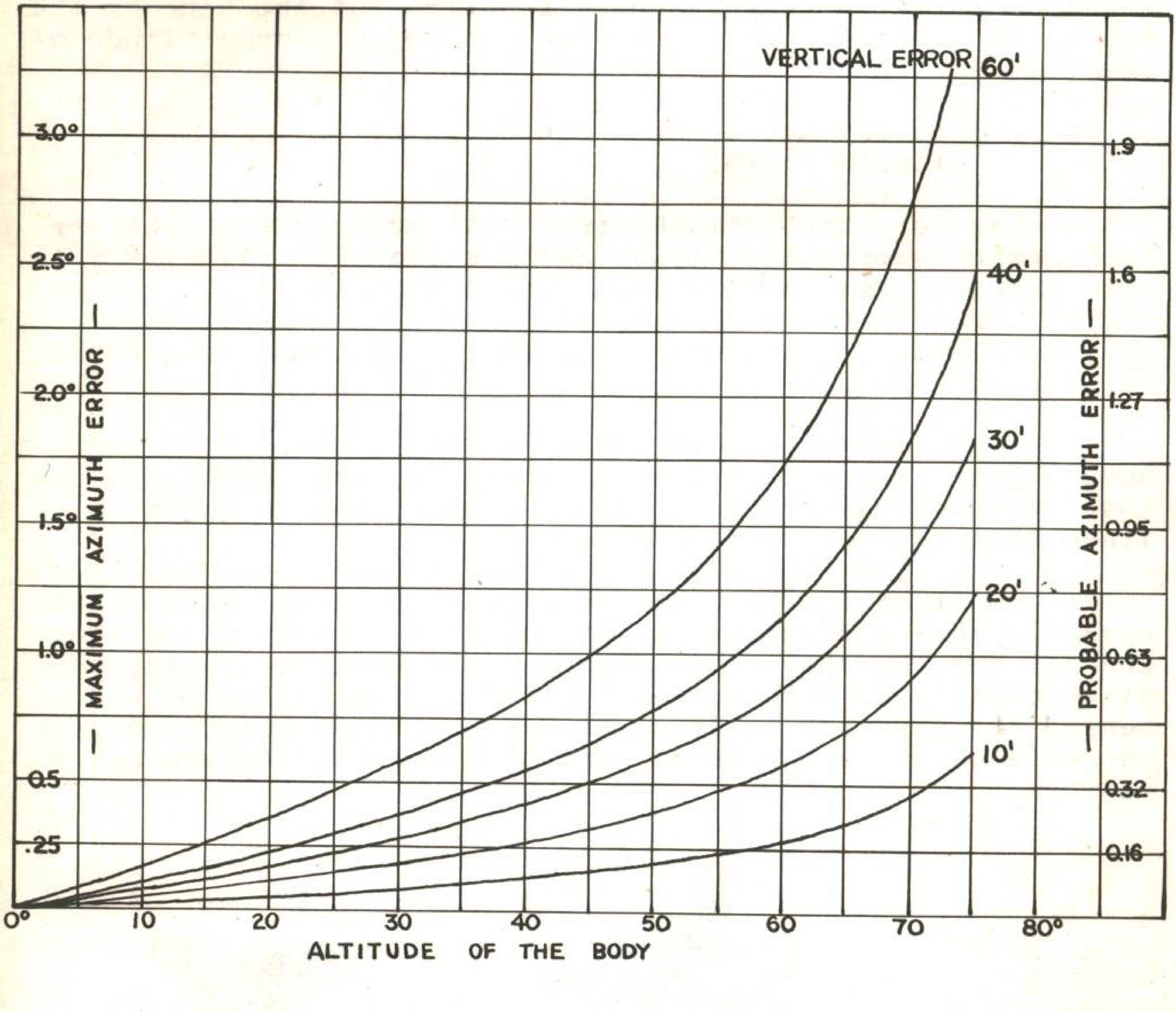
Castle Airforce Base.



Editor's Note:

When taking a sight with the Kollsman periscopic sextant, and at the same time checking heading, it is common practice to note the heading index several times during the period of the sight. Each reading is taken when the bubble, the vertical centre line, and the body are coincident, therefore any vertical mis-alignment will be caused by acceleration effects on the bubble. By mentally averaging several such readings, each one taken at a different period in the acceleration cycle, much of the azimuth error will be eliminated. However, when a heading check is the sole object of an observation, the tendency is to strive for one near coincidence of the bubble, the vertical centre line, and the body and to read the scale at that instant. As W/C Greenaway points out, this instant will commonly occur when an acceleration has pulled the bubble 30' or more away from the vertical.

For those in a mathematical frame of mind, the maximum error appears to be a function of the sine of the angle off the vertical (θ) and the tangent of the altitude of the body (x) where:

$$\sin \text{azimuth error} = \sin \theta \tan x$$

(small angle)

This being so, the azimuth error will be less than the vertical error when the altitude is less than 45° ($\tan 45^\circ = 1$) but will increase rapidly beyond altitudes of 45°. For example, the azimuth error will be double the vertical error at an altitude of just over 63° and four times as great at an altitude of 76°.

It is well known that sighting errors also become more significant as altitude increases, therefore we now have two good reasons to confine heading checks to low altitude bodies.

It should also be noted that because airspeed is normally more constant than heading and accelerations fore and aft are therefore less, heading checks taken on the beam will normally be more accurate than those taken ahead or behind the aircraft. This, as W/C Greenaway points out, is the reverse of the results expected from altitude observations.

The opinions expressed in the contributions to the RCAF OBSERVER are those of the writers and do not necessarily represent official RCAF views. The Editor reserves the right to make any editorial changes in manuscripts which he believes will improve the material without altering the intended meaning.

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