RADIO CONTROL
FOR MODELS

RADIO CONTROL FOR MODELS — Honnest-Redlich

RADIO CONTROL FOR MODELS

A comprehensive work on the theory, construction, and use of radio control apparatus for use in model aircraft and model boats, for the instruction and use of the modelmaker rather than the expert electronic engineer.

By

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Contents

The Author demonstrating a three point landing by use of rudder control only. Alternate rights and lefts slow the plane down and produce a slight "stall". When well practised, spot landings with a very short run can be made. With this particular 72-in. span plane, operation had to commence about four feet above ground level, with half second alternate rudder movements.

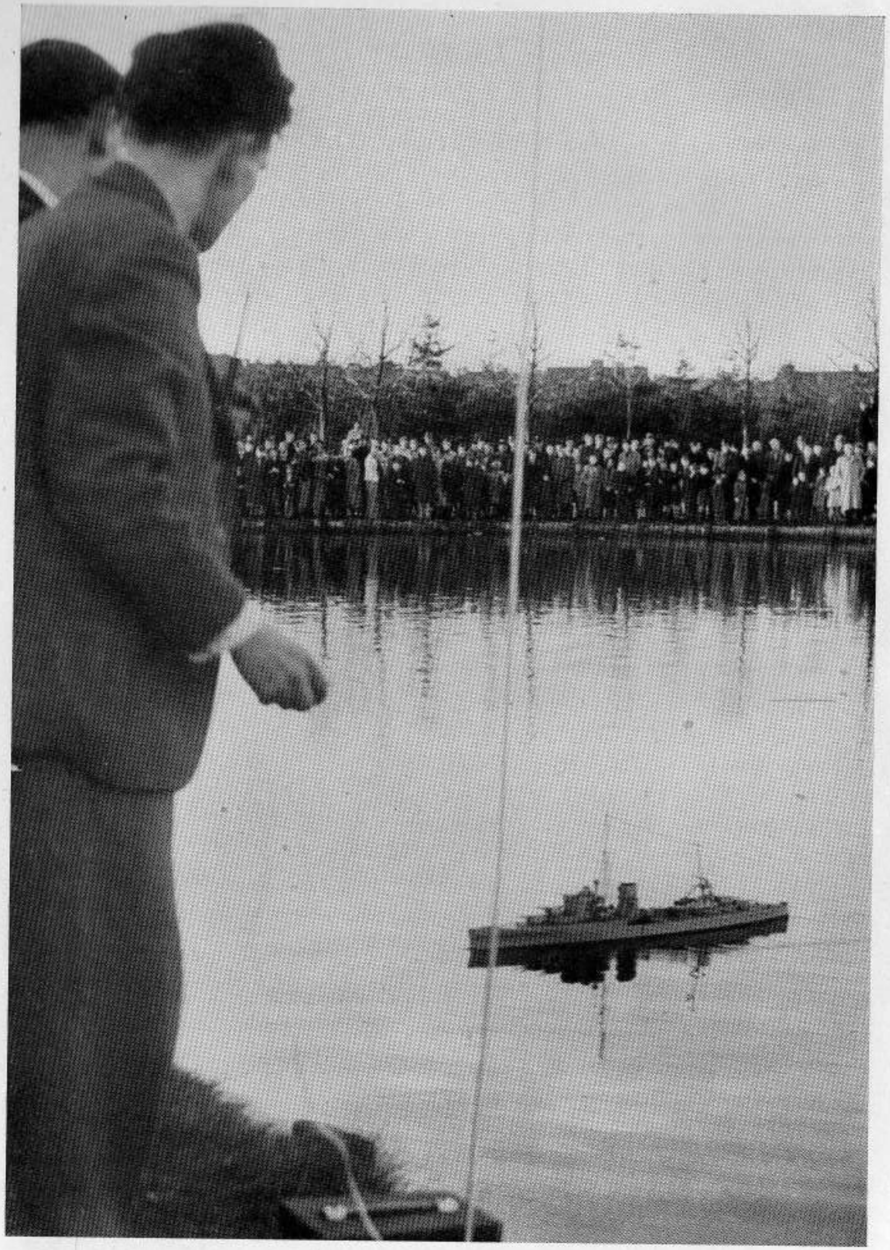
Foreword

THE construction of model planes and boats has captured the interest of a great many of those who require a stimulation for their hands and brains even in their spare time. However, the enthusiasm and interest shown in the design and construction stages often wanes after it has passed its first tests. The times the model is taken to the local open space or lake get less frequent, and often it finishes up in a dusty loft or cupboard. The reason for this, in my opinion, is that once launched it is out of touch with the hands that have created it, and can only pursue its set course at the mercy of wind and wave. Radio Control can recreate that personal touch with the model, and interest in a really "working" model will not flag. Added to this, the ingenious mind will find great pleasure in designing and constructing the intergear which following the radio receiver can translate the radio signal into the various mechanical movements to operate the necessary controls as well as a host of auxiliary operations. Profound radio knowledge is not required to follow the workings of R.C. A general perusal and study of the first chapters of this book is all that is necessary. The interest to go further and develop the purely radio portion will appeal to the two million odd radio amateurs whose hobby has been dormant since the advent of the mass-produced superheterodyne broadcast radio receiver. For the home constructor, a simple meter, soldering iron, drill, screwdriver and pliers are the only tools required to construct the complete job, transmitter, receiver and model. This book has been written with this in mind, and therefore the greatest emphasis has been laid upon the simple fundamentals, with which, after all, the beginner will obtain the best results.

Many of the circuits and gadgets described have been developed over a period of years by various amateurs both at home and abroad. My personal contacts, by which I have accumulated both knowledge and ideas through the medium of conversation and debates upon R.C. are the members of "The Radio Controlled Models Society", my great friend, Mr. C. Pépin of France, and Mr. P. T. Capon, who initiated me into the art of modelling and flying. Not forgetting the host of unknowns I have met on flying fields and at lake sides. The "whys" and "ifs" of the novice are the greatest stimulation to produce a perhaps dormant answer to a problem.

G. HONNEST-REDLICH

1950



Author demonstrating Mr. F. H. Mitchell's scale model of H.M.S. Ajax, on a lake in Amsterdam. E.D. radio equipment with addition of a delay circuit to reverse twin electric motors. Accurate scale was preserved by camouflaging switches and plugs etc., as bollards etc.

Introduction

History of Radio Control—Its uses—Its limitations—Subdivision into: Radio link, control gear, intergear, operative gear.

EARLY in the life of any event, it is difficult to summarise it into any definite sequence. Developments may have been made on parallel lines by several people, and to name one would hardly be fair to the others less known. Especially among hobbyists, a suggestion or idea which has taken study of the subject and time to germinate is often put into operation and given publicity by another.

Therefore I shall only generalise upon the history of R.C. and leave the more distant future to name the pioneers.

The events and great names of "Wireless Telegraphy" are of course the foundation R.C. is built upon, and the moment morse was mechanically recorded by radio was perhaps the conception of R.C.

The earliest date, the birthdate, of R.C. was June 30th, 1905, when at a Paris exhibition Professor Branly demonstrated the switching on and off of machinery, firing of guns and other feats controlled at a distance by radio. I have no full technical details, but according to the date, the radio equipment must have consisted of a spark transmitter and coherer receiver !

Following this, it is sad but not very unusual, the brains of the world were bent upon developing the new child to operate all types of engines of war, culminating in the well-remembered V2. One exception only, the control of unmanned lighthouses by radio was carried out in France.

In 1934 articles began to appear in American radio periodicals upon R.C. for models. The growth was not very quick, due to transmitting regulations which excluded all but the licensed radio amateurs. A transmitting radio amateur has seldom the necessary time to construct models. Only in France have radio and model specialists got together to form very reliable teams.

Then in 1938 there arrived the one major development which by simplifying and lowering the price, put R.C. within the reach of all, the RK 62 thyratron valve, followed by the RK 61. This valve was developed specially for R.C. and has no use in normal radio circuits. Due to the war the thyratron has only just been put upon the market over here.

This, up to date, is the development on the radio side. Following the radio, the method of mechanical control has been based upon the escapement, which first appeared in the U.S.A. again. Various other methods which have been scaled down from war missiles have been attempted and some used with success. Tuned reeds have also developed side by side in France, the United States and in England. The basic idea is the same, but their application has differed.

R.C. is nearly at the point of standardisation ; when that point is reached, with its attendant stability, then we can say that the child R.C. has reached a man's estate.

R.C. to-day is no longer solely in the hands of the specialists, large numbers of non-radio technical modellers have enthusiastically taken it up. It is the ideal means of controlling moving models at a distance. Various other methods have been attempted with some success, control by sound waves, and for boats by water borne electric currents. The first is only usable in absence of all other loud noises, and would exclude for example an internal combustion engine as motive power. The second has been used with great success with boats, but has the disadvantage of circuit complication and a non-portable transmitter with at least two widely spaced electrode connections to the water.

Control by radio can be three dimensional and over the comparatively short visual distances entirely independent of ground contours and conditions, as well as such visual obstructions as houses, walls, trees, etc.

We can control a model in any way in which the model itself is capable of being controlled. It must be well understood that one cannot expect to stunt a model plane which, by design or power is not capable of it. Weight and size of the radio and mechanical control equipment is perhaps the first great limiting factor. The weight is largely governed by the batteries, and miniaturising the mechanical equipment below a certain size is not advisable from the point of view of reliability.

The second great limiting factor is a combination of various time lags. Not being in the model ourselves, we lose that personal touch. A motorist or perhaps even more so, a cyclist tends to correct any deviation of his machine before it is hardly apparent. The time lag is very small. With a R.C. model, however, a deviation has to be seen before we can correct by the transmitter controls. The receiver and following mechanical controls all have their time lags. On top of this, as we shall see in later chapters, it requires quite complicated circuits and equipment to give "progressive" controls, that is, accurately desired fractional movements. As simplicity is generally synonymous with reliability, the majority of R.C. models will have definite predetermined control movements, and it will require practice and skill on the part of the operator to manœuvre with any degree of accuracy.

In order to understand the functioning of R.C. we can split it up into three major parts, as follows:—(1) Transmitter control gear; (2) Radio link ; (3) Intergear.

The transmitter control gear consists of any manually operated knob, lever or dial, or any automatic equipment intended to operate the transmitter. The radio link consists of both transmitter and receiver. The intergear is the equipment which follows the receiver to operate the controls. It must be understood that via the radio link a signal can only be transmitted which by itself can only open or close an electrical switch (relay) at the output of the receiver. This switch operates the intergear which changes the electrical energy into a mechanical movement to operate the model controls. Control of several operations is achieved by transmitting either several signals in a definite sequence, or by signals of different duration, or of signals of differing types, or a combination of such signals. Morse code is a well

known method of giving a signal "intelligence". The intergear sorts the various signals or sequences out and passes them as mechanical movements to the controls. This sounds rather complicated, but in its most simple form a push-button switch (transmitter control) operates the transmitter, which sends out a signal to the receiver (radio link), the receiver switch operates an electromagnetic "catch" which releases a stored mechanical energy in either clockwork spring or rubber skein form (intergear). This energy is used to move a rudder.

Aerial array used by French postal authorities to check frequencies at the 1949 International Competition. A half wave dipole with both reflector and director.

An interesting French radio controlled glider entered for the preliminary sections of their Miniwatt Radio Control Contest. Gliders have been particularly favoured by continental enthusiasts for R.C. work, as owing to licence requirements and the absence of much commercial equipment models are usually the result of "combined operations" between aeromodellers and electronic experts.

CHAPTER I

FUNDAMENTAL PRINCIPLES OF ELECTRICITY AND RADIO

Electrons—Volt and Ampère—Insulators and conductors—Resistance—Magnetism—Alternating currents and their relationship to V.A.O.—Induction—Transformers—Condensers—Values in general use—The radio valve, as amplifier and oscillator—Fundamental radio circuits for transmitters and receivers (basic)—Peculiarities of H.F. currents as used in the R.C. allocated frequencies, which introduce design and installation considerations.

THE basis of radio communication is the transmission and detection of electromagnetic waves between two points in space. Separate fundamental processes take place in this chain of events. At the transmitting end, power has to be generated or existing power changed into such a form that when applied to the radiator or aerial it is launched into space in electromagnetic waves. These waves are known as the **carrier.** The intelligence to be conveyed is either superimposed on this carrier or the carrier itself is interrupted in a definite sequence. The first is called **modulation** and the second is **interrupted continuous waves** (C.W.).

The waves spread out from the aerial, rapidly becoming weaker. At the receiving end a collector or aerial is used to gather as much energy as possible; this is then transformed into a change of current which may be further amplified to a suitable value to operate either oral or mechanical devices.

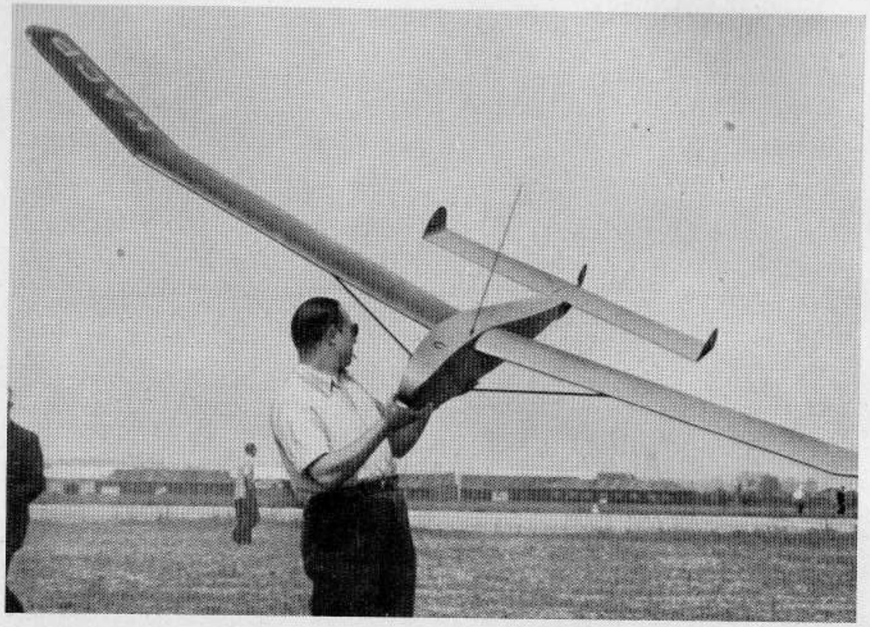
All of this is done by electrical means and therefore a basic knowledge of electricity is necessary in order to understand them.

It is intended in this chapter to put the fundamental principles in a simple understandable form without mathematical proofs, only presenting bare electrical facts.

The Electron is that portion of all matter which indicates its behaviour in an electrical circuit. The number of electrons in the smallest divisible portion of any element, the atom, determine its material characteristics. The ease by which electrons may be detached or moved from atom to atom determines its electrical characteristics. The "flow" of electrical current is actually the shift of electrons in a string of atoms. An electron arriving at an atom upsets its balance and a now surplus electron elsewhere in its orbit is flung out into space; this collides with a further atom and so on.

Whilst the centre or nucleus of the atom has a predominately positive charge, the electron is purely negative. Therefore the "flow" of electricity is from negative (—) to positive (+). Early scientists knowing nothing of electrons assumed and accepted a flow from positive to negative. For general purposes and in elementary circuit descriptions this rule is still accepted, but in dealing mainly with radio valves it must be retained in mind that the electron flow is from negative to positive.

The Volt is the unit of electrical



Large R.C. glider of the Werler, Ducrot, Pépin team at French International Competition, 1949. Note the vertical piano wire aerial, which for the French 72 M-C R.C. band need not be long, also the built in tuning meter

pressure, that is the power required to move an electron from the atom which binds it. The potential energy in a battery or at the terminals of a generator are given and measured in volts (V).

The Ampere is the measurement of the amount of the flow of electrons. This is obviously related to the pressure, the higher the pressure the stronger the flow. Also the power consumed is a function of the two, and volts (V) X amperes (A) is expressed in watts (W) as the power.

Insulators and conductors are the materials classified by their property of releasing electrons. Those which give up electrons readily are termed conductors, most metals, also acid or salt solutions, all in varying degrees are in this category. Other materials which hold their electrons more tightly bound are termed insulators, plastics, rubber, glass, wood, etc.

Resistance is the measure of the difficulty of moving an electron in a conductor. Good conductors have low resistance, good insulators a very high resistance.

Various materials come in between the two and these have a great importance in circuit design.

As copper is mainly used as an electrical conductor, it is used as a reference standard and the resistance of other conductors is given as compared to copper. It is obvious that the cross sectional area of the material also affects its resistance and the rule is that if the cross sectional area is halved then the resistance is doubled.

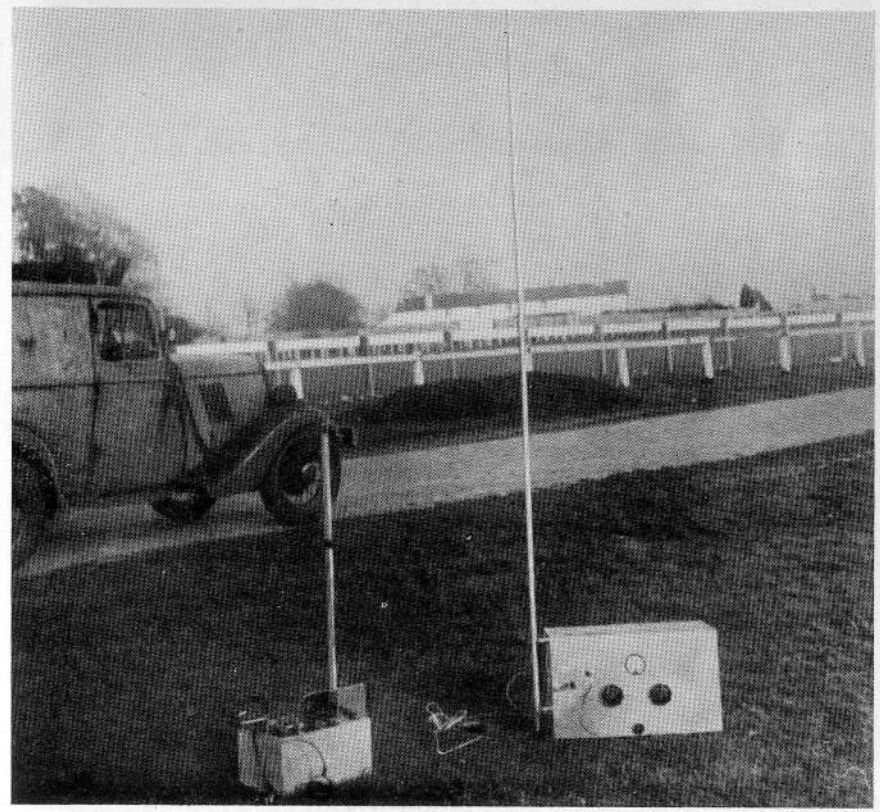
The unit of resistance is **the Ohm** (Ω), or in circuit diagrams R. If we put two or several resistors in series then the resulting total resistance is the sum of all of them. $R = R_1 + R_2 + R_3$, etc. The calculation of resistances in parallel is not quite so simple. The resultant of two equal

resistances in parallel is half that of either, but for unequal resistances we must use the formula, $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$.

Now having the three units V, A and R (often given as e, i, r) we can determine the value of any one by the simple ohms law: $A = V/R$, or in its other two forms, $R = V/A$ and $V = A \times R$. This relationship of the three units runs right through all general electrical problems and is the only formula required for a general understanding of our subject.

Magnetism. When a steady current flows through a coil of wire a magnetic field of force is set up. Even without an iron core this magnetism exists in the neighbourhood of the coil, outside as well as inside the core of the coil. The field can, however, be strengthened by fitting an iron core, or even better, a nearly closed U shaped core, only one leg of which passes through the coil. The iron collects the lines of force and they are then concentrated in the gap between the ends of the core. Ordinary ferrous materials have the property however of retaining their magnetism even when the current is switched off. Special ferrous alloys have been produced which have only little residual mag-

The Author's early 5w transmitter with equipment used for tests of field strength and radiation pattern.



The author's "Eros" twin engined. The smaller high wing engine, E.D. Competition special, was used as a boost to aid initial climb with only a small fuel tank. The main engine, E.D. Mk. III, then had ample power to maintain height for scale type manœuvres.

netism, transformer laminations being perhaps the best known. The slightest air gap in the closed magnetic circuit also helps the lines of force to disappear when the current is switched off. The application of magnetism is perhaps the most convenient means of changing electrical energy into a mechanical one.

An **alternating current** is one which reverses its direction of flow in a recurrent definite period of time. With pure alternating currents the change of direction is not a sudden reversal but a gradual change.

The simplest form is that which follows the sine law and is known as a sine wave. The current starts at zero, builds up to a maximum in one direction, returns to zero, builds up to maximum in the opposite direction and returns to zero again. This complete movement is termed one cycle, and the length of time taken to complete one cycle is called the period. The number of cycles the wave goes through each second is called the frequency.

