can be reproduced immediately the recording process has been completed (e.g. after 1/5 of a second). This property is of the greatest importance and value when recording sound-films. The producer has now no longer to wait for the development of the light-sensitive film in order to decide whether the sound record conforms with his requirements. After each scene has been recorded he can listen in to the playback of the sound-track immediately and decide on the spot of the sound-track for documentary and other repeated.

For broadcasting purposes also, the immediate reproducibility of the sound-track is of the greatest utility. The exchange of programmes between stations, the postponement of the transmission of current items of news (races, speeches, etc.) to a more suitable time of the day, the production of radio plays, all these are much facilitated by the Philips-Miller system, while the tonal quality exceeds that obtainable with the wax disc. The high fidelity of reproduction also offers a method of copying sound-records which in certain circumstances may be very convenient, viz, by making a new record of the reproduced sound track on a second "Philimil" tape. This "mechanical" copying can be carried out at the same time as reproduction, so that a direct duplicate can be obtained of the sound-track for documentary and other purposes.

THE V.R. 18 TRANSMITTING AND RECEIVING EQUIPMENT

By C. Romeyn.

Introduction

With the progressing development of commercial flying, the need for some means of intercommunication between an aircraft in flight and the airport very soon became apparent, and the first passenger and commercial airplanes, although still very small, were already equipped with wireless apparatus. With the steady and radical improvements in technical methods and apparatus during the last ten years both flying and wireless technology have made rapid strides. The importance of wireless intercommunication during flight has progressively increased and at the present day it is impossible to conceive of a passenger or commercial aircraft being without wireless apparatus. Reports of weather conditions along the aircraft route, landing instructions, direction-finding signals, etc., have become indispensable to the pilot.

It is the task of the wireless industry to provide suitable apparatus capable of meeting the special requirements for use in modern aircraft. That an aircraft radio equipment in many respects must differ fundamentally from a permanent and stationary ground equipment is obvious. In the present article the V.R. 18 aircraft transmitting-receiving equipment designed by Philips is described. This equipment has been specially evolved to meet the various requirements for use aboard aircraft, yet in its design attention has, moreover, been given to certain specialised needs.
considering the application of this equipment for the Douglas air liners operating on the Netherlands East Indies route of the K.L.M. air services.

General Characteristics of a Wireless Equipment for Aircraft Use

The V.R. 18 equipment (see fig. 1) consists in the main of the transmitter, receiver, aerial and requisite sources of power, as well as a series of auxiliary components such as the control box, the aerial lead-through, etc. In both electrical and mechanical characteristics, all components have to be designed to meet special requirements. Thus all parts must be as light as possible and take up the minimum of space without constituting an obstruction. Furthermore, the equipment must be installed in such a way that it is not exposed to serious vibration or hard jolts. To permit the interior to be tested readily and quickly, easy dismantling of both the transmitter and the receiver is moreover desirable.

Intercommunication between aircraft and airport is nowadays performed almost exclusively by telegraphic means. In this connection it is interesting to review briefly the historical development of the methods employed. During the early years of flying intercommunication with aircraft was carried out solely by means of the telephone. This instrument alone could be used at that time, since the pilot who had to operate the wireless apparatus already had both hands fully occupied in controlling the flight of the machine and it was thus impossible for him to work a Morse key. The disadvantages of using telephony became, however, steadily more apparent. In the first place, to cover the same range a telephone transmitter has to have a greater power than a telegraph transmitter; yet the most serious drawback of telephony is that it requires a wider frequency band, since, owing to modulation, an additional side band is transmitted at both sides of the carrier-wave frequency. In view of the increasing number of transmitting stations, which were concentrated in a comparatively small geographical area, the few frequency bands available were soon taken up. The only practical means for avoiding intensive mutual interference of stations was to adopt the telegraphic method of intercommunication. This made it necessary to provide a wireless operator for each aircraft in addition to the pilot. This addition to the crew would, however, have become necessary for other reasons, even without changing over from the telephone to the Morse key. The greater demands made on the pilot by the more complex problems associated with navigation (flying at night and through fog) were already making the care of the telephone an onerous additional responsibility, while on the other hand wireless intercommunication for the self-same reason, viz, the much-increased number of reports required for safe navigation, itself demanded closer attention. Moreover, it had become practicable to carry a special operator, as larger aircraft were being built in which more room was provided in the pilot's cabin.

Intercommunication between aircraft and airports is thus at the present time almost exclusively based on telegraphy. By international agreement the wave-lengths of 600, 944, 918 and 932 m have been allocated for wireless aircraft transmitters, of which the 600-m wave-length is only allowed for transoceanic flights.

The Transmitter

The transmitter of the V.R. 18 equipment is constructed for continuous-wave and tonic-train telegraphy. In the former a high-frequency oscil-
A high negative bias $V$ is applied to the grids of the control and amplifying valves, which inhibits the oscillation. During transmission this negative bias is removed in synchronism with the Morse signals (see fig. 2).