As alternating currents never remain at a steady value, the voltage and current can only be given for a mean value. The average value of a sine wave is the root of the mean square of its highest or peak value. The R.M.S. voltage or current is far less than its peak value. For example, with a 240-volt mains supply the voltage rises to a peak of over 300 volts. The main consideration is one of insulation. Wiring

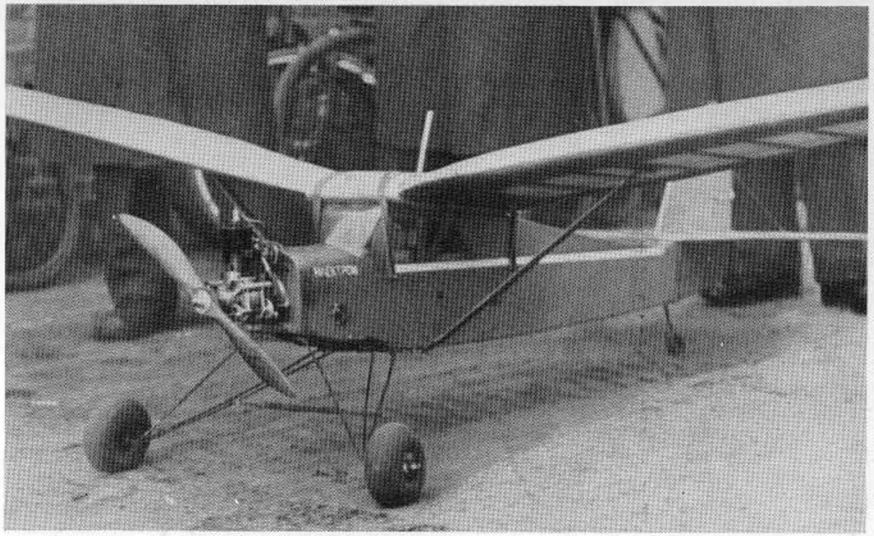
and components for A.C. operation need to be far better than for the equivalent D.C. voltage.

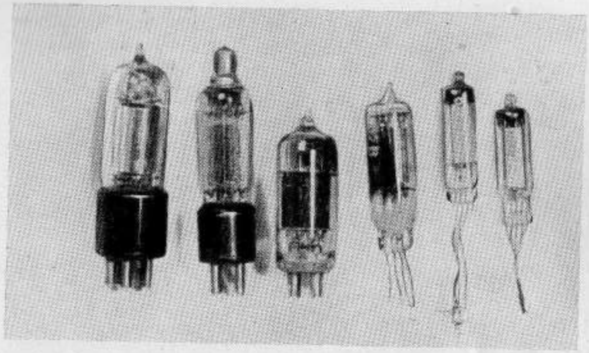
If in an A.C. circuit all components are purely resistive then Ohms law is applied as with D.C., but if a coil of wire is included in the circuit, the magnetic lines of force build up, collapse, build up again in the opposite direction and go to zero again, being repeated every cycle. During the rise and fall of the magnetic lines a secondary current is induced in the coil, this is opposed to the original current and therefore impedes its flow. This "Choking" effect may be used to separate A.C. in a D.C. circuit. Now, if a second independent coil is wound on the same former or core, then a current is also induced in it when A.C. is applied to the first one. The ratio of voltage transformation from the original coil or primary to the secondary is the same as the turns ratio, hence a transformer with a three to one ratio of turns will give 30 volts at the secondary if 10 volts are applied to the primary. The unit of measurement of a coil, its inductance value, is the Henry.

Condensers. In its elementary form a condenser consists of two conducting plates separated by an insulating gap. If a D.C. voltage is applied to the plates a momentary current will flow until the plates are saturated. Other than that initial very short flow, the circuit is as good as open. If, however, A.C. is applied the short initial flow is repeated every cycle. It will be seen that if the frequency is raised high enough the cycle will change before the plates are saturated and a current will flow as if the condenser were not there. Therefore, the resistance of a circuit with a condenser (capacitive) can be decreased by either increasing the condenser size or by increasing the frequency of the applied A.C. The unit of measurement of a condenser is the Farad.

We have here two very convenient

An early "test bed" for experimenta radio receivers. 15 c.c. Magpie engine, 72-in. span, rear wires of undercarriage sprung in slots.





Various types of valves used for R.C. receivers. From left to right. Hivac pentode and screengrid valves, 7 pin button based valve, Hivac decapped triode, deaf aid sub-miniature, Hivac X FG1 thyratron.

methods for separating A.C. from D.C. if both appear in one circuit.

Unit values in general use for radio are spread over wide limits. **Voltages** referred to in this book will be between one and 250 volts, **Amperages** between one ampere and one-thousandth of an ampere (one milli-ampere). **Resistances** between one ohm and five million (meg) ohms. **Condensers** between ten millionths of a microfarad (pico or pf) to eight microfarads (mf). Note—the Farad is far too large a unit and condensers of microfarad capacity are the largest in general use.

Coils between two microhenrys and 100 microhenrys for radio coils, and from one to 50 henrys for iron-cored chokes and transformers.

High Frequency Currents

Before turning to the design and layout of radio circuits we must consider and remember one further point, that is the behaviour of high frequency currents as opposed to the relatively low frequencies which we have studied in connection with iron-cored coils and transformers.

Mains frequencies, between 25 and 100 cycles, and audible frequencies between 50 and 12,000 cycles, can be transformed and "choked" by iron-cored coils, but the higher the frequency the more the core has to be split up into insulated laminations as a solid core would in theory consist of an infinite number of short-circuited turns in the field of the coil, which would consume power and detract from the efficiency of the inductance.

Above the audible frequencies the core has to be constructed with an iron dust core, each grain being insulated from the other by air-spacing achieved by loose packing or by mixture with various powdered or quick-drying liquid insulators. This holds good up to the medium wave radio band (approximately 1,000,000 cycles).

Now the 27 megacycle band of Radio Control needs greater care and attention, even the former the coils are wound on must be of "low loss" material, because insulators are by no means perfect and can cause heavy losses to the minute currents we receive via the aerial. We also know that the lines of force of a coil also extend outside the coil, therefore, we must keep our tuning coils well clear of other components and wiring.

One other peculiarity of high frequency currents is that they tend to progress on the surface of the conductor only. In order to lower the resistance of the conductor we can plate the wire, condenser plates, etc., with silver. Due to the better

conductivity of silver, even a few thousandths of an inch of plating will give greater efficiency. This is definitely necessary on the 465 megacycle band. Wires and components carrying H.F. should have a clean, smooth surface and connections should be as short as possible. Moving contacts, such as variable condenser spindles, aerial plugs and sockets, etc., should be tight fitting over a large surface area. Wobble or looseness in a turning condenser spindle, for example, is fatal for reliable performance.

The **radio valve,** in all its forms, is perhaps the Slave of the Lamp of the 20th Century. From the humble domestic radio receiver to the lately developed 'Electronic Brain', with its hundreds of valves, it dominates nearly all design considerations of the electrical, mechanical, optical, and chemical industries. Mainly because of its immense versatility and inherent reliability in coping with speeds and changes of speed which nearly surpass human comprehension. But, like all things, it has to have proper treatment in order to function. Lack of attention or a fault in a mechanical device is perceptible to our senses. A motor running without oil is readily audible. Our electrical eyes and ears, must however be care and commonsense, or a combination of both plus electrical indicating devices, meters. Where certain safe voltages or currents are specified, they must be adhered to. Better results may be obtained by higher voltages, but for how long ? The valve manufacturer knows exactly what his product can stand with reliability.

The Author's half wave dipole aerial used on tests for the French 72 M C band. Field strength tests however showed that over the visual distance of model control, the vertical quarter wave aerial was hardly inferior.

The two types of valve circuit we shall use are (1) As amplifier, (2) As oscillator (or producer of L.F. or H.F. waves). Certain variations and combinations of both can also be made, due to the flexibility of the valve but we can resolve all to the fundamental circuits.

The **Triode valve** consists of three internal components or electrodes: (1) Producer of free electrons, the cathode, which in a battery valve is usually a filament, and will be referred to as such. In a larger or mains valve the cathode may be a coated tube heated by an internal filament, and is referred to as cathode. (2) The control grid. (3) The anode or collector.

Certain valves have more than three electrodes but they do not enter greatly in R.C. circuits and their function will be explained in the instances they are used.

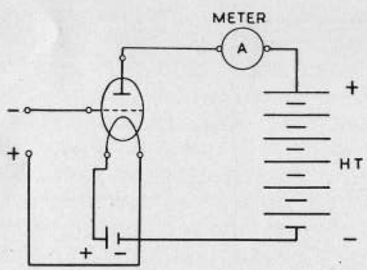


Fig. 1. Valve circuit with milliampere meter to indicate variation of anode current.

In a **closed circuit** (Fig. 1) electrons flow from the negative terminal of the H.T. battery, through the valve via the heated filament (which only in a heated state allows a flow through the vacuum of the valve) arrive at the anode and pursue their course through the meter to the positive terminal of the H.T. battery, the meter being included to indicate the amount of flow (ampere). Up to now we have neglected the grid. If we apply a voltage between the grid and filament (negative to grid and positive to filament) we will note a change of current in our meter. The higher the negative voltage applied to the grid, the lower the current in the **anode circuit.** The lower the voltage, the higher the current. According to the type of valve, a certain negative voltage will stop a current flow altogether (the cut-off point). If now we replace the meter with a resistance (Fig. 2) and

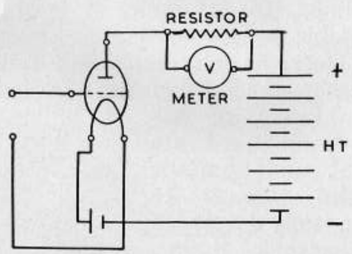


Fig. 2. Valve circuit with volt meter to indicate voltage variation at the load resistance.

measure the voltage across it we find that our variation of voltage to the grid (from 0 to the voltage required for cut-off) is followed by a voltage variation across the load resistance. Also we shall see that a small variation at the grid produces a much larger one at the load resistor. Here we have our basic amplifier.

We shall in this book use the valve as an A.C. amplifier, with an A.C. voltage applied to the grid, producing a fluctuating D.C. voltage at the anode resistor. The D.C. is blocked if we take our output via a condenser from the anode and we are left with an amplified A.C. voltage.

The second method is to use a transformer in the **anode circuit,** which again separates the A.C. component from the D.C. battery voltage (Fig. 3).

One further refinement is a steady

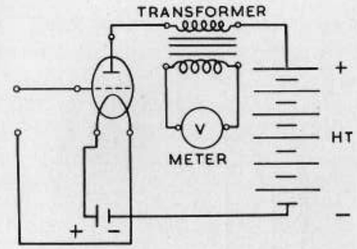


Fig. 3. Valve circuit with output transformer to separate the A.C. from the D.C. component. Note the meter must be an A.C. reading type.

negative bias to the grid to locate it between zero and cut off voltage. This is in order to allow the output A.C. to fluctuate between either limit without having its peaks "clipped" or distorted (Fig. 4). In

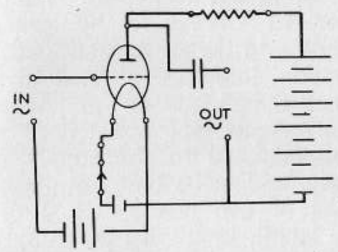
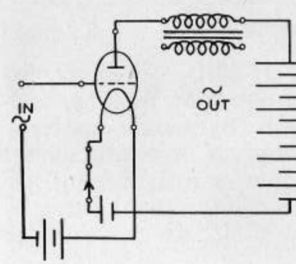


Fig. 4. Valve circuit with A.C. output via a D.C. blocking condenser, and below, via a transformer.



this simple valve circuit we have three separate circuits: (1) The **filament or heater circuit** ; (2) The **anode circuit** ; and (3) The **grid circuit.** Two of these (2) and (3) flow through the vacuum of the valve, and by inserting a switch in the filament circuit, we can with ease switch off all three, as the circuits through the valve vacuum rely upon a heated emitter of electrons.

The valve as oscillator can most easily be explained by following a **circuit diagram** (Fig. 5). Our grid

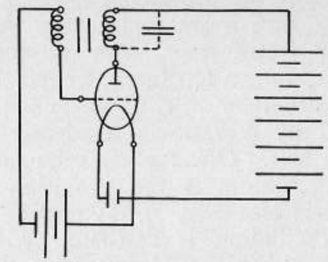


Fig. 5. Circuit of valve as L.F. oscillator, using a transformer to feed a portion of the output back into the input side.

input circuit is connected to one winding of a transformer, the other winding being in the anode circuit. If the connections to the transformer are made so that part of the amplified output of any random fluctuation is fed to the grid circuit in a direction which will boost the original voltage swing, then sustained oscillations will be generated of a frequency determined by the natural resonance of the transformer. Due to the valve amplification, greater oscillation power can be drawn from the anode circuit than from the grid. We can vary the resonance point of

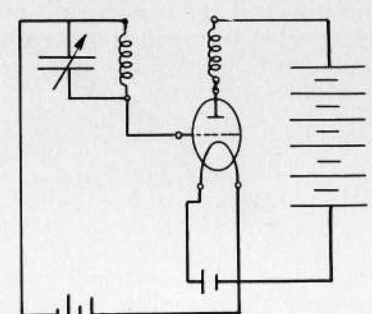


Fig. 6. Circuit of valve as H.F. oscillator, the grid coil being tuned.

the circuit by placing a condenser across one transformer winding. The larger the condenser the lower the frequency. This is a convenient method of "tuning" the circuit. The circuit as shown is an L.F. oscillator for producing an audible note. But, if we replace the iron-cored transformer with air-cored coils of only a few turns, we have an **H.F. oscillator** (Fig. 6) which can be tuned by a variable condenser of small size. One further refinement for oscillators is the provision of **self grid bias** (Fig. 7). A portion of the oscillation is rectified by the valve with the addition of a grid blocking condenser and a grid leak resistor, and remains as a steady bias voltage between grid and filament.

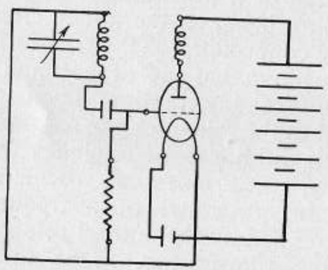


Fig. 7. Valve H.F. oscillator circuit with provision for automatic grid bias voltage.

Power generated and radiated by the transmitter must be selected by the particular receiver. A circuit comprising coil and condenser is not only capable of oscillating at one definite frequency, but is also receptive at that frequency only. This applies to all frequency bands, but at the higher frequencies the tuning is more critical, and great care must be taken to ensure that both coil and condenser are mechanically stable. The slightest movement of the turns of the coil, or of the condenser vanes, will cause the signal to fluctuate. This applies to both transmitter and receiver.

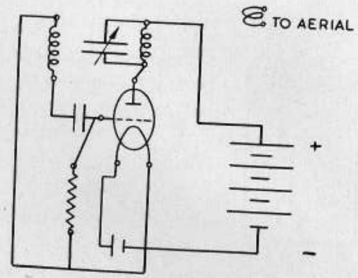
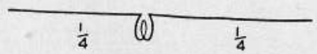
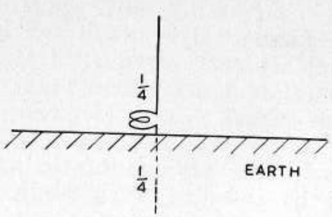


Fig. 8. Basic transmitter circuit, aerial being fed from anode coil.

Now, referring to Fig. 8, we have our usual H.F. oscillator but with the **tuned coil in the anode circuit.** The power to the radiator (aerial) is taken from here, and greater stability is obtained by tuning this circuit. Just as, mechanically, we match a motor to the drive by gearing according to the power and load, so our aerial load is connected to the oscillator coil geared or stepped down. Again, the aerial itself has to be matched to the supply frequency, and in its best form would consist of two arms, each $\frac{1}{4}$ of a wave length long with the coupling coil in the centre, thus:



This, at 27 M.C. would require an aerial of about 16 ft. long, and we compromise by using a quarter wave aerial, which if an earth connection is used is very little inferior, as we can imagine the other quarter wave section reflected in the earth thus:



At the receiver end with a model, we cannot hope to have an aerial more than a few feet long, and in order to obtain the greatest input to the coil we couple to the extreme end through a small **isolating condenser.**

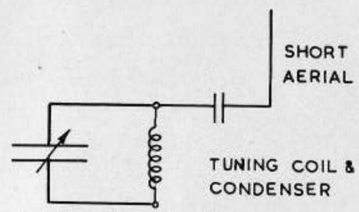


Fig. 9. Connection of aerial to receiver coil via a condenser to avoid overloading the tuning circuit.

The tuning coil and condenser are connected to the input circuit of a valve with the usual grid condenser and grid leak resistor to provide rectification. This is necessary to change the high-frequency wave into a steady change of current (Fig. 10), indicated by a meter in the anode circuit. This basic receiver is usually used as a **"field strength meter"** to determine the radiation strength of transmitters and their aerial systems. If we replace the meter with a suitable relay we have the receiving end of a R.C. link, but due to lack of sensitivity its range is very short, a matter of ten to fifty feet according to the

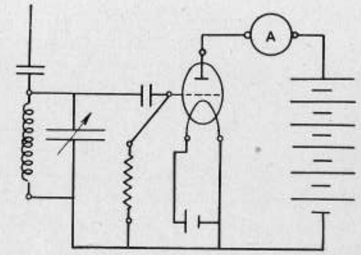


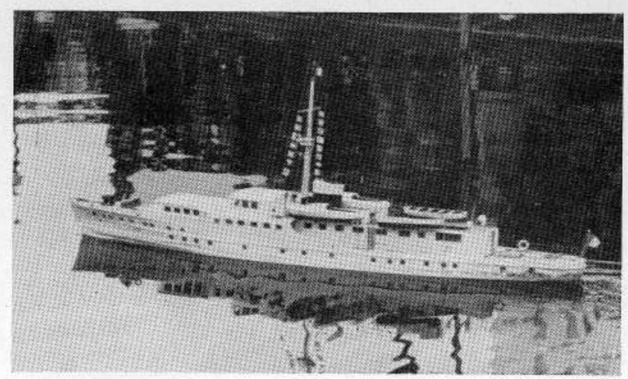
Fig. 10. Basic detector circuit, can be used to check transmitter radiation.

power of the transmitter.

This transmitter and receiver are what is termed a **carrier operated** type, that is, we radiate a pure wave of definite frequency and strength from the transmitter, which is detected in the receiver and converted into a current change. Now a second method, which calls for an addition in both transmitter and receiver, is called the **"modulated carrier"** control.

The transmitter again radiates a wave of a definite frequency, but its strength is varied in a pattern following that of an audible note. The receiver extracts the note from the carrier, which is now audible in the phones. Several methods can be used to convert this note into a useful current change and will be described in Chapter 4.

Yachts such as this give ample scope to the model builder and yet afford a splendid test bed for equipment not nearly so liable to accidental damage as the more fragile aeroplane. Equally weight considerations are less vital so that heavier "prototype" equipment can be tried out before cutting non-essential weight.



Mr. J. Ballard gives a helping hand to the author at a demonstration in Amsterdam. This was the first time R.C. had been seen in Holland, an ideal modellers' country from the point of view of both water and flat open country.

CHAPTER II

POWER SUPPLY FOR TRANSMITTERS AND RECEIVERS

Batteries—Primary cells—Accumulators—Weight and size considerations for required power—Other power supplies—Mains—Vibrators—Rotary converters.

BOTH transmitter and receiver need a power supply and, unfortunately it comprises the greater portion of weight and size of both.

Dry batteries or primary cells are the most popular for general use, having no free liquids and being readily obtainable everywhere even in remote districts. They all, irrespective of manufacturer, have a terminal voltage per cell of 1·5 volts. This voltage drops the moment a load is connected to the cell, if the load is heavy the voltage will drop very low. Even with a suitable load the voltage drops to about 1·3 or 1·4 volts. With the load connected, after the initial drop the voltage remains fairly steady but still with a steady fall until after a time the voltage drops steeply (Fig. 11).

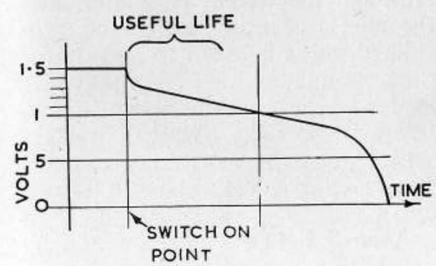


Fig. 11. Typical life curve of a dry cell. Useful life is only that portion of curve from full voltage to a 20% drop.

For certain portions of our circuits we cannot afford to have great voltage changes. Unfortunately the one which imposes the greatest load on a single cell is the filament of our valves, which for sensitivity and stability reasons have to be held to a close tolerance of applied voltage. For the usual 1·4 volt midget battery valves the permitted tolerance is from about 1·2 to 1·5 volts. When switched on, after a period of only minutes the voltage has dropped to 1·2 volts, and for our purpose the cell is finished. After a rest period the cell revives, but never to the original capacity and our useful period is then very much shorter. This is one major point for reliability.

If a cell for receiver valve filaments has been used once or for testing, mark it plainly, it can be used for further check tests, but never for operation, because you never know how long it will last. It is advisable to test various sizes of cells on the receiver and time them with a watch until the receiver fails to follow the operation of the transmitter. Take two thirds of this time for a safe fresh L.T. cell life for your receiver.

The types of **H.T. batteries** used for receivers are the "deaf aid" types, made of flat disc cells in layers, usually in 22½-volt units. The H.T. current drain of R.C. receivers is very small and we have practically no voltage drop. Lightweight types in various models with three valve receivers have usually lasted an entire season, even when used for several hours two or three times a week.

HEARING AID BATTERIES (H.T.)

Siemax	Voltage	Dimensions in inches	Weight in ounces	Connections	Max. current M.A.	Ever Ready
S 105	30	$1\frac{5}{16} \times 1 \times 2\frac{13}{16}$	$3\frac{1}{2}$	End caps	3	B 105
S 106	45	$1\frac{15}{16} \times 1\frac{3}{8} \times 3\frac{13}{16}$	$8\frac{1}{2}$	Three-pin socket	4	B 106
S 109	45	$2\frac{5}{8} \times 1 \times 3\frac{15}{16}$	8	,, ,,	4	B 109
S 110	$22\frac{1}{2}$	$1\frac{5}{16} \times 1 \times 2\frac{3}{16}$	3	End caps	3	B 110
S 112	45	$2\frac{1}{2} \times 1 \times 4\frac{1}{16}$	8	Three-pin socket	4	B 112
S 115	$22\frac{1}{2}$	$1\frac{5}{16} \times 1 \times 3\frac{15}{16}$	$4\frac{1}{2}$	,, ,,	5	B 115
S 116	33	$2\frac{5}{8} \times 1 \times 3\frac{1}{16}$	$6\frac{1}{2}$	,, ,,	5	B 116
S 119	30	$1\frac{11}{32} \times 1 \times 3\frac{11}{32}$	$3\frac{1}{2}$	,, ,,	3	B 119
S 120	15	$1\frac{5}{16} \times 1 \times 1\frac{9}{16}$	$1\frac{3}{4}$	End caps	3	B 120
S 121	15	$1\frac{1}{8} \times \frac{11}{16} \times 1\frac{1}{2}$	1	,, ,,	2	B 121
S 122	$22\frac{1}{2}$	$1\frac{1}{8} \times \frac{11}{16} \times 2$	$1\frac{1}{2}$	,, ,,	2	B 122
S 123	30	$1\frac{1}{8} \times \frac{11}{16} \times 2\frac{9}{16}$	$1\frac{3}{4}$	,, ,,	2	B 123

HEARING AID BATTERIES (L.T.)

Siemax	Voltage	Dimensions in inches	Weight in ounces	Connections	Max. current M.A.	Ever Ready
S 9	1·5	$1\frac{3}{8}$ dia. $\times 4\frac{3}{16}$	6	Two-pin socket	400	D 9
S 15	1·5	$1\frac{5}{16}$,, $\times 3\frac{1}{2}$	$4\frac{1}{2}$	,, ,,	300	D 15
S 18	1·5	1 ,, $\times 3\frac{11}{16}$	5	,, ,,	350	D 18
S 29	1·5	1 ,, $\times 3$	3	Centre contact	350	D 29
T 12	1·5	1 ,, $\times 1\frac{7}{8}$	$1\frac{1}{2}$	,, ,,	150	U 11
	1·5	$1\frac{3}{8}$,, $\times 2\frac{3}{8}$		,, ,,	300	U 2

Details of commercial batteries used for R.C. receivers. These are standard types easily obtainable.

Transmitters require a heavier battery, usually of from 90 to 120 volts for their H.T. Ordinary radio batteries are quite suitable for this and readily obtainable in these sizes. for the L.T. a battery or cell has to be chosen to suit the type of valve used. 1·4-volt valves again, would require a single cell dry battery, or for added capacity several cells connected in parallel, that is positive to positive, and negative to negative. These can be purchased as the 1·5-volt blocks used for portable radio receivers.

A **falling L.T. voltage** is accompanied by a gradual change of frequency of the transmitter, and although the weight is greater, and the effects of acid have to be considered, there is much to be said for the accumulator for L.T. supply. A lead and acid accumulator has a terminal voltage which quickly settles to two volts and remains steady at that voltage until it runs down.

A **small, light accumulator** for L.T. supply to the receiver, which has the benefit of longer operation and no falling off of sensitivity (Fig. 12), can be made up out of cut down accumulator plates with a thin celluloid case.

A permanent connection cannot be made to the terminal posts due to

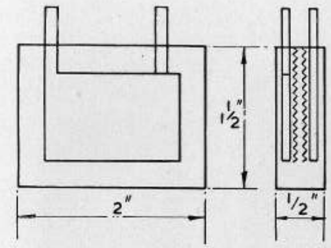


Fig. 12. Dimensions of a home-made accumulator of about ½ of an ampere-hour capacity.

acid corrosion. Small claw or crocodile clips are best used, but the terminal posts have to be scraped clean before use. This size accumulator can be charged from a six-volt car battery in series with a resistance wire of about 20 ohms. Even a $4\frac{1}{2}$-volt box bell battery will recharge the miniature accumulator through the same resistor (Fig. 13).

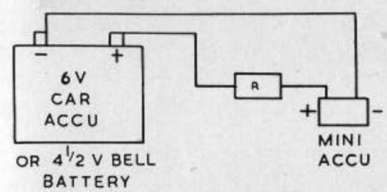
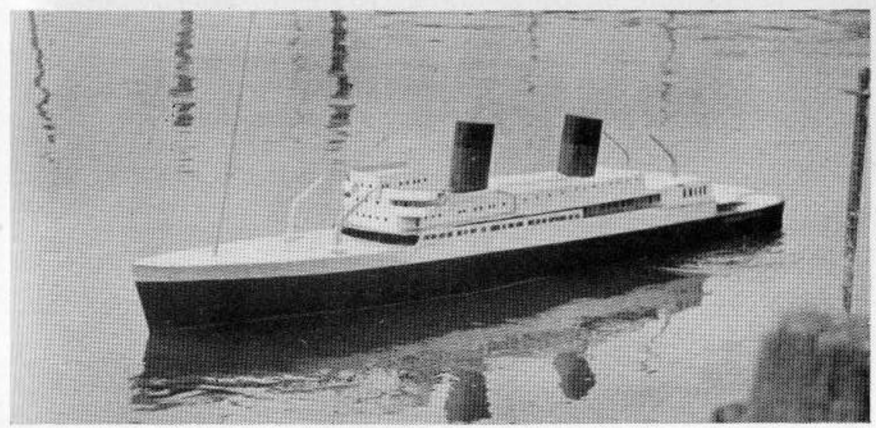


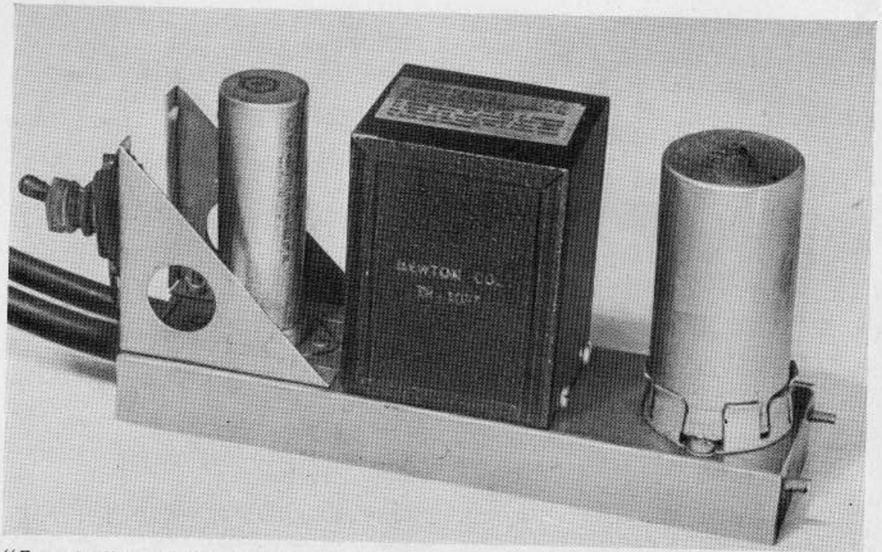
Fig. 13. Method of charging a small accumulator from a car battery.

Average types of dry cells and batteries used for R.C. receivers. These are all "Deaf Aid" types, and are stocked by model and radio dealers all over the country.

For the more pretentious transmitter with several valves and employing the full power rating which the G.P.O. permit for R.C., we find that dry batteries for both L.T. and H.T. become too bulky and the constant renewal due to the heavy current drain would be far too expensive.

This magnificent model of the ill-fated French Trans-Atlantic liner Normandie is an excellent example of the type of boat that can really provide a fitting medium for radio control, combining as it does a distinctive prototype that demands skill in construction with sufficient size for a wealth of equipment.





''Ex-services'' type of vibratory converter. With an input of 6v. and output of 200v. at 40 MA is eminently suitable for a car accumulator driven five watt transmitter. Enough surplus current is available for a modulator stage if required. A smoothing condenser is incorporated.

The mains would be a perfect supply, but obviously impracticable except for those fortunate enough to have an aerodrome and lake in their back garden.

A car accumulator either six or twelve volts, is a most convenient source of power. It can supply the filaments of the transmitting valves (usually 6·3 volts) either direct or in series. The same accumulator can also supply the H.T. stepped up to the required voltage by either a vibrator converter or a rotary transformer.

A **vibrator converter** consists of a buzzer type vibrating reed carrying several contacts. These contacts are connected to the accumulator and a small transformer in such a way that as the reed vibrates it sends a current from the accumulator through the transformer primary winding, first in one direction and then in the opposite direction, several times a second. This is a very rough form of A.C. and the transformer steps it up to a higher voltage in the secondary from where it is changed back into D.C. either by another set of contacts on the reed or by a valve or metal rectifier. Due to the ''roughness'' of the A.C. and subsequent D.C., it has to be filtered and smoothed. These units are supplied generally complete in a screened case with input terminals for the low voltage and output terminals for the high voltage.

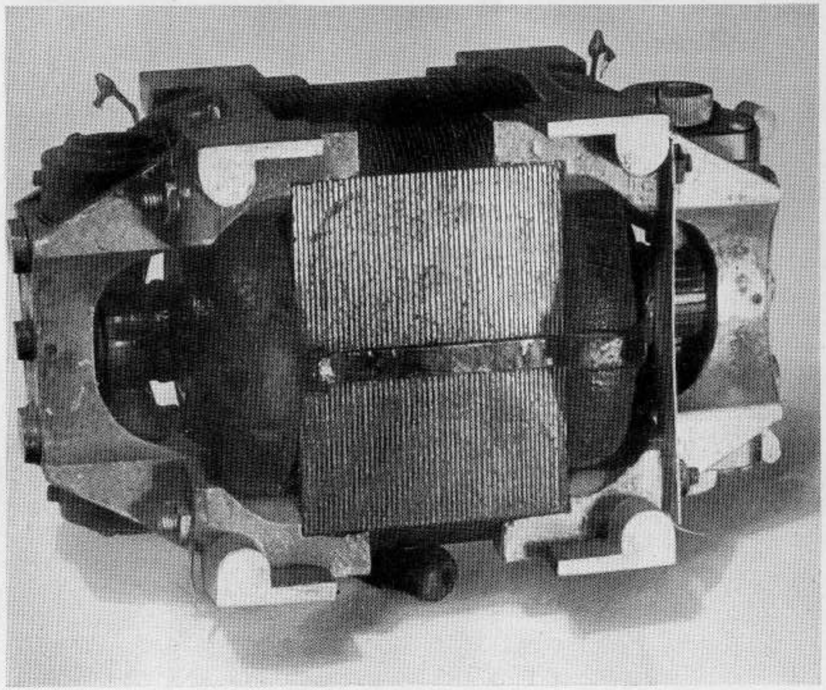
A **rotary converter** consists of a low voltage (6 or 12-volt) electric motor driving a higher voltage dynamo. In actual fact the two have been combined so that both motor and dynamo windings are on the same armature, but brought out to different collectors and terminals.

The ''purity'' of the rotary converter output is better than that of the vibrator converter. Its regulation, that is the stability of the output voltage according to the load imposed

upon it, is also better. It has the disadvantage of being not quite so small a unit to be easily built into a transmitter case.

At the receiver end in the model it would be quite possible to construct a vibrator converter for the H.T. (run off a miniature accumulator) but its weight and extra power consumption would eliminate it for all but the largest models, and in that case we could afford heavier batteries anyway.

Typical rotary converter. D.C low voltage motor input at one end and a high voltage D.C. output at the other. The output of this type converter requires little or no ''smoothing'' for normal R.C. transmitters.



Pioneer in the development of radio-controlled model aircraft, Squadron Leader Peter Hunt, on right, is seen with his latest creation, accompanied by the airframe design department, on left—a team arrangement which has enabled him to devote his full energies to improvements on the electrical side.

CHAPTER III

R.C. CIRCUITS, CARRIER OPERATED

The one valve transmitter and one valve super-regenerative receiver—The push-pull transmitter—The crystal controlled transmitter—The miniature gas-filled triode and basic circuit—The super-regenerative receiver with separate quench circuit—Construction of simple transmitter and receiver.

ANY **H.F. oscillator** is a transmitter in itself. It only requires an aerial in order to radiate the greatest percentage possible of its output.

However, there are various aspects to consider from the point of view of efficiency and stability. Efficiency is the percentage of H.F. output via the aerial with respect to the power consumed from the H.T. battery. Stability refers to the frequency which should remain within close limits. Our coil tuning condenser and valves, combined, with their spacing layout, and insulation, determine the efficiency. The same again plus their mechanical rigidity and that of the chassis they are mounted on determine the stability. Hard and fast rules cannot be given, they are a matter of practical experience.

Generally, for single valve transmitters on the 27 M.C., as well as the greater part of the short-wave band, a type of oscillator called the "**autodyne**" is used. This circuit (Fig. 14) functions with a single tuned coil. Feedback from the anode circuit is achieved by returning the other end of the coil to the grid via the grid blocking condenser. The H.T. voltage is now fed to the anode via a tapping on the coil. As far as the H.F. voltages at grid and anode are concerned, the battery circuit is at a neutral potential and must be connected to a neutral point of the coil. This neutral point is not at the centre of the coil due to unequal internal capacities of the valve. Generally it is slightly towards the grid end of the coil. Use of a different valve will slightly upset the neutral point and the inclusion of an H.F. choke in the tapping lead will obviate an accurate tapping point. The aerial coil is coupled to the oscillator coil, and the earth end is connected to H.T.- and L.T.-line.

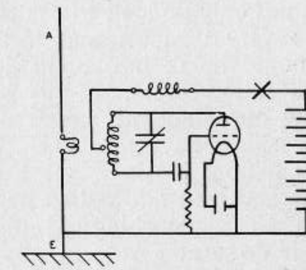


Fig. 14. Basic single valve transmitter circuit using one coil only.

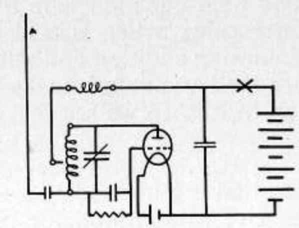


Fig. 15. Basic super-regenerative receiver circuit which differs from the transmitter only in component values and the return of the grid resistor.

A key or switch is connected at X in the H.T. line.

The **super-regenerative receiver** again employs the autodyne reactive circuit (Fig. 15) and at first glance may appear to be the same as the transmitter. Before going into detail we must explain one or two points.

We require a valve circuit which not only rectifies our H.F. carrier, but also amplifies. A reactive valve circuit is at its most sensitive when just on the verge of oscillating. That point is not only difficult to achieve, but also very unstable and if the valve should break into oscillation all amplification ceases. In this case we allow our autodyne circuit not only to oscillate, but oscillate fiercely. The oscillation is then quenched suddenly and then allowed to build up again. This quenching and building up if done at a rate of above 20,000 times a second (above audibility) permits the circuit to be on the verge of oscillation for quite an appreciable period. It has for normal broadcast use two drawbacks, firstly, oscillations are radiated from the aerial, and due to the quenching, the tuning is flat. The first hardly affects us, due to the extremely short aerials used on models, the radiation has only limited range (even so at times to 50 feet). The second "fault" is of great help to us, we are not concerned with separating one station from another, and a broad tuning makes it easier to adjust and hold our models in tune.

This **quenching action** is achieved by the following addition and alteration from the basic autodyne circuit. Referring to Fig. 15 we see that the grid leak resistor is returned via the coil to the H.T. positive line. We have seen that a grid condenser and grid leak give us an automatic bias. Now, if the grid resistor is chosen high enough, a high bias will result which if it exceeds the cut-off value, will stop the oscillation. This negative bias voltage is then leaked off to the H.T. + line and oscillation begins again. The frequency of the quench is determined by the values of the grid resistor, grid condenser, and also of another condenser from the anode circuit to the filament of the valve. This condenser is a bypass for the quench frequency. At point X we connect our indicating device or relay.

The operation is this: Our transmitter radiates an H.F. wave on depressing the key. The result in the receiver due to a complex action of rectification, and amplification, is that the current in the anode circuit drops from its steady value to a lower one. The amount of current drop is not quite proportional to the signal strength due to certain limiting actions, but generally, the weaker the signal, the smaller the drop in current.

The **push-pull transmitter circuit** (Fig. 16) is a more stable design and as such is recommended for the beginner. Internal valve capacities are balanced out and connections can be made direct to the centre of the coils. To see its relationship to our previous oscillators, shade one half of the diagram. The grid leak and condenser is then at the filament

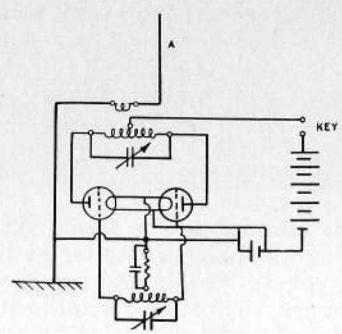
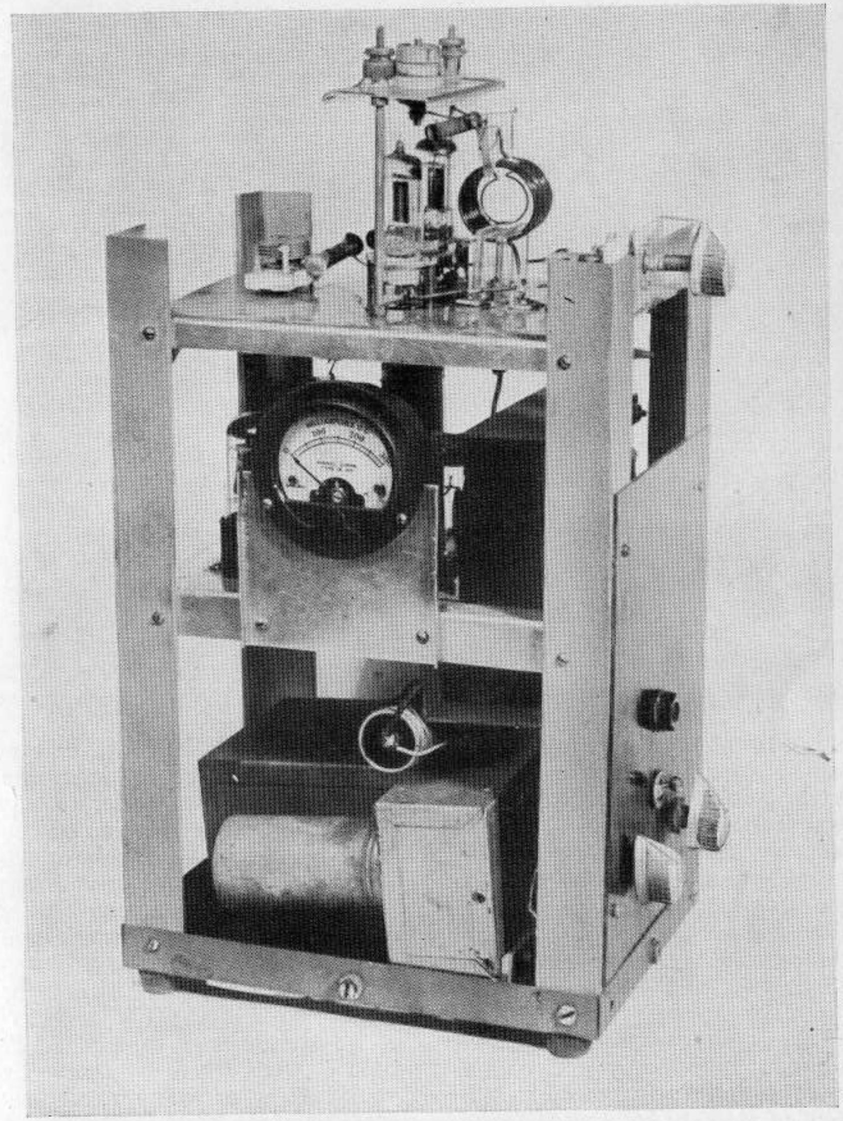
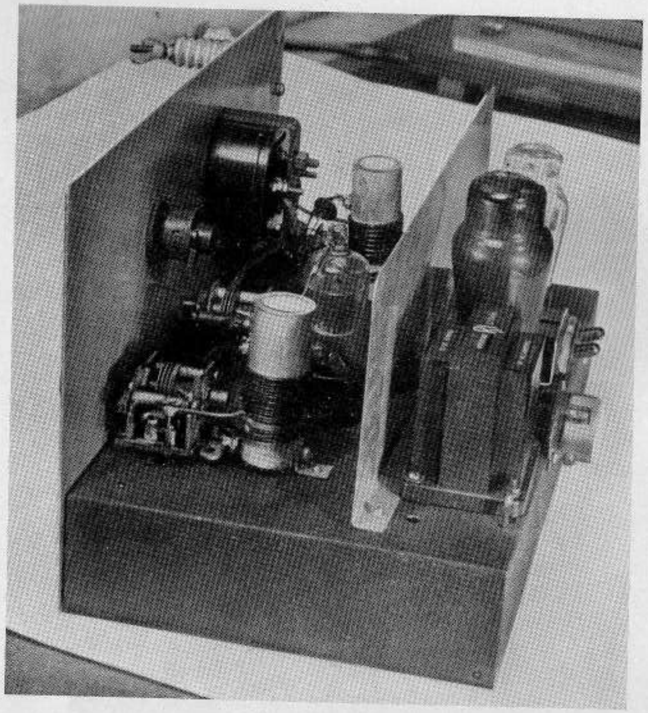


Fig. 16. Transmitter circuit using valves in push-pull with both grid and anode circuits tuned.