By means of a rotary interrupter, which is in series with the Morse key, the radiated high-frequency oscillation can, moreover, be interrupted 1000 times per second. This method of transmission, tonic-train telegraphy, is used for making the connection with some station. Owing to the greater width of the frequency band as a result of modulation with the 1000-cycle frequency, tuning is rendered more simple. But as soon as the connection has been set up, the wireless operator changes over to continuous-wave telegraphy, since the latter causes less interference owing to the absence of side bands.

The Douglas air liners on the East Indies route of the K.L.M. have to cross regions in Asia where airports are few and far between. In order to keep in communication with at least one airpost a powerful transmitter is required, and for this reason the power output of the V.R. 18 equipment in the aerial circuit has been rated at 75 watts. The range when using a trailing aerial (see below) is then at least 600 km for continuous-wave telegraphy and 300 km for tonic-train telegraphy. In certain circumstances the range may be considerably greater and on several occasions this equipment has been able to transmit over distances exceeding 6000 km. During flights in the European zone, where a large number of well-equipped airports are situated close to each other, a fairly small transmitting power is, on the other hand, sufficient for efficient intercommunication, provided atmospheric disturbances are not too serious. In fact, a transmitter with an excessive power output is undesirable for this zone, since it may interfere with the wireless signals being transmitted simultaneously from an airport to other aircraft in flight. The transmitting power of the equipment can therefore be regulated, the aerial power being reducible to either a half or a quarter by increasing the negative bias of the amplifying valves.

The interior of the transmitter, with the chassis pulled out, is shown in fig. 3.
Fig. 4. Simplified circuit diagram of receiver V.O. 18. The circuit shown is that of a five-valve superheterodyne receiver, where A is the first tuning circuit, H the high-frequency amplifying stage, O the modulating and oscillating valve, Osc the oscillating circuit, which is tuned to an oscillation with a frequency differing by an almost constant amount (differential or intermediate frequency) from the tuning frequency of A and H. The three variable condensers of these three stages are mounted on a common shaft. F1 is the first and F2 the second intermediate-frequency band filter; by means of a variable coupling the band width passing through these filters can be varied. The intermediate-frequency amplifying stage M is situated between the two filters. The intermediate-frequency alternating voltages are applied to the diode D, which also contains in the same glass-body the three-electrode valve \( \text{Z} \) of the low-frequency amplifying stage L. \( \text{Z} \) is the heat oscillator which generates an oscillation differing from the intermediate frequency by a specific (variable) frequency (usually 1000 cycles). The oscillation of the heat oscillator is also applied to D, so that at the exit of the rectifying stage an oscillation with the differential frequency (1000 cycles) is to be heard. E is the terminal stage with the output transformer.

The Receiver

When crossing those areas of Asia sparsely provided with airports an aircraft must be equipped with a very sensitive receiver. The superheterodyne method adopted in the V.R. 18 equipment is particularly suitable for obtaining the high sensitivity required. A lay-out of the circuit employed (simplified) is shown in fig. 4. An octode (O) serves as a converter valve. It is preceded by a high-frequency amplifying stage (H). The intermediate frequency generated in the converter valve is again amplified (in M), then rectified (in D) and amplified once more in the low-frequency stage (L). A small heat oscillator (Z) is provided to render the continuous-wave signals audible, (since no audible frequencies per se are obtained from these signals after the rectifying stage). This oscillator generates oscillations with a frequency which differs only slightly from the intermediate frequency. If this frequency together with the intermediate-frequency signals is passed to the rectifying stage, the Morse signals become audible on the differential frequency between the two. The frequency of the heat oscillator can be regulated, so that the pitch of the Morse signals can be adjusted as required. This simplifies the separation of stations operating on wave-lengths close together. The receiver is rated for wave-lengths between 520 and 1300 m.

The apparatus, on a wave-length of 600 m, furnishes a power output of 10 milliwatts with a 0.75 \( \mu \)-volt amplitude of the incoming signal. This is roughly the maximum sensitivity which can be attained at present.

The sensitivity of the receiver can be regulated by hand, or an automatic volume control (see S in fig. 4) may be put into action with the aid of

1) Measured in accordance with the usual definition of sensitivity.
which the receiver adjusts itself continuously to a fairly constant output power and the volume can then be adjusted by hand to the required value. Volume control is particularly useful when approaching radio beacons, as without it the volume has to be continually readjusted.