The author's experimental transmitter, adaptable by switching for any current R.C. system, carrier or modulation operated. Power variable from one to five watts. Modulation note and depth of modulation variable. Power from six volt accumulator via a vibrator convertor on lower deck. Centre deck is modulator stage consisting of a 6J5 L.F. oscillator and a 6V6 modulator valve. Top deck is the H.F. oscillator. Two 6C4 valves in a cross-fed Hartly circuit, anode modulated. Note the symmetric layout and short connections in the H.F. stage. Milliampere meter is an ex-Services type shunted to read a tenth of full scale.



A "classic" type of crystal controlled transmitter built by Mr. F. Hemsley to the author's design. This was designed to obtain the utmost H.F. power out of a given input wattage. An aerial matching coil is incorporated to prevent any frequency drift due to aerial load, also to transmit the full output via the aerial. A separate L.F. oscillator and modulator stage is at the rear of the chassis, well screened from the H.F. oscillator. A rigid chassis is also very necessary for frequency stability.

end of the coil, otherwise one would require two of each. The grid and anode coils are not wound on the same former or even coupled inductively. Feedback is achieved through the internal valve capacity. The frequency determining circuit is the anode one, the grid coil and condenser tuning will, however, have an effect on the power output of the transmitter.

The **Crystal-controlled transmitter** although more costly and complicated, is, from a frequency stability point of view, to be advised for the amateur. The crystal itself is usually a section of a large Rochelle salt crystal, cut and ground to definite dimensions. It has the property, amongst others, of producing oscillations when included in a suitable circuit. It can also act as if it were a tuned circuit of such accuracy that it will only accept its own natural frequency. It can be obtained from the manufacturer on order to any suitable frequency within certain limits. Unfortunately, above 20 M.C. only specially cut crystals are obtainable. But we can easily extract a convenient harmonic and use one of a lower frequency.

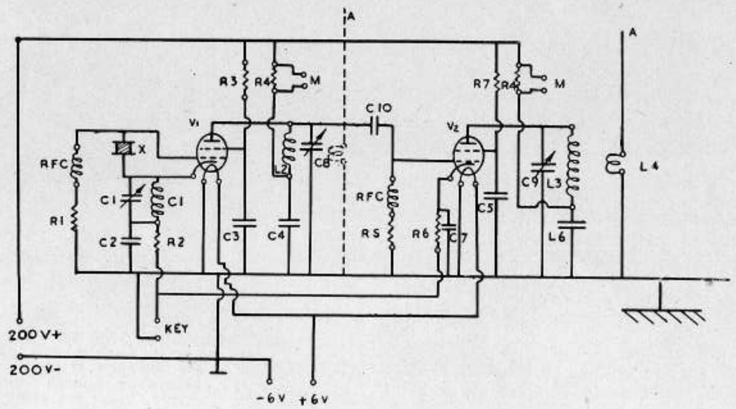
The **"Tritet" circuit** is perhaps the most suitable (Fig. 17).

A crystal ground to 6·78 M.C. would when twice frequency doubled bring us to approximately the centre of the 27 M.C. R.C. band (26·96 to 27·28). The transmitter shown employs valves with cathodes as emitters as these types would be used in equipment of this type, power being taken from a car accumulator.

The grid circuit of V1 oscillates due to the crystal at 6·78 M.C. The cathode circuit is tuned to the

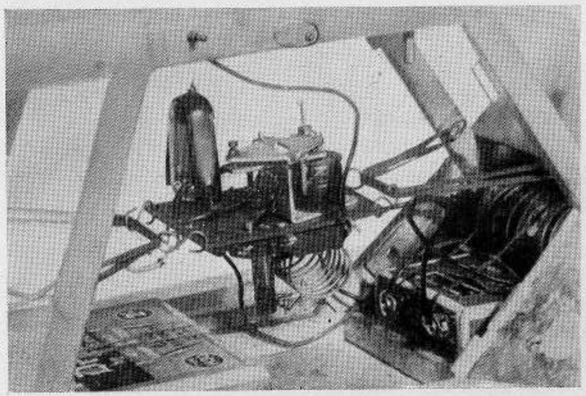
crystal frequency and the anode circuit to the second harmonic at 27·12 M.C. Output to the aerial can be taken from here (shown dotted) but due to extraction of the harmonics the H.F. power is not what the valve could supply if tuned to the fundamental or crystal frequency. Therefore, we add another similar valve in order to amplify the output of V1 and take our output from the anode circuit of that. Circuit values for a five-watt input are given. The operating key should be able to carry a fair current at a high voltage and should be well insulated, or better, a remotely controlled relay should be used. A milliammeter in the output valve H.T. circuit is necessary in order to adjust voltages not to exceed the permitted five watts.

The **miniature gas-filled triode** is perhaps the single development which has made R.C. so popular and widespread in the U.S.A. Those fortunate enough to be able to obtain them can produce a receiver of small size, complete with all batteries, weighing less than ten ounces. One particular manufactured example weighs just under seven ounces. The advantages of this valve are, firstly, due to a trace of a special gas left in the vacuum of the valve, the grid control is not progressive. That is, a voltage variation at the grid is not followed by a similar variation at the anode. At one point the anode current will rise precipitately and will fall just as suddenly when we reach a point in the other direction. So, if we adjust our circuits to operate on this point we get a sudden and heavy current change, irrespective of the strength of our signal, until of course it is too weak to operate it at all. Secondly, this valve has been designed to operate at a low H.T. voltage (45 V) and its filament requires a very low

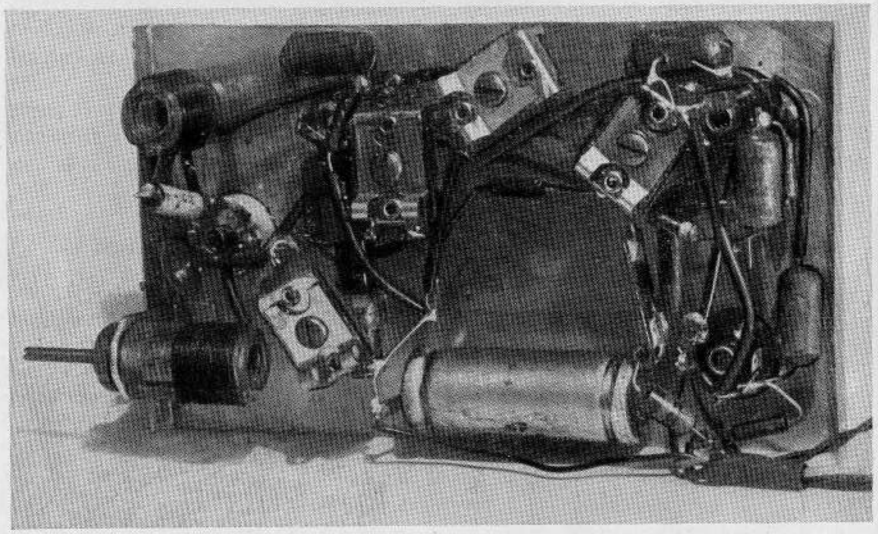


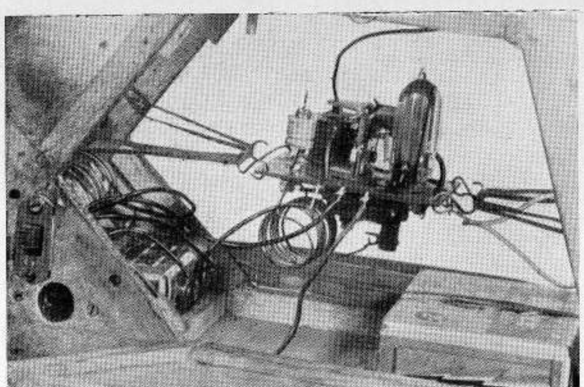
R1.	15,000Ω	R.F.C. 2·5 μH CHOKES.	C1. ·00015 V.C.	V1 6V6
R2.	250Ω	L1. 6 TURNS 22 S.W.G. 1½" DIA	C2, C7. ·01 MICA	V2 6V6 METAL
R3.	15,000Ω	L2, L3. 5 TURNS 18 S.W.G. 1" DIA.	C10. ·001 MICA	
R.4	100Ω	L4. 1 TURN AT END OF L3.	C8, C9 ·00005 VC	
R.5	15,000Ω	M CONNECTIONS FOR METER.	(V2. SHOULD NOT PASS MORE THAN 25 MA AT 200V HT)	
R.6.	1,000Ω	X. CRYSTAL		
R.7.	2,500Ω			

Fig. 17. Transmitter with crystal frequency control. This "Tritet" circuit is in general use with amateur transmitters.



Top and bottom: Mercury-Cossor receiver installed in the AEROMODELLER *staff-built version of Dr. Walter Good's Rudderbug, probably the first design to achieve widespread popularity in this country. Rudderbug has proved a very useful test bed for a variety of sets sent to the* AEROMODELLER *for editorial comment.*





Centre: Under-chassis view of the author's 4-valve super-heterodyne receiver. Ranges of over 10 miles are possible with even a low wattage transmitter. This type of receiver would lend itself to multiple chanel jobs of the "following" control types, and could be controlled at out-of-sight ranges.

power. This, in addition to its own miniature size, keeps the weight of the receiver low. Its one disadvantage is its relatively low life compared with pure vacuum valves. Also it is very susceptible to misuse. If its stated voltages and currents are exceeded even for a short time it becomes useless.

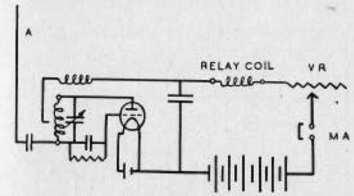


Fig. 18. Basic thyratron carrier operated receiver circuit. Carefully tuned will give a good range.

The circuit (Fig. 18) follows that of the one valve super-regenerative receiver, but it is wise to fit a variable resistance (about 20,000) and provision for connecting a milliammeter in the anode circuit, in order to adjust for operating point as well as not to exceed the safe H.T. current.

The **Super-regenerative Receiver with separate quench circuit.** The self-quenching super-regenerative circuit scores on the points of simplicity and lightness, but has the one major disadvantage of lack of stability. Slight variations of aerial load, power supply, etc., cause the quench frequency to change, upsetting the operating point. Also, although we talk of a definite quench frequency, it is only the average over a period of time. In actual fact quite a range of frequencies appear. In order to adjust and stabilise our sensitivity and operating point it is not only necessary to control and fix our quench frequency, but also to be able to determine the amount of quench. A separate stable oscillator coupled to our detector is the most reliable solution.

Referring to the circuit diagram (Fig. 19) we see that it can be easily split up into (left) our standard super-regenerative receiver, and (right) an H.F. oscillator. Taking the oscillator first, the coils are wound, in conjunction with the parallel condenser of the grid coil, to oscillate at the required frequency (approximately 20,000 cycles). At the anode of V2 we have a rising and falling voltage corresponding to that frequency. Now, if we take our voltage required for V, from the anode of V2, then that voltage rise and fall is superimposed upon the H.T. battery voltage. So that V1 will oscillate and quench at the frequency of V2.

Variation of the values of the self-bias grid condenser and resistor will determine the amount of quench voltage transferred to V1. The anode by-pass condenser of V1 must be returned to the anode of V2 instead of the L.T.-line, and it is advisable to by-pass the H.T. battery with a condenser.

With suitable valves and circuit values this receiver will give a current change of over one milliampere, and can be relied upon to have a ground range of well over half a mile.

Construction of a Simple Transmitter and Receiver. In the interests

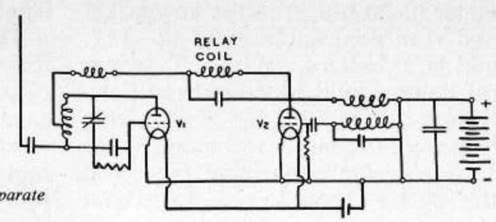


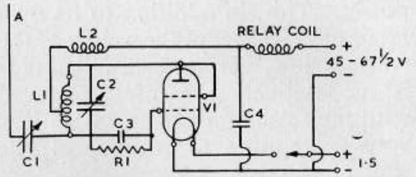
Fig. 19. Receiver circuit improved by use of a separate quench oscillator.

of all concerned, especially the G.P.O., use the lowest power possible for experimental work and general check tests. Encasing the equipment in a metal box does not entirely prevent radiation, even battery leads, especially if they are a quarter, or multiples of a quarter wavelength long, can radiate quite strongly. If no means are available for checking frequency, contact a local amateur with a transmitting licence; he will probably be only too keen to help you, and check your frequency. Construction of a simple absorption wave meter, also a field strength meter, is given in Chapter 13.

Make a point of drawing your circuit diagram first, then visualise your components and position them, remembering spacing of H.F. components short connections carrying H.F., and generally simple wiring.

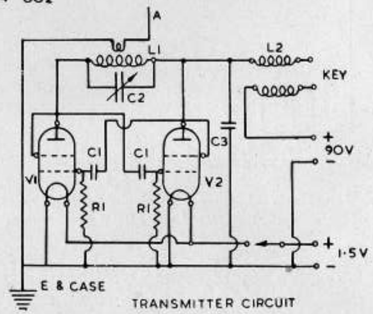
To follow our own advice, here (Fig. 20) is our transmitter and receiver circuit. The transmitter is a push-pull type which requires only one coil, and is therefore easy to adjust, feedback being achieved by a cross connection of grids and anodes through small condensers. In this case two separate grid leak resistors are required. The double coil L2 is a choke in the key leads to prevent H.F. radiation.

The wiring is so simple that an explanation is not required. 22 S.W.G. tinned wire and P.C.V. sleeving should be used. Battery leads of P.C.V. flex should be twisted together. After checking wiring carefully, connect a milliampere meter (0–30 range) to the key socket and then connect leads to the L.T. and H.T. battery. With L.T. switch off there should be no current flow. Switch on the L.T. and if all wiring is correct the meter will show about 12 M.A. On connecting the aerial the meter should rise to about



C1 20 PF TRIMMER
C2 20 PF
C3 100 PF
C4 ·002
R1 4 MEG
V1 3S4

RECEIVER CIRCUIT



TRANSMITTER CIRCUIT

C1 27 PF
C2 20 PF TRIMMER
C3 ·001
V1 & V2 3S4
L1 TUNING & AERIAL COIL
L2 DOUBLE CHOKE
R1 15 K

Fig. 20. Circuits of transmitter and receiver giving values of components.

15 M.A. This is a safe value for these valves. If the current consumption is not correct, it can be *raised* by *lowering* the grid leak values (keeping both equal of course), and lowered by raising the grid leak value.

The transmitter and batteries should now be fitted in a case; if a wooden case is used then separate metal box must enclose the tuning unit in both cases leaving a hole above the tuning condenser adjusting screw. The final adjustment for frequency must be made with the full length of aerial fitted.

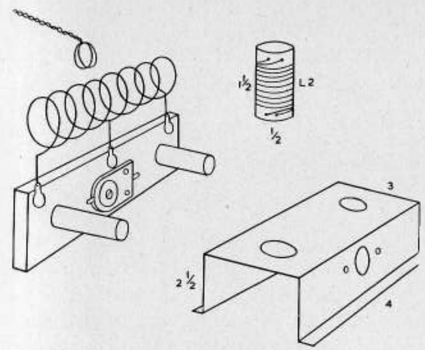
The receiver is quite straightforward, and it only remains to obtain the lightest and smallest relay capable of pulling in and out at under one milliampere. Unfortunately, the more sensitive and reliable relays are fairly heavy, but even a five-ounce

relay would be preferable to a lighter one which is hardly sensitive enough.

Operation. On receipt of a signal, the anode current flow of the receiver drops, and the reed or armature of the relay falls back on to the contact to operate the servo equipment. It will be seen that in this case when our receiver is switched off current will still flow in the servo equipment unless a switch is incorporated, or the servo battery disconnected.

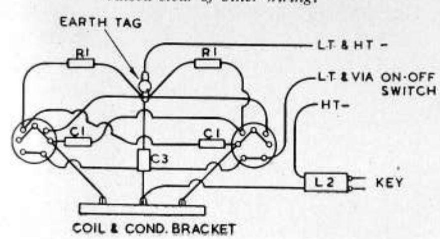
The tuning and adjusting sequence is given for a bench test at close quarters, providing that the same length of aerial is used as in the model then only a slight retune should be necessary when built in.

A milliampere meter (0–5 range) should be connected in the H.T. lead of the receiver. Switch the receiver on and turn both tuning and aerial condensers about halfway. Turn the aerial trimmer gradually in until the valve passes one milliampere. Then switch on transmitter (using an aerial only about 12 inches long to simulate distant reception) and press key. Keeping key down, turn the tuning condenser very slowly until at one point a current dip is noticed on the meter. Now release key and note how large the dip is. By slightly readjusting both tuner and aerial trimmer (alteration of one will require readjustment of the other) one position will be found where the dip (when keying) is greatest. Now adjust relay to drop out when key is depressed and click in when key is released (Chapter 5). The current dip will get smaller with a weaker signal, so finally adjust your relay to operate on the weakest signal possible.

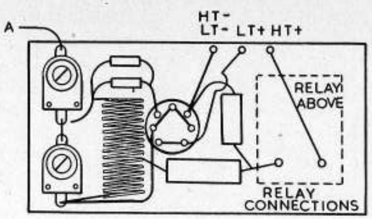


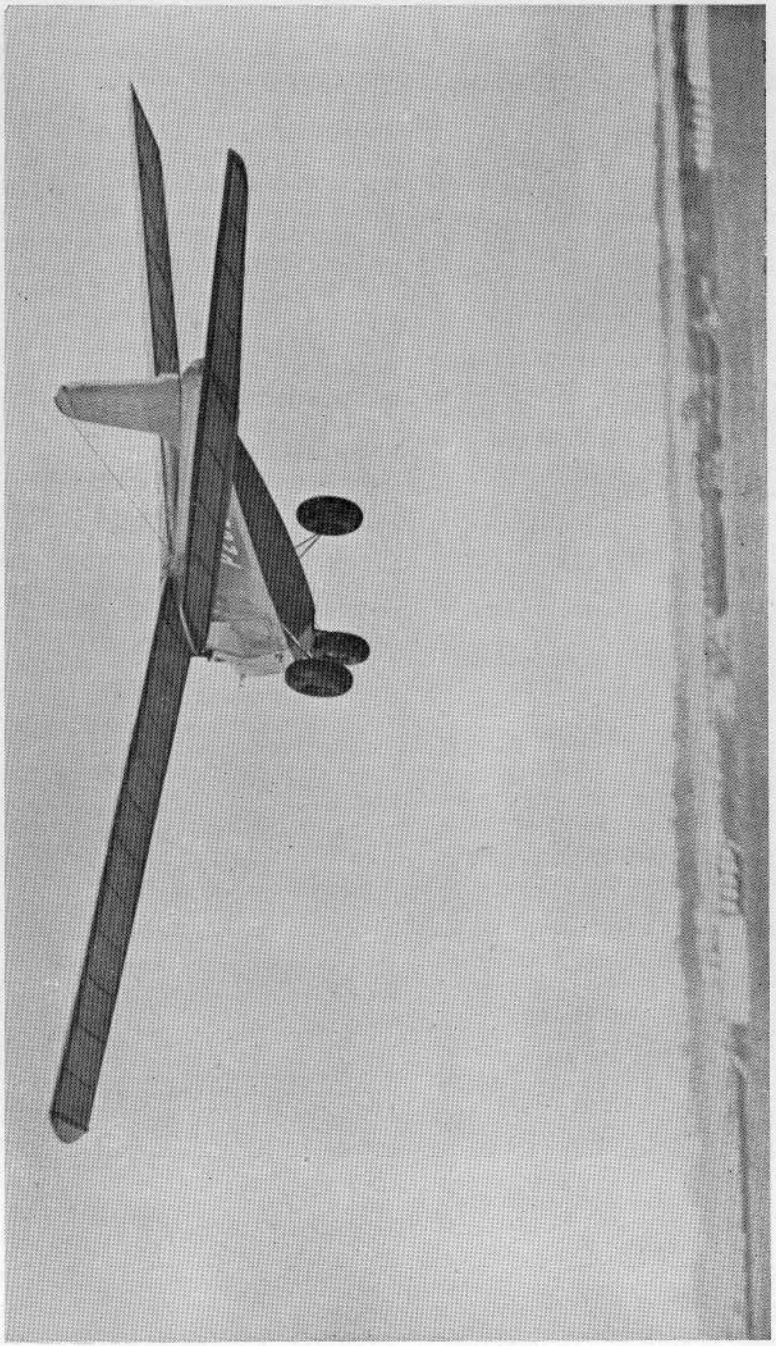
TRANSMITTER COMPONENTS.
COIL. 8 TURNS, 1" DIA, 16 SWG BARE COPPER WIRE 1" LONG
COIL BRACKET, ⅛" PERSPEX.
STAND-OFF TUBES, 1" LONG
AERIAL COIL, TWO TURNS INSULATED WIRE PUSHED
INTO CENTRE OF COIL & CEMENTED INTO POSITION.
LEADS TWISTED UP TO CONNECTION TO A & E TERMINALS
ERIAL TERMINAL INSULATED EARTH TERMINAL
ONNECTED TO CHASSIS.
2: PAXOLIN TUBE TWO 28 SWG DCC WIRES
OUND TOGETHER SINGLE LAYER.
IASSIS 18 SWG ALUMINIUM

TRANSMITTER WIRING DIAGRAM.
A symmetrical layout is essential, all earth connections should be made to one soldering tag. bolted to chassis halfway between valveholders. C3 lies underneath all wiring, close to chassis. Both C1 condensers should be raised clear of other wiring.



RECEIVER WIRING DIAGRAM.
Panel of $\frac{1}{16}$ paxolin 4 ins. × 2 ins. L1, 15 turns 24 swg. enamelled wire 10½ ins. long. When finally in position apply a spot of cement between turns here and there, so that the coil is mechanically rigid. Tapping point 6 turns from grid end. L2, 60 turns 34 swg., ssc. on an ebonite tube ¼ in. dia. Drill at ends to take a 26 swg. wire for connecting leads. Trimmers must be adjusted with an insulated tool in order to avoid hand capacity effects.





A British-built version of Dr. Walter Good's famous Rudderbug in flight. Replicas, double and half-size versions have been doing well at meetings all over the country, on account of its ultra-stable layout, though the tricycle undercarriage is only at its best where tarmac runways are available for take-off and landing.

CHAPTER IV

R.C. CIRCUITS, MODULATED CARRIER

Advantages—Three-valve direct modulation control—Transmitter modulation—Basic positive feedback circuit—Electronic tone selective circuits—Mechanical tone selective circuits.

ONE great drawback of receivers operated by an H.F. carrier only is that it is most difficult to provide for amplification in the receiver after the first valve. Even if H.F. amplification is provided, the rectified output is of such low amperage that a high resistance sensitive relay is necessary.

Therefore in order to produce a receiver capable of high amplification, with the inherent benefits of ease of control, stability and perhaps the main point, capable of operating a sturdy inexpensive non-sensitive relay, we have to turn to an entirely different method.

We modulate the H.F. carrier of the transmitter with an audible note. The detector valve of the receiver separates this note from the carrier and we can easily and without bulky components, amplify it with further valve circuits. This L.F. note is easy to ''handle'' and can be used in various ways to produce a really large current change for our relay. Another main advantage requires a slight explanation beforehand. Up to now we have operated our equipment by switching our H.F. carrier, leaving the receiver untuned to any reception during the off position. Now you know, when you tune your broadcast radio receiver at home, that when tuned to a strong station all background noise disappears. Tune away from a station and all of the static and man-made interference for miles around is audible in your speaker.

Now with L.F.-modulated R.C. transmitters there is no reason for not leaving the H.F. carrier permanently radiating so that our receiver is tuned to a ''silent spot''. We operate our receiver by simply keying an L.F. modulation note on to the carrier. The problem of interference from miniature ignition engines is for example very great. Let us now summarise the advantages and also the disadvantages.

Advantages

(1) Stability due to circuit design.
(2) Sturdy relays less sensitive to vibration troubles can be used.
(3) Complete freedom from interference.
(4) Easily tunable, no sensitive meters required, can be tuned with an audible note heard in a pair of phones.
(5) Receiver is less sensitive to variations in battery voltages.
(6) Various systems of using the L.F. note in the receiver can be devised, each having their own applications.

Disadvantages

(1) Extra components and valves required.
(2) Subsequent extra weight.

As you will see later on in this book, point 5 under advantages is of greatest interest to the modeller with inventive genius. Points 1 and 4 will

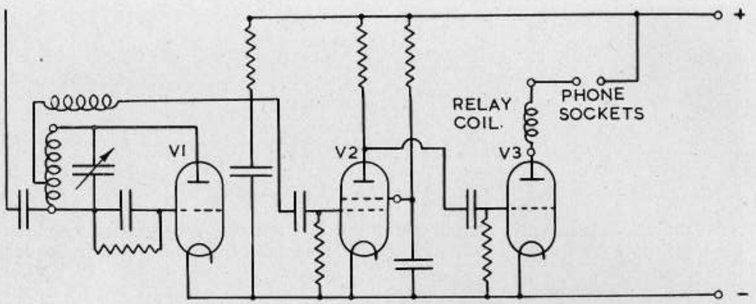


Fig. 21. Basic valve circuit for reception of modulated carriers. This circuit is quite standard and can be used as a S.W. broadcast receiver.

appeal to those who have no great radio experience. Points 2 and 5 for consistent and reliable results.

The disadvantages can be lumped together as one is the product of the other. Unfortunately they prohibit the small R.C. plane.

The **three-valve direct modulation control** is the most simple, straightforward method, and again we shall begin with a circuit diagram (Fig. 21) and progressively describe the components and their operation. Our usual super-regenerative detector valve V1 has a resistance instead of relay in the anode circuit and is now analagous to our basic L.F. amplifier, passing on the amplified L.F. to the grid of V2. V2 is another L.F. amplifier; this time a screen grid valve is chosen because of its higher amplification in a resistance condenser coupled circuit. The extra grid which must be run at a lower voltage than the anode is fed with H.T. via a resistance and decoupled to the negative line with a condenser. The anode voltage is very low due to voltage drop in the resistor and therefore the grid-bias required for this stage need not be high, in fact we can return the grid leak to the negative line.

The output of V2 is fed to the grid of the output valve V3. Here again the grid resistor is connected to the negative line, and due to the lower resistance value of the relay (compared with the anode resistor of V2) and the subsequent high voltage at the anode, the current flow will be high.

An L.F. signal arriving at the grid of V3 after amplification will be rectified by the grid condenser and leak and build up a steady negative bias according to its strength.

Therefore we have a current change in our relay coil from the highest the valve will pass without grid bias, to practically zero when the transmitter is keyed. With miniature valves generally used, and with H.T. battery voltages of between 45 and $67\frac{1}{2}$ volts, the full current is in the neighbourhood of 3 to 8 milliamperes.

One disadvantage is the fact that off signal the H.T. current flow is high, dropping only on receipt of an actuating signal. Therefore H.T. batteries will have to be of a heavier type capable of supplying the high standing H.T. current.

The transmitter modulation is not quite as simple as it may at first thought appear. Our audible note can be easily produced by means of a simple L.F. oscillator, but it must modulate the carrier as near as possible 100%. That is, it must be like a shout in a microphone, not a whisper, otherwise the amplification required in the receiver would lead

to excessive size and weight.

An L.F. oscillator valve does not produce enough power to fully modulate an H.F. oscillator valve of equal power. Therefore we need an L.F. amplifier in between. Several other methods can be used, but without instruments it is difficult to control the purity and amount of modulation.

Manufacturers who use these systems have all of the facilities to check on wave form and modulation depths.

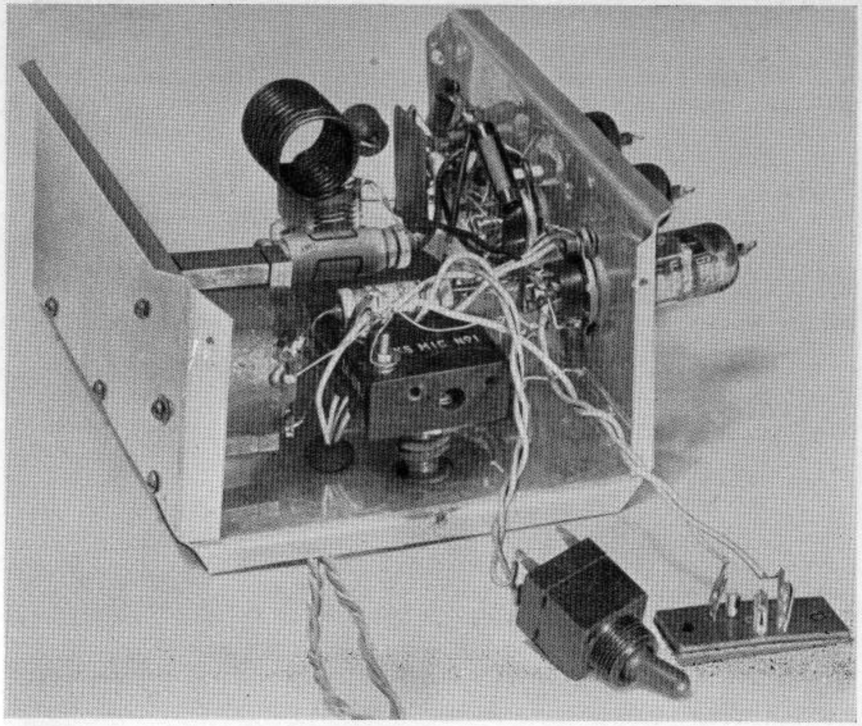
Fig. 22 has been given an **H.F. oscillator** of conventional basic design, but a push-pull or any other H.F. generator can be substituted.

Beginning with V1, which is a normal L.F. oscillator producing a note the frequency of which can be adjusted by the size of C2. The output is passed through a blocking condenser to a volume control (V.C.) which will enable us to adjust the depth of modulation. The signal is then applied to the grid of V2, an ordinary L.F. amplifier with a grid biased to amplify without distortion.

Now the anodes of both V2 and V3 have a common L.F. choke in circuit. This is to superimpose the L.F. note upon the H.T. supply to the H.F. oscillator V3. C1 is required to by-pass any H.F. in the anode circuit.

An easy test for the **depth of modulation** can be made in the following fashion. Connect up both transmitter and receiver, tune the receiver

Chassis of three valve dry battery operated transmitter for modulated carriers. Note spacing of tuning coil and condenser well away from other components.



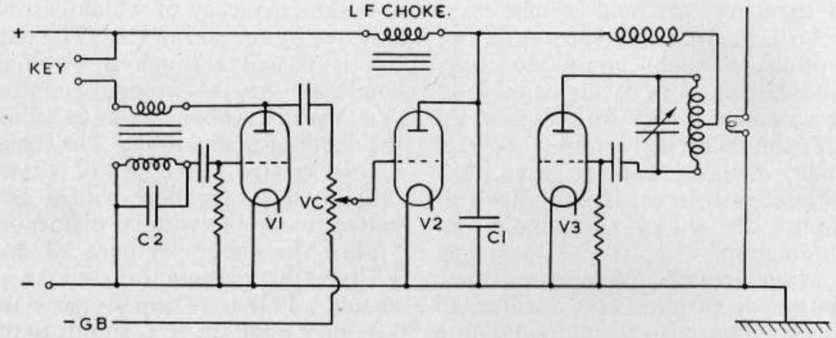


Fig. 22. Transmitter with L.F. oscillator and amplifier stage modulating a single valve H.F. oscillator.

to the H.F. carrier (silent spot) and then with volume control turned ¼ on depress the modulation key. A note will now be heard in the phones. On slowly increasing the transmitter volume control, the note in the receiver phones will increase until at one setting the note will go ''flat'' and there will be no further increase in volume. Turn volume control back to just before this point. This of course should be done with transmitter and receiver separated by a reasonable distance and with short aerials, in order to simulate working conditions. The pitch of the note itself may also be critical. L.F. amplifiers of normal types have ''peaks'' in their frequency response, that is, they amplify certain notes better than others. To find the optimum frequency of our receiver, we connect a milliampere meter instead of the phones in the anode circuit of the output valve. Permanently key the transmitter modulation, and replace C2 (transmitter) with condensers of various sizes. The condenser value which gives us our *lowest* reading is then the correct one. This adjustment must definitely be done under weak-signal or long-range conditions.

The **basic positive feedback circuit** given here has two major advantages added to those already tabulated for ''Modulated Carrier Control''. The first is that the current variation applied to the relay is constant irrespective of distance from the transmitter and consequent signal strength. As long as an audible signal is received, the relay is operated at *full* strength. The second great advantage is that off signal the anode current is nearly zero, and only rises to the full value when an operating pulse is transmitted. This allows us to use smaller and lighter H.T. batteries. Only one addition has to be made, a grid bias battery is required, this however, due

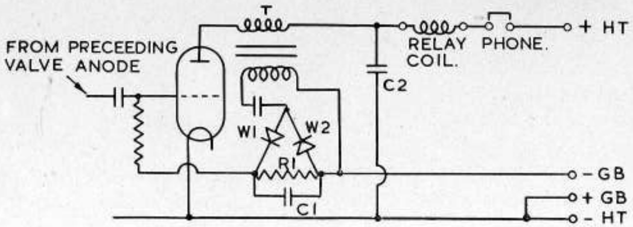


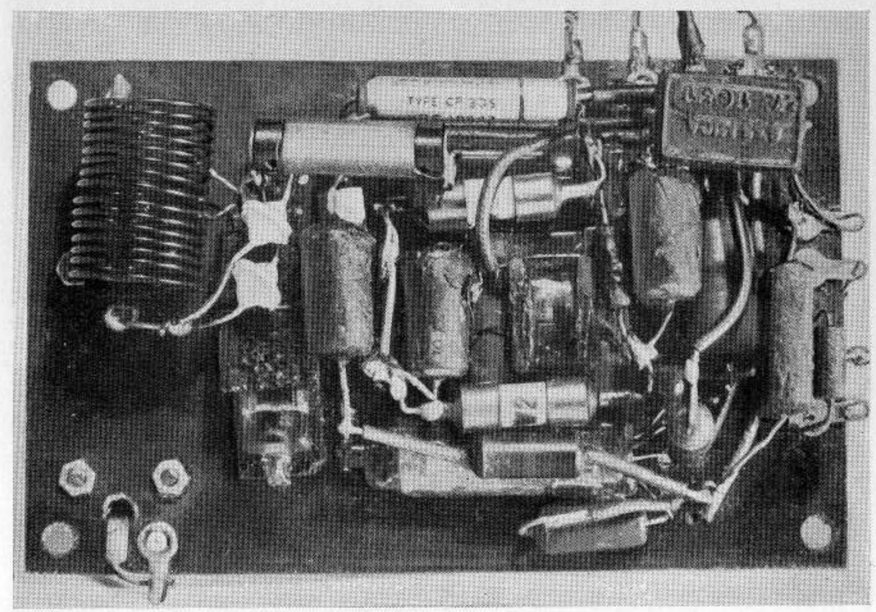
Fig. 23. Positive feedback applied to the output stage of a receiver of modulated carriers. This addition has the dual benefits of increasing range tenfold, and of very low battery consumption.

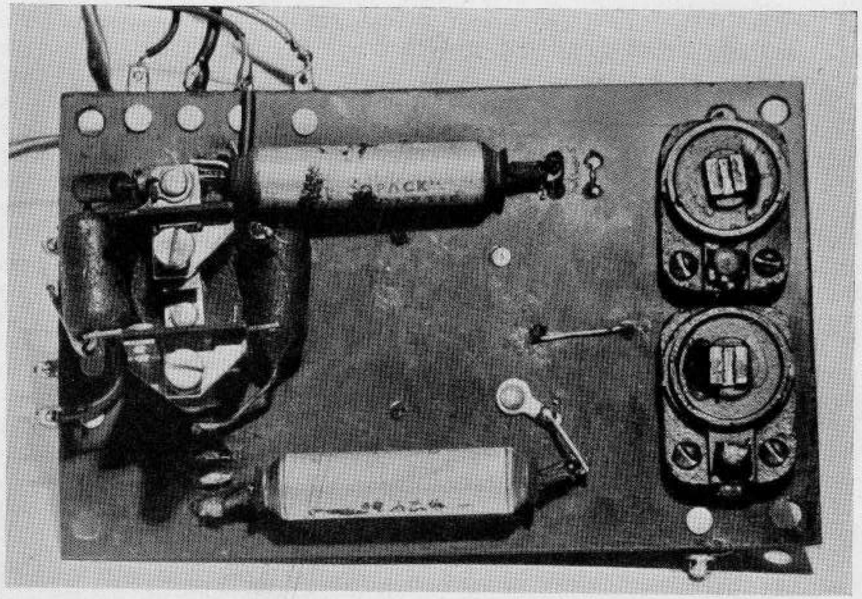
to the fact that there is no current drain in the grid circuit, can be of the smallest cells obtainable.

Fig. 23 is the basic circuit and applies to the output stage only, previous stages not being changed in any way. It functions as follows: The output valve grid is biased to nearly the cut-off point, and the already amplified L.F. signal arriving there is further slightly amplified and passes through the primary of transformer T. The L.F. note is passed via the secondary to the ''voltage doubler'' rectifier system, W_1, W2, R_1, C_1, which is included in the grid return circuit. The rectifiers are so wired that the D.C. voltage developed is opposed to the grid bias. This lowering of the actual bias voltage at the grid raises the amplification factor of the valve, and this process is cumulative until the positive bias voltage of the rectifier system cancels and overrides the fixed negative bias battery voltage. The subsequent anode current change on signal is from nearly zero to the full amount the valve can pass. The condenser C2 is to by-pass the L.F. note to the negative line after it has passed the transformer primary. For full efficiency the choice of valve is critical. The best choice is one which requires a low negative grid bias voltage for cut-off conditions, and at the same time capable of passing a high anode current. Output pentodes are the types which have these characteristics. The screen-grid connection being then taken to H.T. +.

A representative midget type has a cut of bias of six volts with an anode voltage of 60 and the anode current rises to six milliamperes on signal ! Six milliamperes will hold a relay

Under-chassis view of miniaturised three valve positive feed back receiver. Close spacing of components in L.F. and output portion is not harmful. Tuning coil and associated components are well spaced.





Top view of three valve receiver. Total weight of receiver, escapement and all batteries was under 10 ozs. Ground range at 1½ miles was still full signal strength.

armature in so tightly that one can hardly prise it off, and is of course absolutely unaffected by vibration. As far as modulation frequency is concerned, the same applies as in the previous sub-chapter. The transmitted note should match the ''natural'' frequency response peak of the circuit.

The systems we have studied up to now employ at their output one relay, which by opening or closing contacts permit one function only. In order to operate more than one device, either a mechanical or electrical **sequence control** is required. Sequence operated devices have the drawback that to go from one operation to another they may have to move over several unwanted ones.

Tone selective circuits not only eliminate this delay, but even make it possible to operate several circuits simultaneously. However, the transmitter modulation circuit becomes more difficult and calls for valves and material which put it into the expensive class.

Briefly explained, we have several tone selective circuits in the receiver which have at the transmitter corresponding L.F. oscillators which can be selected by switch or push-buttons to modulate the transmitter. One fundamental condition must be observed, however. The L.F. frequencies must be chosen so that none of them have harmonics common with the others. Also there must be a definite separation between both fundamentals and harmonics. The amount of separation is determined by the selectivity or frequency response of the receiver selector circuits.

To avoid complicated circuits, sections will be given by block diagrams, only the portions to be described are given fully. Fig. 24

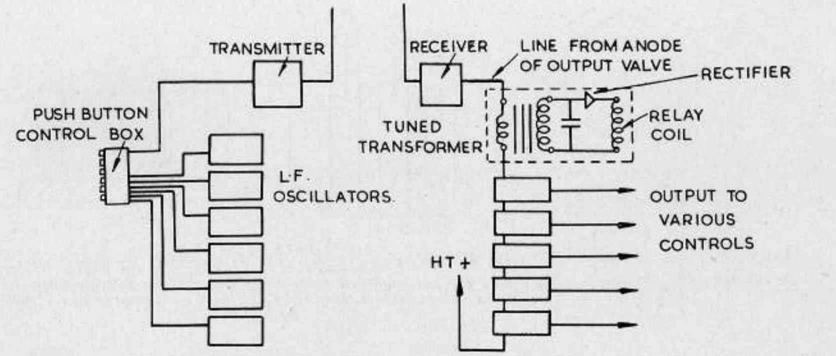


Fig. 24. Block diagram of electronic tone selective circuits. Weight and cost make it suitable only for permanent installation in very large models.

shows a transmitter which can be modulated with various frequencies at will by **push-button control**. The output from the receiver (which can be the same as Fig. 21, with the exception that the grid leak of V3 is returned to fixed a negative bias) is taken through the primaries of several transformers, the secondaries of which are tuned to the selected frequencies. The A.C. voltages developed in the secondaries are rectified and operate the various controls through their relays.