A further requirement which has to be met in the receiving apparatus is the possession of a high selectivity. This feature is necessary to set up a reliable channel of communication in areas where air traffic is heavy, and is also of great value for flying in the tropics in order to reduce the effects of atmospheric interference. The circuit of the superheterodyne receiver permits a very high selectivity to be obtained in a very simple manner, for the intermediate frequency is constant so that a large number of invariable oscillating circuits can be tuned to it (see $F_1$ and $F_2$ in fig. 4). In some cases, however, a high selectivity is undesirable, particularly during wireless telephone reception (by cutting off the side bands, speech becomes distorted or even unintelligible) and particularly when picking up stations; in this case the wireless operator listens whether he is being called by any airport and must therefore listen as it were to all stations at the same time. To permit this to be done the selectivity of the apparatus is variable; the band width can be adjusted to 3.8, 5.5 and 7.5 kilocycles. The smallest band width is used for receiving continuous-wave telegraph transmitters, the medium width for telephony and tonic-train telegraphy, and the largest for picking up stations.

A photograph of the receiver with the chassis pulled out is reproduced in fig. 5.

**Fig. 5.** V.O. 18 receiver with chassis pulled out. The housing and chassis are made of duralumin.

**The Aerials**

The Douglas air liners are equipped with a trailing aerial, i.e. a wire 60 m long which is loaded with a weight at the lower end and can be paid out during flight through a lead-through in the body of the aircraft. The paying-out and winding-in of the aerial is performed by a winch. An electrical counterpoise is provided by the metal fuselage of the aircraft.

In many cases a trailing aerial cannot be used. The time required to fly from one airport to another at a small distance, e.g. from Schiphol to Waalhaven, is only a few minutes at the high speeds attained by the Douglas machines. This time is not sufficient for paying out the aerial. Nevertheless, unbroken radio communication is necessary, for the aircraft must receive its landing instructions from the airport during flights. Moreover, it is desirable when landing to take in the aerial in good time and yet remain in communication with the airpost up to the last minute. For this purpose each machine is equipped with an additional aerial which is fixed permanently above the body. This is also naturally the only means whereby landing can be controlled from radio-beacons.

The Douglas air liners must be capable of flying in all weathers. Should they fly through storm clouds, a long trailing aerial will increase the danger of being struck by lightning. The aerial is therefore taken in and transmission and reception must then be maintained with the aid of the fixed aerial. To keep in communication with the airport, which in this case may be at a greater distance, and in spite of the lower radiation of the fixed aerial, which has only one quarter of the "effective height" of the trailing aerial, every care has been taken that the maximum possible portion of the available energy is radiated. In view of this, not only the trailing aerial but also the fixed aerial has, therefore, been carefully adapted to the amplifying stage, by introducing a special aerial-loading inductance and aerial coupling. A single manual movement of the switch provided is all that is required to change over from the trailing aerial to the fixed aerial.

**Power Supply**

Perhaps the nature of the power supply best brings out how far improvements in aircraft design have had a fundamental influence on the design of the aircraft wireless equipment. In the past an outboard generator was used with an auto-regulat-
ing air-screw (the anode voltage and the filament voltage had to be kept constant; in other words, the speed of the air-screw had to be independent of the "wind" velocity over a wide range, i.e. of the flying speed). As the flying speed was increased, which was achieved mainly by giving all and even the smallest components of the aircraft a stream-line design, the use of an outboard generator was no longer permissible in view of its high air resistance.

To act as a source of power for the whole equipment, the 12-volt starting battery is now used with the V.R. 18 set. The filaments are fed directly from the battery. The anode voltages for the transmitting and receiving valves are furnished by two converters which are driven from the battery. The anode voltage of the receiving valves must be properly smoothed and any interference eliminated. Formerly the necessary supply was therefore furnished by a dry battery; the converter now used for this purpose is of special design with a very low interference from the commutator brushes and in which all causes of interference have been most carefully eliminated by means of condensers and chokes.

The converter for the transmitting valves furnishes a uni-directional voltage of 500 volts at 300 milliamps and the converter for the receiving valves 200 volts at 40 milliamps. The starting battery is recharged during flight by a dynamo, which is driven from the aero-engines. Compared with the outboard generator, the battery offers the additional advantage that the machine can for some time continue to send out wireless messages from the ground, for instance after a forced landing.

Installation of Equipment

The transmitter with the associated converter is accommodated in a corner of the luggage cabin. It is suspended by shock-absorbing cables and is thus adequately protected against jolts and vibration. The receiver is set up on spring rubber supports in front of the operator's seat (fig. 6), together with the control box, on which are arranged, among other items, the Morse keys, various switches and the aerial ammeter. For night flying, dial illumination is provided, being capable of regulation and so placed that it does not interfere with the pilot's field of vision. The components of the transmitter and receiver are mounted on special chassis, which can be taken out separately. Like the boxes and the converter housings, these chassis are made of duralumin or aluminium in order to keep the weight as low as possible. The whole equipment (transmitter, receiver, two converters, winch and aerial lead-through, control box, switches, cable and telephone) weighs about 92 lbs.

Fig. 6. Installation of the receiver (above) and the control box (below) in front of the wireless operator in the pilot's cabin of a Douglas air liner.