The method just described separates the frequencies by electronic means, tuned circuits. The second method is to separate mechanically by means of **tuned reeds.** The same transmitter as before can be used, also the receiver up to the anode of

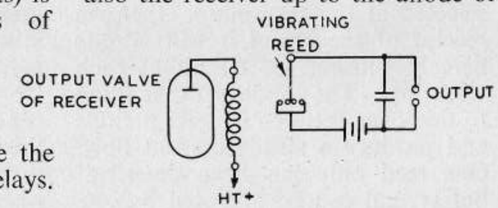
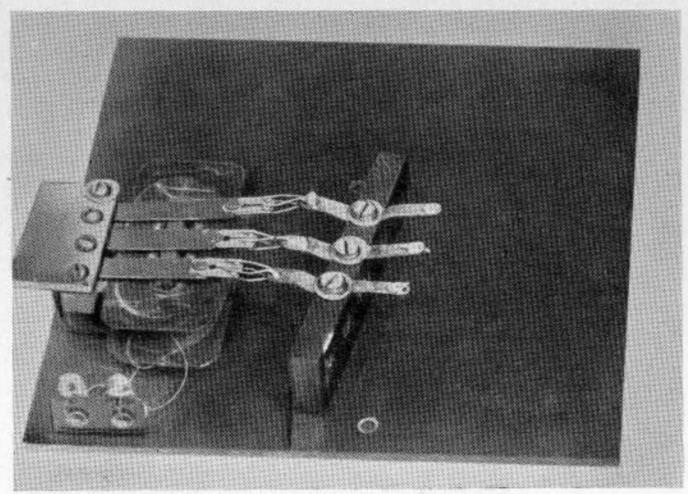


Fig. 25. Basic tuned reed circuit. Reeds are more selective to L.F. notes than the heavier tuned transformers.



Early experimental three reed unit. Reeds had riveted-on contacts which were positioned between sets of fixed contacts.

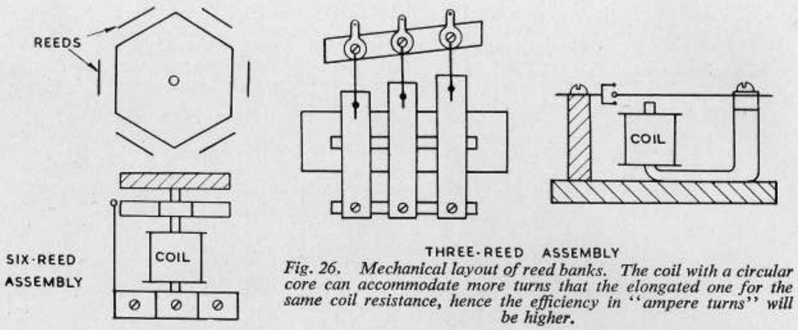


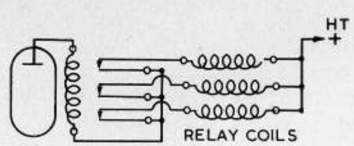
Fig. 26. Mechanical layout of reed banks. The coil with a circular core can accommodate more turns that the elongated one for the same coil resistance, hence the efficiency in "ampere turns" will be higher.

the output valve. In the anode circuit we have a coil, in the magnetic field of which is a ferrous reed (Fig. 25). The reed is positioned between but not touching two contacts and these contacts and the reed are in circuit with a battery and the control we wish to operate. If the natural vibration of the reed is matched to the modulation frequency selected at the transmitter, then on receipt of the signal it will vibrate fiercely, closing the circuit at each vibration. The condenser C is fitted to tide over between contact periods and produce a steady current flow. One reed only has been described but several can be operated by one coil only. Fig. 26 gives a clear view of a simple method of construction.

Another variation, which if light-weight relays are used would be ideal for operation of three circuits in a reasonably-sized plane, uses reeds which in the rest position short contacts over and in the vibrating condition open the circuit for the majority of the time (Fig. 27). Here the relays in the rest position draw each one third of the total anode current and are adjusted to close at that current. When a reed begins to vibrate then the current through the relay drops and the relay opens.

To sum up the two methods of electronic and mechanical tone selective circuits. The transformers of the first method to be at all selective have unfortunately to be heavy and even the best are not so selective as a vibrating reed. Transformers, however, are easy to tune to any particular frequency by using parallel condensers. Mechanical reeds on the other hand are by no means easy to tune accurately. In fact it is far wiser roughly to set your reeds and then tune the L.F. oscillators of the transmitter to them.

Fig. 27. Three reed bank with associated relays fed from the valve H.T. circuit.



CHAPTER V

THE RELAY

Description and uses—Sensitivity considerations, mechanical and electrical—Applications—Simple circuits, multiple—Locking relays—Delay circuits.

The Relay

THE **relay** is one of the major links in the chain of events between the receiver aerial and the control we wish to operate. The radio valve amplifies our signal intensity but does not deliver enough power to operate a mechanical device of any usable size. At some point we must have enough energy to do so. The relay does not produce that energy, but it can easily switch on the energy stored in a battery. In fact, that is what it is. A switch operated by a relatively weak current. A sensitive relay, which in its coil consuming only 1/100 watt, is capable of switching on a circuit consuming 10 watts. Combinations of relays, electrically connected or even mechanically interconnected with single contacts or banks of contacts, have countless uses in the field of R.C., especially where several controls are operated from a single impulse channel. Nearly every model R.C. receiver must possess as its final electrical output one sensitive relay, usually a single pole two-way type, and upon this relay, its sensitivity, its adjustment to a definite current range, lies perhaps the greater percentage of the reliability of the equipment.

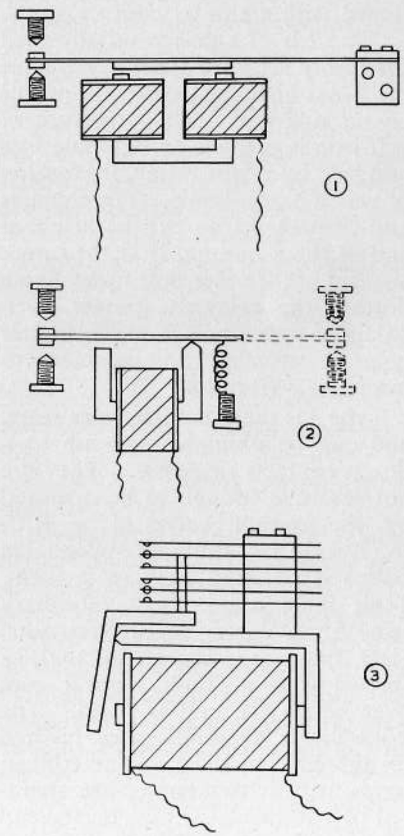


Fig. 28. (1) Sensitive reed relay. (2) Sensitive balanced armature relay. (3) Multiple contact relay of G.P.O. type. 1 and 2 can be used for receiver relays, 3 only as a secondary relay.

There are three basic types of relay found in R.C. gear (Fig. 28). Types 1 and 2 are usually made as **sensitive relays,** type 3 is usually produced for several **banks of switches.**

Type 1 is a general purpose sensitive relay known as a **" reed " type.** It consists of a U-shaped (soft iron or special magnetic iron pole piece) upon which the coil or coils are placed. Facing the ends of the poles is a reed (usually of phosphor bronze) with a soft iron armature. The end of the reed has on either side a contact stud (silver, platinum or tungsten). This stud lies between two adjusting screws which also are used as contacts and as such are tipped with a similar contact metal.

Type 2 is of a design usually used for **highly sensitive types.** We have the usual U-shaped core and in this layout one coil. The armature of soft iron is pivoted on one pole face and held by a light spring, the tension of which is adjustable. The contacts and contact screws can be at either end of the armature, if at the opposite end of the other pole face (shown dotted) the relay is known as a balanced armature type. This latter type is usually non-sensitive to mechanical vibration.

Type 3 is the usual **telephone relay,** and can be obtained with up to a dozen contacts or more. They are not sensitive enough to be operated by the output valve of a R.C. receiver, in fact quite an appreciable power is required to operate them. Their main use is as a subsidiary relay for switching multiple circuits. Here the pole piece is flat and L-shaped with a round central core over which the coil is fitted. The armature is an angle piece pivoted on the edge of the L. The contact strips, usually two banks, are operated by two insulated pins on the end of the angle piece. The fixed contact strips have clearance holes for extension pins on the further side of the contact strip. Operation can be described by Fig. 29. In the rest position A makes contact with B,

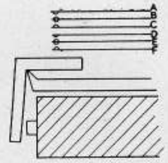


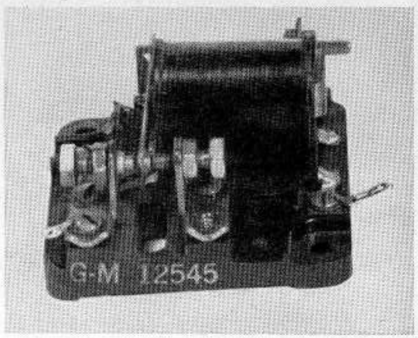
Fig. 29. Two pole change-over relay of G.P.O. type.

and D makes contact with E. When current flows through the coil and the armature is pulled in then A leaves B and contacts C. D leaves E and contacts F. On switching off the coil current, then the contact blades which are tensioned downwards, press the armature into the rest position.

There are several considerations for sensitivity adjustments of types 1 and 2. The amount of turns on the coil are in relationship to the current value with which we propose to operate the relay. Turns are unfortunately very seldom specified. Usually the D.C. resistance of the coil or coils is given. This is only proportional to the amount of turns if (1) the wire gauge is the same, and (2) the length of wire per turn is the same.

As a *rough* guide for types generally in use, for operation *under* one milliampere, a coil resistance of between 5,000 Ω and 12,000 Ω is required. For between one and two M/A

Super sensitive relay of American design. Coil resistance of 12,000 ohms made current changes of less then ·1 M/A possible. Weight is however 6 oz.

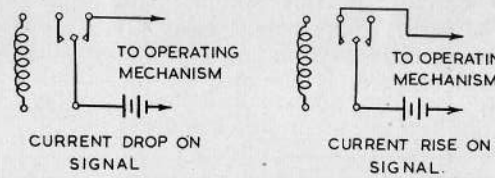


3,000 Ω to 5,000 Ω, for between two and five M/A 2,000 Ω to 4,000 Ω.

The only adjustments we can alter are (1) the reed or armature return spring tension ; (2) the amount of movement of reed or armature between the contact screws ; and (3) the distance of reed or armature from the pole faces. All three are dependent upon one another, and adjustment of one may necessitate a readjustment of the others.

One thing is important, the reed or armature must never be allowed to actually touch the faces of *both* pole pieces. If no air gap is left in the magnetic circuit, then even when current through the coil is cut off, the armature will "stick" to the pole faces due to residual magnetism. The "in and out" ratio, is also proportional to the distance of the armature from the pole faces. That

Fig. 30. Connection of receiver relays for carrier and modulated operated receivers.



is, if a relay is adjusted with armature close to pole faces to fall in at 1 M/A coil current, then on gradually reducing the current we find that it does not fall out until $\frac{1}{2}$ M/A is reached, therefore the in and out ratio is 50%. If we adjust the relay with the same gap between contacts but with the armature further away from the pole faces, also to close at 1 M/A, then on reducing the coil current we might find that it opens at about ·8 M/A. This is a closer ratio and for anode relays of great importance. We have seen that on the majority of simple receivers, the "current dip" is smaller with a weaker signal. On a very weak signal it may be only from 1 M/A to ·9 M/A. Our relay, although capable of pulling in at 1 M/A, must also be able to fall out at ·9 M/A or it will not follow the signal.

To summarise for types 1 and 2. Adjust first contact to allow for a clearance of at least three thousandths of an inch on the pole face. Close up the other contact to permit of about a ten thousandths of an inch movement of the armature. Tension return spring or reed to pull armature contact against back stop. Pass maximum current to be used through coil and if armature does not "click" on to other contact, reduce tension of return spring or reed. Reduce current by 20% and if armature does not fall out, adjust contacts to give greater air gap between armature and pole piece. Repeat the performance until the closest ratio is obtained, but still maintaining a positive "click" in and out. A flabby movement is quite useless.

Several hours can be spent adjusting a relay but from the point of view of reliability of the entire R.C. receiver it is quite definitely worth it.

Type 3 is a robust, heavy type, and consumes enough power to obviate delicate adjustments. The only requirement is to know the operating voltage, which is usually marked on the coil.

The first use we have for a relay is in the anode circuit of our receiver output valve. We have, as we know, two types of receiver, the one has a current drop, the other has a current rise in the anode circuit every time the transmitter is keyed. In the first case the back contact is used for a

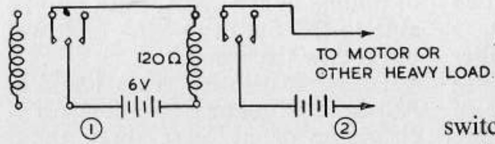


Fig. 31. Circuit of relays in tandem to switch heavy currents by a weak signal current change.

connection, in the second case the front contact is used (Fig. 30).

The various **uses of relays** can best be seen from the following diagrams and their explanations. At this instance they will be given as single circuits. More complicated combinations of relays for use in specific circuits will be given later. To avoid confusion in these basic circuits, separate batteries for each relay are shown. It is, however, possible to operate several relays from a common battery.

Sensitive relay (1) has contacts which are only capable of carrying a low current, in this specific case 50 M/A. A more robust relay (2) with contacts capable of carrying several amperes is actuated by the first.

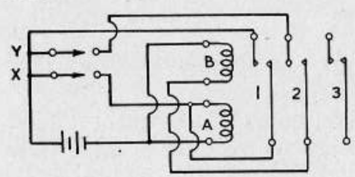


Fig. 32. Electrical locking relay, requiring a second signal to release.

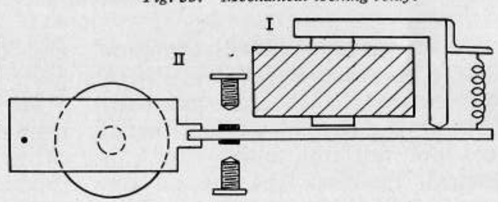
Locking relay, electrical. (Fig. 32.) Electrical "locking" circuit, a short impulse from switches X or Y (which could be anode relays of dual receiver) will permanently close or open output circuit. The relay has two equal coils and operates three single-way switches. A pulse through coil A via switch X closes contacts. Contact I now carries current through coil A and relay remains closed until a short pulse through coil B (connected in opposition to coil A) via switch Y and contact (2), releases contacts and all circuits remain open. Contacts (3) can be used as a single pole switch or a change over switch leading to controls.

Locking relay, mechanical. (Fig. 33.) When relay (1) is energised, armature is pulled down and armature of "latch" relay (2) rises behind extension on armature of relay (1), preventing it rising even when current flow ceases. If relay (2) is energised armature is attracted and armature of relay (1) is released. Contacts of relay (1) are used for output circuit.

Methods of reversing electric motors:

Small permanent magnet field motors (electrotors, etc.) can be reversed direct from sensitive relay, using two batteries. Current through motor is reversed by operation of relay.

Fig. 33. Mechanical locking relay.



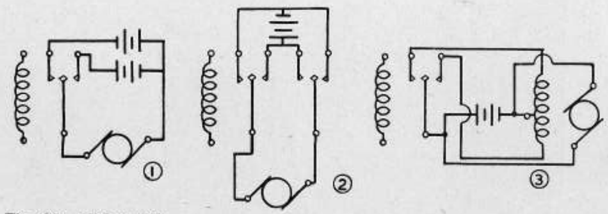
Relay with two-pole change-over contacts will reverse permanent magnet field motor with only one battery.

Motor with centre tapped field coil can be reversed by single pole relay.

Delayed Relays

R.C. circuits often call for a relay which has a definite time lag, either delayed closing or delayed opening. This can be done electrically which

Fig. 34. Relay circuits for reversing electric motors. (1) Single-pole relay and two batteries for permanent magnet field motors. (2) Elimination of reverse battery by use of a two pole relay. (3) Single pole relay with center tapped field motor.



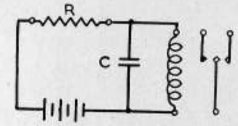
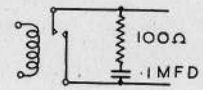


Fig. 35. Relay with delayed closing and opening by addition of a resistance and condenser in the coil circuit.

Fig. 37. Sparko quench circuits to prevent "sticking" of relay contacts.



has the benefit of an easy control over the actual time of the delay.

The circuit of Fig. 35 is for a delayed closing relay. The battery current passes through resistance R and relay coil which has a condenser in parallel. The condenser charges up slowly due to both series resistance R and the parallel leakage through relay coil. Relay contacts do not pull in until condenser C is fully charged. Values of resistance, condenser, relay coil resistance and battery, also reed tension, all affect time of delay. With the following values about $\frac{3}{4}$-second delay can be obtained: R 2,000 Ω, C 200 M/FD. (low voltage type); relay coil 2,000 Ω, battery 15 volts (deaf-aid type). If resistance R is made variable the time delay can be easily adjusted within limits.

The circuit (Fig. 36) is for delayed opening. The resistance is omitted and the battery can be of lower voltage with the same type of relay. R, in previous circuit drops half of available voltage.

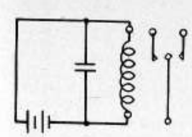


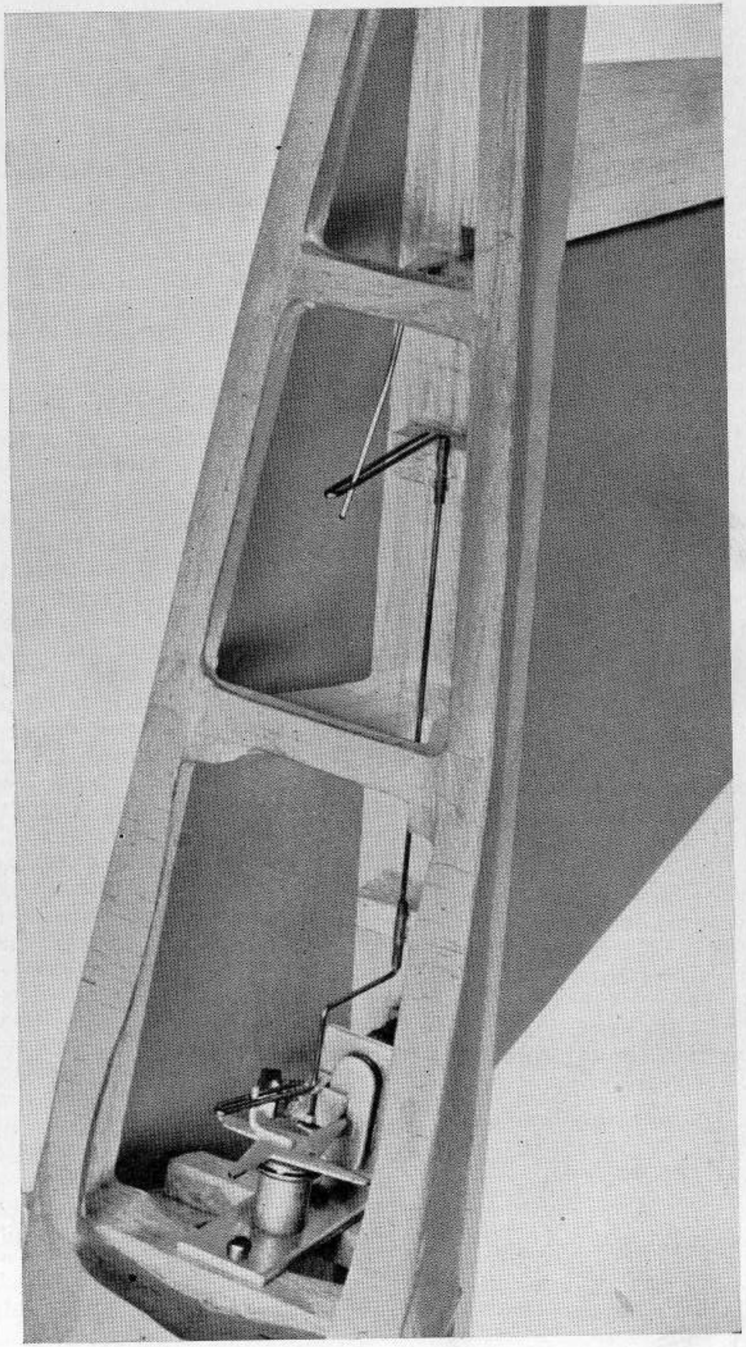
Fig. 36. Relay with delayed opening due to parallel reservoir condenser.

These additional relays will be used in circuits used in the following chapters, for model boats or very large planes, normal ex-Service types can easily be used or adapted, but there is no reason why a good miniature relay could not be adapted, by rewinding the coil to suit battery voltage and fitting extra contact.

One further point of importance. The currents used are hardly heavy enough to actually cause an "arc" between contacts and subsequent burning or welding together, but our switched circuits are often inductive (iron-cored coils, etc.) and on opening the circuit a very heavy inductive current flows for a fraction of a second. A condenser and resistance in series connected across the contacts will absorb and smooth out these peak currents. Fig. 37 gives values generally used in our low voltage R.C. intermediate circuits.

In most cases of general circuit examples, the input or anode relay has been shown as "pulling in on signal." According to type of receiver, of course, the action may have to be reversed.

In order to avoid confusion, and to show contacts clearly, the accepted method of drawing relay circuitry has not been adopted.



Method of linking escapement to rudder used on the Rudder Bug. This enables some range of adjustment to be made, and provides a very short travel for the linkage.

CHAPTER VI

CONVERSION TO MECHANICAL ENERGY

The escapement, simple, multiple, switching, with extra delayed control—The Ruddevator—Control by electric motors and solenoids—Transmitter controls.

The Escapement

The point now arrives where our relatively weak electrical current is converted into a mechanical movement, either direct to our control surfaces or to operate a switch controlling various circuits. Again we must bear in mind that power means weight, and direct conversion from one type of power to another entails quite an appreciable loss of power. However, we can use stored mechanical energy and release by trigger action without large losses. The trigger can also control the amount of mechanical movement released. The escapement of a watch or clock, which allows one tooth to pass at a time, is the basis for the most universal control units.

Although the escapement wheel is only a portion of the complete job, it is universally called an "Escapement" in R.C. language, but "**Servo**" or "**Actuator**" are often used as trade names for units based upon it.

Fig. 37 shows the most simple type of escapement. The cross is tensioned to rotate in an anti-clockwise direction, by in its simplest form, a rubber skein, or by a clock type spring and gearing. The claw (of iron or with a ferrous armature) engaging the tip of one arm of the star, prevents rotation, until the magnet is energized.

However, as the claw attracted by the magnet releases the star, the opposite end of star engages the just released arm after nearly a quarter turn.

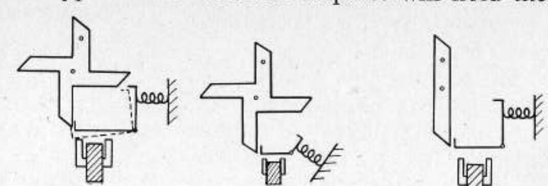
On the magnet releasing, the claw is returned to its rest position by a return spring, engaging the next arm. If at point O we fit a spindle, then at each magnet impulse the spindle will move over a quarter of a circle. A rudder control wire fitted to this spindle will move the rudder over a cycle of centre, right, centre and left.

This is known as **sequence control** and it is obvious that in order to obtain a required position we may have to move over one or two unwanted positions first.

There are several variations of the simple escapement, irrespective of the type of drive. Fig. 38 is a variation which will give a half or full rudder movement by a simple alteration to the length of one leg of the claw.

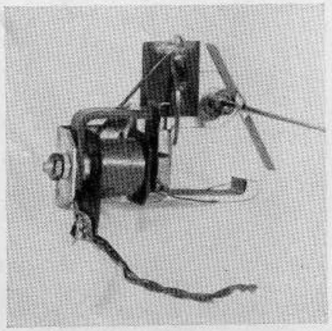
A sustained impulse will hold the

Fig. 37. 38. 39. Three basic types of escapement. (1) Four position, impulse operated, full right, centre, full left positions. (2) The same with half rudder positions on sustained signals. (3) Two position, self-centring type, requiring a sustained signal.



star in a one-eighth rotation position, going to a quarter turn when released. The **"self-centring" escapement** (Fig. 39) has only two arms, and requires a magnet current for as long as a rudder right or left is required. On releasing the rudder centres itself from either position.

The last two types, requiring long periods of magnet current flow, require either heavier batteries or quicker replacement. However, battery consumption can be held down by the following simple method (Fig. 40). It will be seen that when the relay contacts close the coil will be energised, pulling the claw down, this breaks a light switch, putting a resistance R in series with the coil. Far less current is required to hold the claw on to the pole pieces than to pull it there, and R is chosen in conjunction with the coil resistance to just hold it. Hence the heavy current required to pull the claw in flows only for a very short time.



Lightweight, half ounce, self-centring escapement. This prototype double coil current saving type is capable of several hours' use with one pencell only. In the rest position, the rotor makes contact on a phosphor-bronze blade, shorting out the high resistance coil.

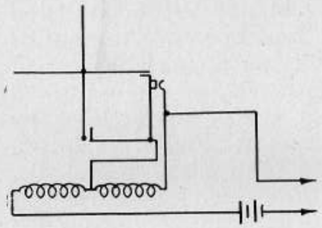


Fig. 41. Battery saving device using a double coil. This is more efficient than Fig. 40 and battery drain can be reduced to as low as M/A.

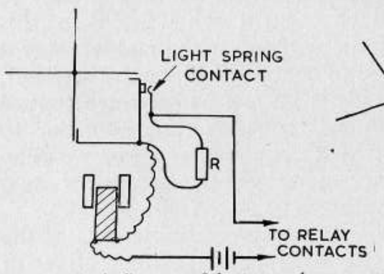


Fig. 40. Basic diagram of battery saving escapement with series resistance. Normally used with self-centring types.

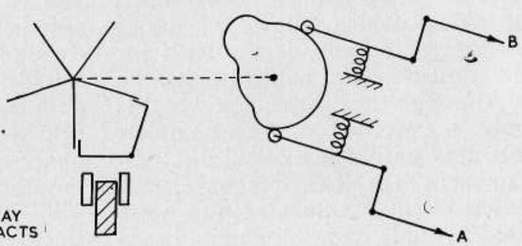


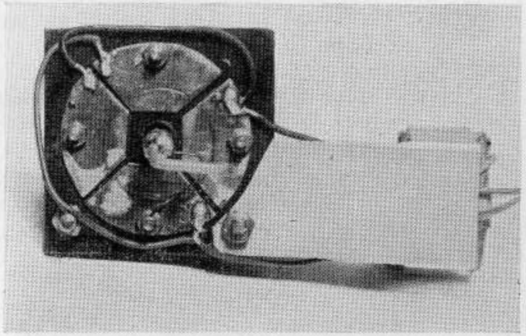
Fig. 42. Dual control using a five-arm escapemen and shaped cam.

The same arrangement can be made with two separate coil windings, of low and of high resistance. The high resistance winding coming into operation after the attraction of the claw (Fig. 41).

More than one control can be operated by the sequence method, and diagram Fig. 42 shows an example of a **dual control** (for example, rudder and elevator). A five arm escapement wheel is used, driving a **shaped cam.** Two levers rest upon the edge of the cam, leading to controls A and B. The sequence is:

Position 1—A centre B centre
" 2—A right B "
" 3—A left B "
" 4—A centre B up
" 5—A centre B down

Any variation of this can be



Self-centring motor operated rudder servo. See page 90, Fig. 67. Cross connected brass segment and wiper arm are mounted on a light paxolin panel.

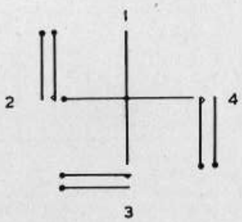


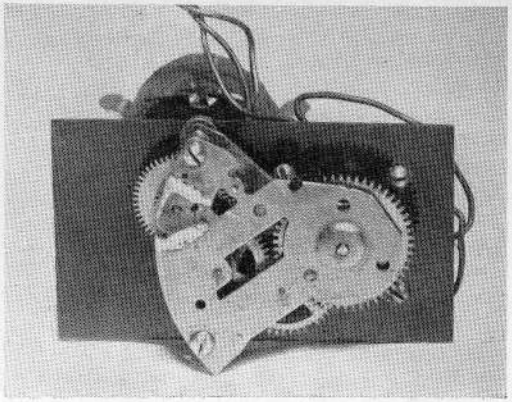
Fig. 43 Schematic diagram of switch blades operated by a striker on one escapement arm.

developed, with increased escapement arms, to give further controls, engine, etc. But the more positions, the more unwanted ones must be traversed to arrive at the required one. Also it is so easy to "miss a step" and the only knowledge of what the next position will be, is the behaviour of the model, which can often turn out to be expensive.

On larger planes and mainly for boats, it is often more convenient to move the controls direct by small, well-geared-down electric motors. In this case one has the possibility of a gradual movement of the rudder and other controls. Instead of the **escapement** moving a control lever, we use it **to operate switches.** Fig. 43 shows the rough arrangement. A series of leaf switches are placed around the escapement in such a position that a striker on one arm can close them. Position (1) has no switch, this is the rest position, to which the escapement must be returned after every control. This is the most simple method of switching which can be done with an escapement. More advanced methods of switching are done by other means in order to avoid movement of unwanted positions and also because of the limited amount of turns of the escapement drive.

With the help of a **delayed relay** we can obtain one extra control with a simple sequence escapement.

This method requires also no alteration to the transmitter. In Fig. 44 our anode relay switches a normal rudder escapement by short impulses from the transmitter. The back unused contact of the anode relay switches a relay which is delayed both to open and close (choice of resistance and condenser values in conjunction with relay coil



Rear view of another motor operated servo, showing reduction gearing, a portion of a small clock. Electrotor drive can be seen behind panel.

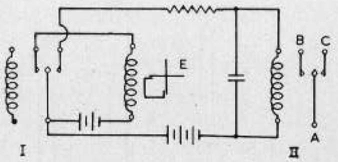
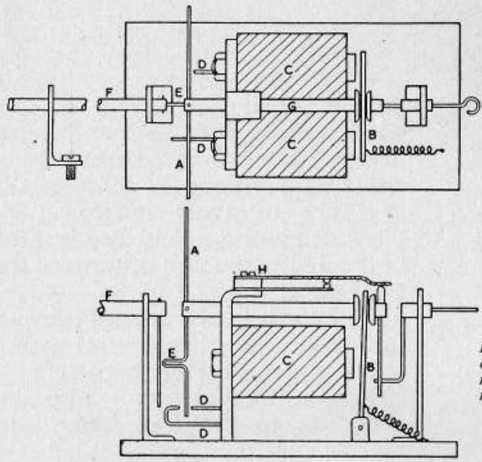


Fig. 44. Circuit of escapement and delayed secondary relay, to give another operation without affecting the escapement sequence.



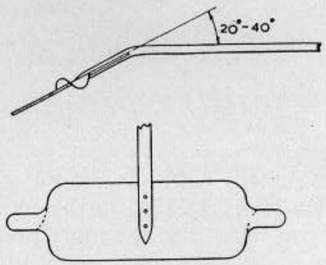


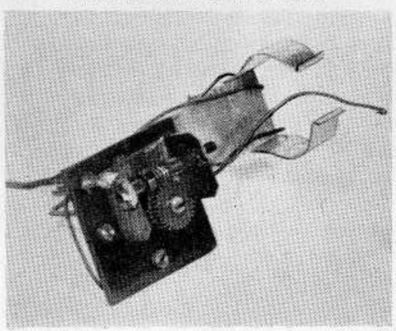
Fig. 45. The "Ruddervator". An escapement-operated vane to give both rudder or elevator movements with a freewheel device in the self-neutralising position. This sequence method can be neutralised from any position.

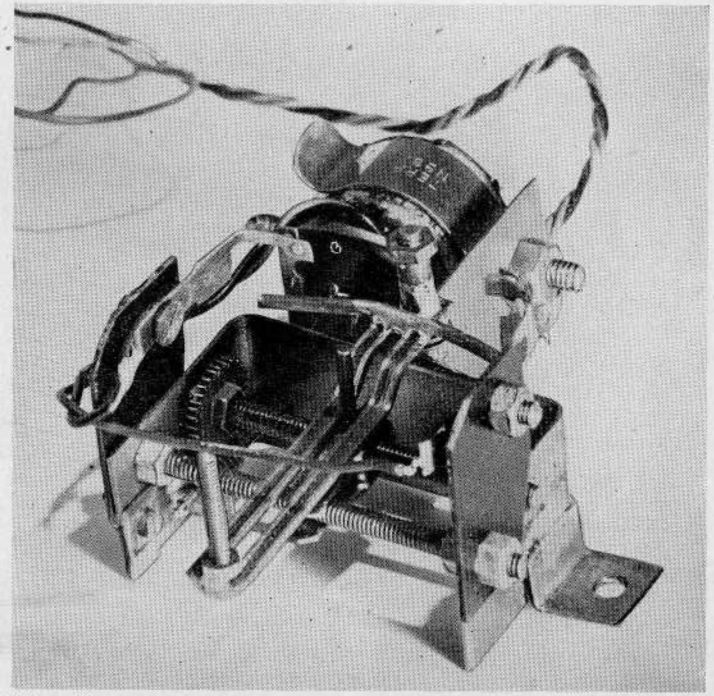
resistance). A delay of approximately $\frac{1}{2}$ to $\frac{3}{4}$ of a second is to be aimed at. Off signal, the armature of relay 1 rests against the back stop, completing the circuit of relay 2 so that AB is making contact. Our short keying impulses (less than $\frac{1}{4}$ second) rotate the escapement from turn to turn, but due to the delay period relay 2 does not change and AB remains closed. If we hold the transmitter key permanently down, then relay 2 circuit is opened and after the delay period armature A clicks over to contact C. By releasing the key for short periods (less than $\frac{1}{4}$ second) we can still use the escapement without opening AC. The contacts of relay 2 can be used for switching off electric motors or reversing them, switching off diesels, switching off or varying the speed of ignition engines (see Chapter 10). This is perhaps the most simple addition that can be easily made to any normal or commercial R.C. unit to give an **independent additional control.**

The Ruddevator

I could not fail to include this most ingenious "control" gadget which has come to us from the U.S.A. It does not, however, lend itself to an aeroplane which even if it is not a scale model, does try to appear normal in outline. Basically, it is a bent vane at the extreme tail of the plane and free to rotate in the slipstream. By R.C. it can be stopped in any one (in sequence) of

Rear view of motor operated servo (page 90) showing worm drive and clip for electrotor.





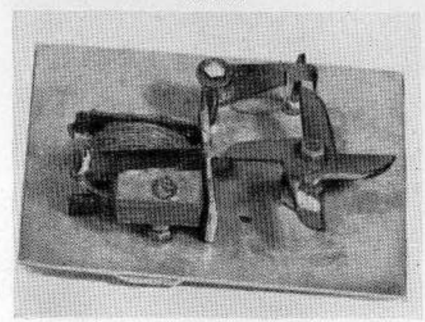
Motor driven progressive rudder mechanism. The arm is moved by a pin soldered to a six-B.A. nut which travels on a six-B.A. threaded rod rotated by an electrotor via a worm drive. The front six-B.A. rod serves to fix the bracket and to locate the arm. Note the limit switch blades and their strikers.

four positions: Bent to the right, up, to the left, and down. These four positions and the free rotation give us full rudder and elevator control with a sequence of only four movements. In its latest form (Fig. 45) it consists of a rubber skein driven cross (*a*), which by action of armature (*b*), attracted by coils (*c*), can be moved in the direction of its axis in order to engage with fixed stop pins (*d*). At the same time projection (*e*) engages the pin of rotating vane spindle (*f*). The spindle (*g*) has a projection which operates a switch (*h*) to retard dual ignition point engines when in the elevator down position. The rubber drive is, of course, indirect, to permit easy movement of axis (*g*).

Rotation of the vane is achieved by bending the tips. A speed of approximately 6 to 8 a second should be aimed at when plane is gliding, in the slip stream of a revving prop it will of course increase.

One important point is that all

Simple four position escapement, showing construction of rotor which must be accurately made. Clearance between tips of rotor and claw must be as small as possible and equal on each arm if reliability is to be achieved.



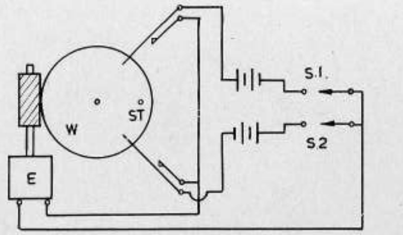


Fig. 46. Servo mechanism fitted with "limit switches" to prevent over-running.

bearings should be free and loose, to permit easy movement, and "whip" in spindle (*f*), which may of course be several inches long, should be avoided.

Control by Electric Motors and Solenoids

The rudders of even large model planes can be moved even by a simple rubber driven escapement. Large or medium-sized boats, however, require more power to drive their rudders. Our escapement-operated switches may be used to control small electric motors operating through worm drives or trains of gears to the final rudder drive. In practice, "limit switches" must be used, otherwise our rudder would rotate through an entire circle, if the transmitter key were depressed long enough. In Fig. 46 an electric motor and worm drive the gear wheel (w) which could be mounted on the rudder pinion itself. Striker (st) opens limit switches at the end of the required travel.

Escapement-operated switches S1 and S2 give, through their batteries,

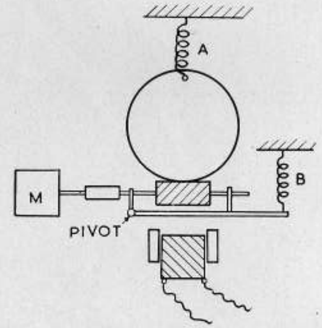
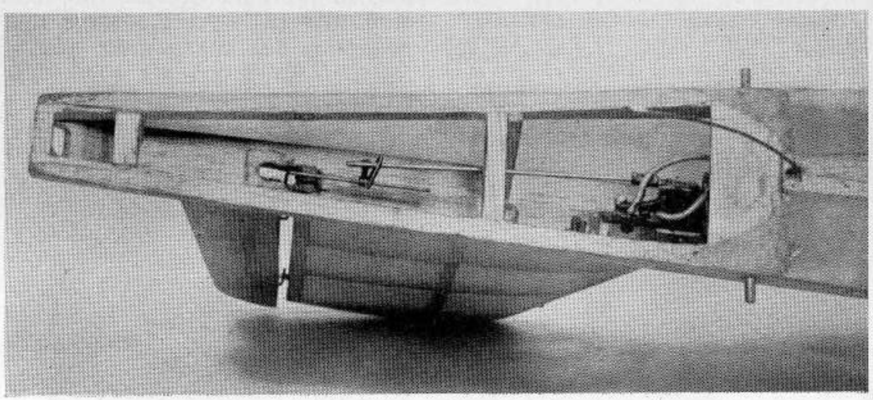
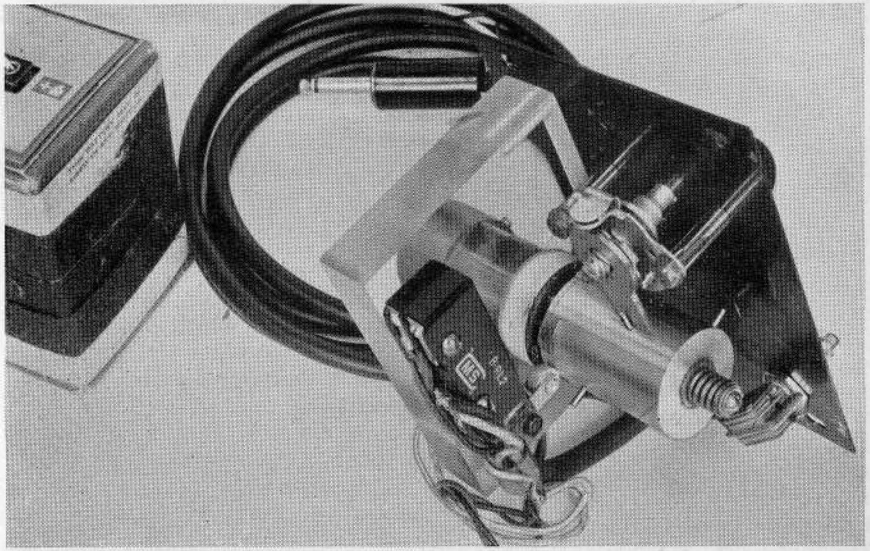


Fig. 47. Servo worm drive with electro-magnetic "disengager" for self centring.

a right or left hand movement. A third switch on the escapement could be used to centre the rudder by disengaging the worm from the gear wheel. The worm is flexibly coupled to the motor and fitted with a soft iron armature, so that an

AEROMODELLER Rudderbug escapement installed as near rudder as possible. Note adjustable link that enables degree of rudder movement to be altered.





Sequence control box for transmitter— an American accessory used on original testing of Dr. Good's Rudderbug.

electric magnet can release it from the gear wheel (Fig. 47), which is returned to centre by spring (*a*). A return spring (*b*) holds worm in mesh again. Fig. 48 shows a method which is **self-centring** from either position

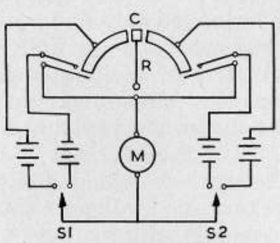


Fig. 48. Example of self-centring servo mechanism. Separate batteries and single pole relay contacts are shown to make the various circuits clear.

when the impulse ceases. Motor (m) drives rudder arm (R) to which a contact (c) is fixed. **Single pole, two-way relays** (or switches), S1 and S2, operate the rudder arm in either direction as far as the limit switches (note that the arm strikes the insulated ends of switch blades and does not make electrical contact). When S1 or S2 is released then the motor is reversed via the segments S until the arm reaches the central neutral position between them. In this simplified circuit diagram four batteries are used, but if relays with two sets of contacts are used, two batteries only are required.

One other simple method of conversion to mechanical energy is the **solenoid.** If a piece of soft iron is placed in line with the hollow core of a coil, then when the coil is energised, the soft iron will be sucked into the core of the coil and remain in its centre, only falling out when current is switched off. Fig. 49 shows the section of a simple arrangement of a solenoid which can be used in a variety of ways.

One for example being to operate the cut-out of a diesel motor. Rudders can equally well be operated by two, and with the addition of a return spring in the hollow coil core to push the soft iron armature out again, would be self-centring.

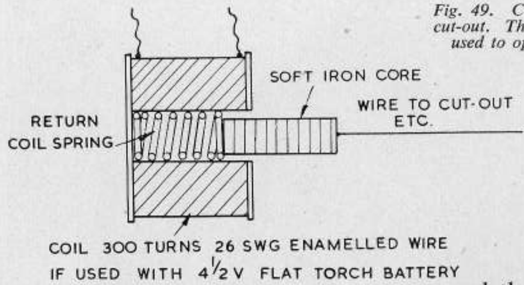


Fig. 49. Construction of solenoid to operate engine cut-out. This has many uses and can for example be used to operate a ratchet type of selector switch.

For model warships, **solenoid-operated guns** can be made to fire small, soft iron shells over several yards, even with a small dry battery. But a trip switch in the gun barrel must switch off the current at the moment the "shell" reaches the centre of the solenoid otherwise it would be held there and not leave the barrel (Fig. 50).

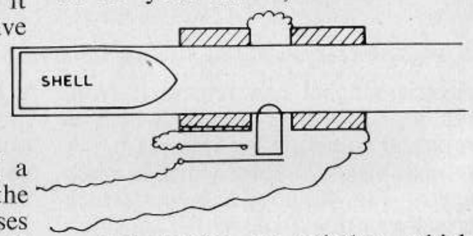
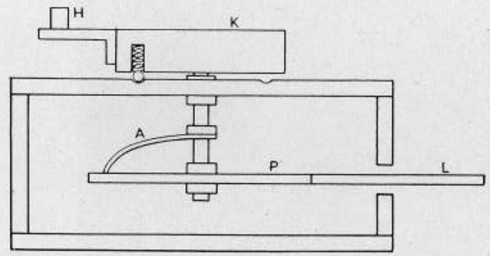
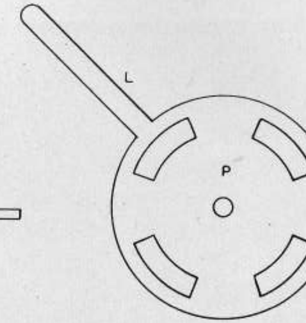


Fig. 50. Solenoid-operated guns can make a R.C. battleship realistic. Gadgets of this description can be afforded where weight is not a problem.

Up to now we have assumed a simple switch or "key" at the transmitter to produce the impulses we have required at the receiver end. A more logical approach is a **control box** which gives a definite indication of the function of our receiver controls. With the exception of the tone selective circuits, we have dealt with sequence operated devices, and a definite knowledge of the number of impulses to be given for a required operation is of great advantage. The "let me think, I am flying straight now, the last turn was a left one, I think, if I press once I should turn right", attitude is liable to lead to trouble in an emergency. However, the best radio equipment, relays, escapements, etc., can still miss a step, or make two instead of one. Therefore do not make your control box too complicated.

My personal advice on sequence control is, a sequence of events for one control only. There are two methods for getting into step again. Firstly to have a separate push-button on the box which is used to operate the model until in step with the knob or lever again, and the second method is to have a symmetrical box which can be rotated in the hand and held in the position where the knob or lever is in step again. Before I begin the description of such a control box, I should like to lay stress upon an important item, which is often neglected. Your eyes should be on your model, so do not fit control knobs or switches which have to be looked at to find positions. Use levers wherever possible, or fit large pointers or handles to knobs. Eyes and memory are not required to know that when you turn a lever or pointer to the left, that you have gone through the switching sequence for that operation. Fig. 51 shows in detail a simple sequence control box used for rudder operation and an addition to use a further control on the lines of that described under Relays (Fig. 44). The knob (K) with pointer handle (H) has a spring-loaded ball which engages in depressions in the top panel to give four positions, left, centre, right, centre (clockwise rotation). The knob spindle carries a wiper arm (A) which passes over brass segments on a switch panel (P). For normal





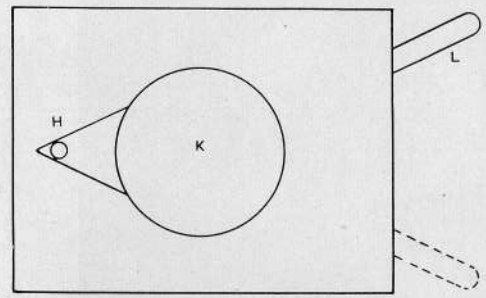


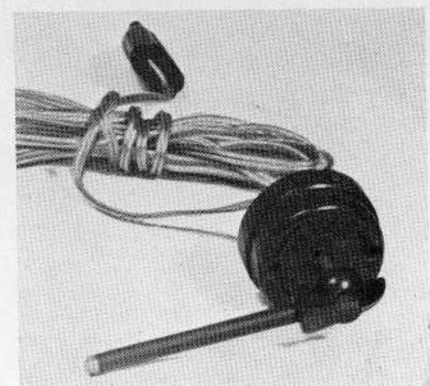
Fig. 51. Control box for use with escapement operated servo in conjunction with delayed relay used for reversing electric motors used for boat propulsion.

rudder sequence operation the lever of (P), which allows the switch panel to be rotated over one-eighth of a turn, is in such a position that with the knob in any of its locating positions, the switch arm rests between segments. A movement from one locating position to another operates the transmitter. To remain in sequence with the escapement, the control knob must be rotated in the same direction as the escapement rotates the rudder: a ratchet or coiled spring on the spindle will prevent rotation in the wrong direction. To synchronise the knob with the model, simply turn the box until the pointer is in the correct position.

In order to use the second control of Fig. 44, instead of transmitting an impulse between knob positions, we have to be able to transmit a continuous signal which can be *interrupted* between knob positions. Movement of lever (L) to the dotted position achieves this by rotating the segment panel so that arm (A) rests on a segment in the locating position. We must remember that with escapement control we are now out of step, and the box must be rotated a quarter turn in order to line up again. On returning the lever again the same applies.

For **tone selective circuits,** the control box is at its simplest, a push-button assembly, with a separate button for each operation. The exception being the switches for rudder operation. A telephone type lever switch gives the best indication of rudder position control.

Rotary keying switch with lever extension. Rotation must be in one direction only. Synchronisation is effected by rotating the entire switch.



Col. Taplin in characteristic "take off" attitude at a demonstration to the Royal Dutch Air Force.

CHAPTER VII

ADVANCED INTERGEAR

Selector switches, necessity for delay—Electrical delay, mechanical delay—Requirements at transmitter—The "Knupple", a modified version to give one progressive control—A two-rudder position and engine speed control.

WHEN more than two operations are required (rudder with intermediate positions, engine speeds reverse, auxiliary equipment) then a selector switch operated by the signal pulses is perhaps the simplest solution. Two requirements are however necessary. Firstly, a delay period before the chosen circuit operates, otherwise as the switch rotates step by step to the required positions, unwanted circuits would begin to function. Secondly, a zero position to which the switch can be returned, either manually by pulses, or automatically.

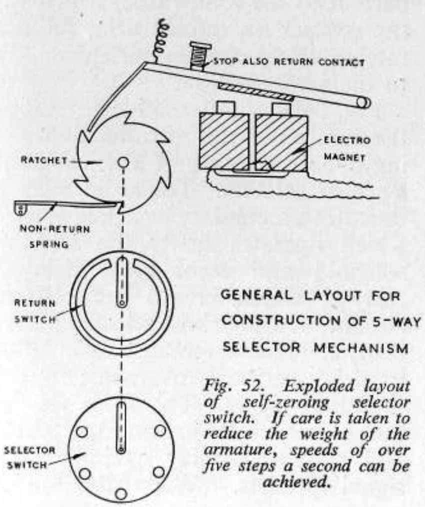


Fig. 52. Exploded layout of self-zeroing selector switch. If care is taken to reduce the weight of the armature, speeds of over five steps a second can be achieved.

The selector switch can be driven by an escapement with a star wheel containing the same amount of arms (plus one for zero) as switch positions are required. The drive, either rubber skein or clockwork, etc., must be able to provide for more turns than required for a simple rudder escapement.

A more advanced selector switch which is **ratchet-driven by an electro-magnet** is shown in Fig. 52. Incorporated here is an automatic return to zero.

The delay can be achieved by a dash-pot actuated switch which closes slowly. The dash-pot receiving a slight push at every step movement of the selector switch. When the switch contact finally remains at rest upon the chosen position, it can then close the circuit feeding the switch positions.

Dash-pots are, however, unreliable in operation and not easy to set to time limits. Therefore an electrical delay is to be preferred. Using the usual condenser delayed relay, choice of condenser values will enable us to determine the delay period. This is a matter which must be chosen in conjunction with the mechanical arrangement of the selector switch assembly. A slow-moving switch requires a longer delay than a fast one.

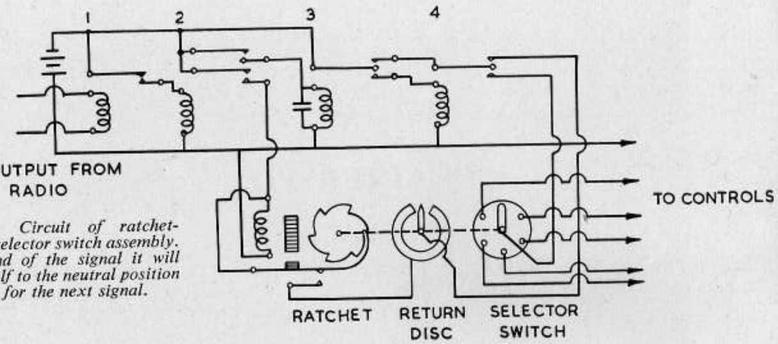
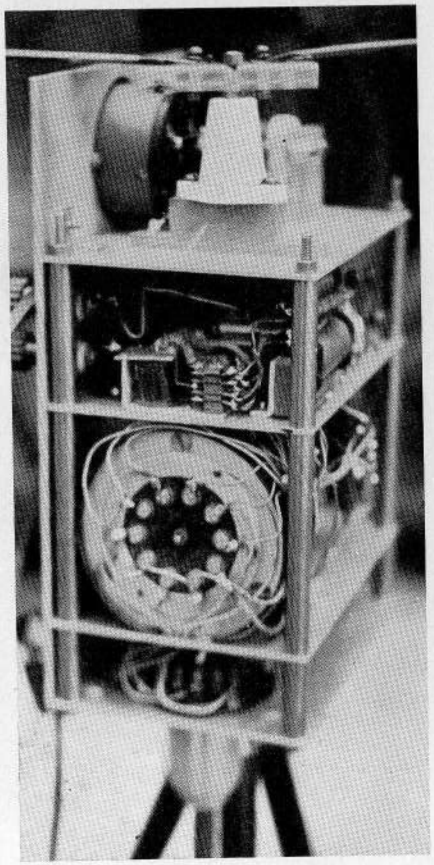


Fig. 53. Circuit of ratchet-operated selector switch assembly. At the end of the signal it will return itself to the neutral position ready for the next signal.



Automatic selector switch keying device seen at French meeting. A great amount of detail is added by French amateurs to their transmitters to eliminate the "push-button plus memory" method of transmitter operation.

Fig. 53 gives the circuit arrangement of a five-position, **self-zeroing selector.** Its operation is as follows:

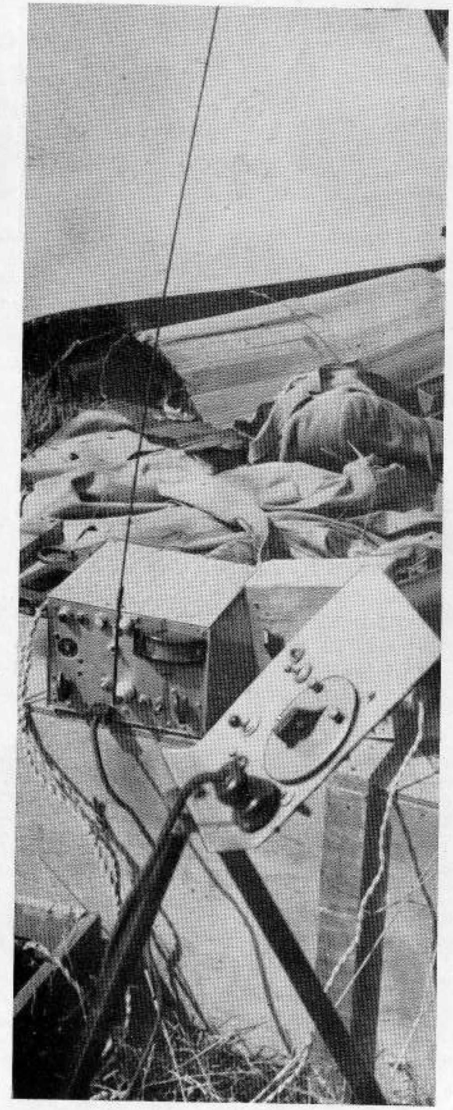
Each impulse from relay 1 closes relay 2 and clocks over the ratchet wheel. Delayed relay 3 closes, which in turn closes delayed relay 4. Both 3 and 4 remain closed even during pauses between the pulses. When the required amount of pulses ceases, leaving the selector switch on the required stud, relay 3 opens and passes current through the selector switch to the chosen operation. Relay 4 opens after a delay period (chosen in conjunction with time lag of various controls) and passes current to the return disc, which via the contact on ratchet arm, returns ratchet, selector, and return assembly to the zero position.

Fig. 54 is an alternative variation, the duration of the operation depending upon the length of time the final signal is held on. The radio relay 1 operates a secondary two-pole relay 2 which operates firstly the selector solenoid and secondly a delayed relay 3 which breaks the zeroing circuit. During short selector pulses delayed relay 4 remains open until its delay period is overcome by the final long signal. This feeds via the selector switch the various operations and remains feeding as long as a signal persists. When the signal

ceases, then radio relay 1 returns to its backstop, opening the contact of relay 4 and of course isolating the feed to the operation. At the same time relays 2 and 3 fall out, contacts of relay 3 now feeding the zeroing switch. In this circuit, delay periods need only be short, $\frac{1}{4}$ second, requiring lower battery voltage and/or smaller condenser values.

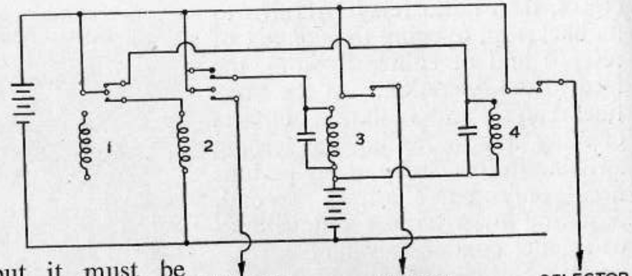
Selector Switches, Transmitter Controls

A simple push-button or key at the transmitter could be used to control a selector switch with only a few positions, but for speed and accuracy an automatic control box is necessary. A telephone dial is perhaps a simple solution. It must be remembered however that the normal G.P.O. type dial sends impulses only on the *return* stroke, and when rotated by finger the switch is isolated. This requires a receiver, the various operations of which function instantaneously, or are completed over the delay period of the feeder relay. A better proposition is a dial which sends out impulses when *rotated* by finger, then the duration of the final control impulse can be determined by the time the dial is held in its positions. For example, a rudder mechanism driven by an electric motor via a reduction gear may take several seconds to reach full rudder. Dialling the position, and holding it there for a proportion of the time required for full rudder, will give intermediate rudder positions. With the self-zeroing selector switches no further control is required at the transmitter, non-zeroing types require a separate push-button switch in parallel with the control box dial switch, in order to be able to correct to zero if the selector should get out of step. A telephone dial type switch with only the required number of contacts can



Transmitter and operating panel by C. Pepin. A simple control box like this can be used with various transmitters for widely differing methods of transmission.

Fig. 54. Relay circuit for self-zeroing selector switch, using three secondary relays.

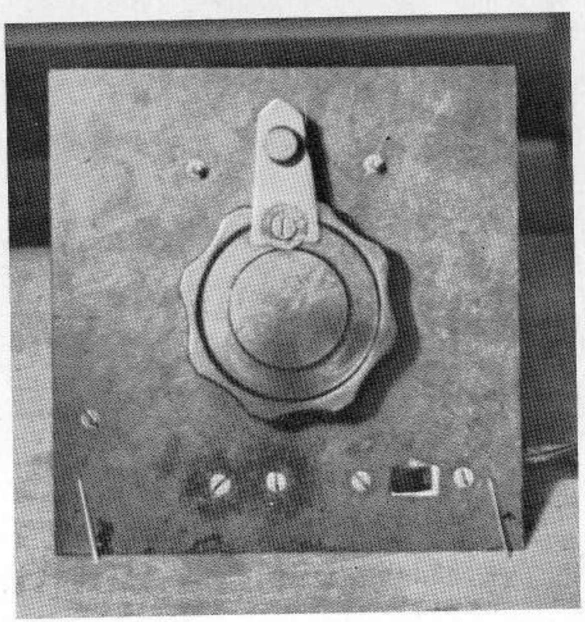


easily be made, but it must be remembered that on the backstroke the impulses must be blanked out. This can be done by a thin bakelite disc which follows just behind the wiper and then covers the contacts on the return stroke.

The Knupple

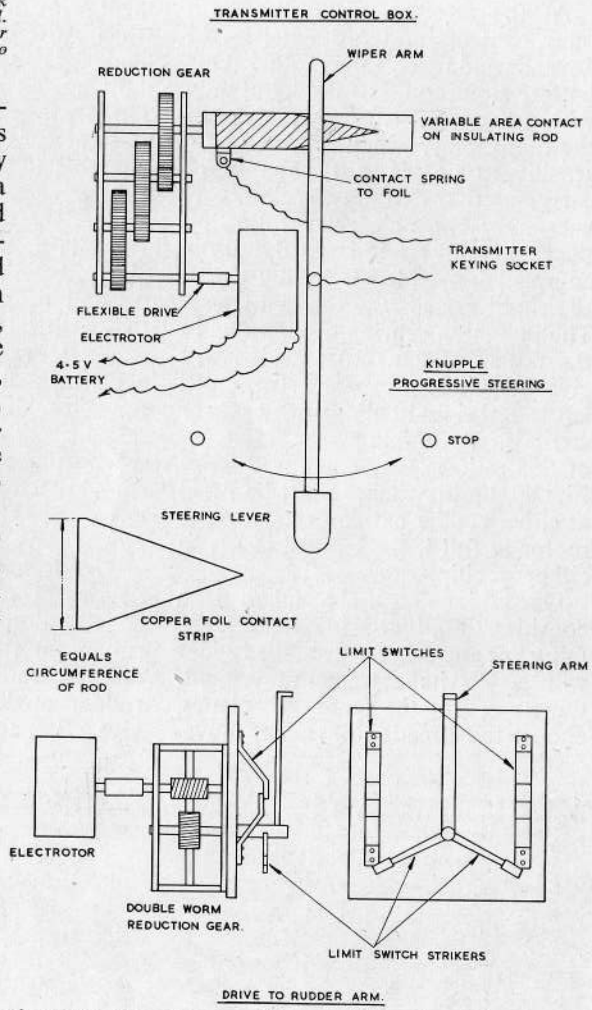
In the difficult search for a progressive rudder movement, that is a control which can "inch" a rudder a desired fractional angle in order to maintain accurate trim and scale type flights, the following is perhaps the most simple and reliable type. Originally, in more intricate form, it was used in the German "Glider Bomb." In that particular case a double control for elevator and rudder was used, the servo equipment was duplicated and operated by separate channels. The main control box had a lever working up and down, left and right, on a ball socket. This similarity with the normal full size aircraft "control column" gave the system its name, **Knupple-truncheon or control column** as used in aircraft.

Basically, the system is this: On receipt of a signal an electric motor rotates in one direction, without a signal it is reversed. Now, if we can accurately transmit a train of signals of definite length, separated by intervals of the same length, then our motor at the receiver end will rotate the same amount of turns in one direction as the other. If a high reduction gearing follows the motor then the final shaft will remain for all practical purposes stationary, due to the inevitable gearing backlash, pro-



Control box of progressive rudder system. Note the large knob with pointer, position of which can be felt, leaving the eyes 100% on the model.

Fig. 55. The "Knupple" mark space ratio progressive control. Mechanical layout of transmitter control box and receiver servo mechanism.



viding, of course, the signal repetition period is high enough. Roughly four signals and spaces a second is the required amount. If the repetition period is increased over that amount, then relay and motor, etc., inertia may not be able to cope with it. Now, with this 50% space 50% signal, our final drive remains stationary. If we alter the transmission to a 80% signal and 20% space, then our servo motor and final drive will creep over to one side. A 20% signal 80% space will creep the rudder in the opposite direction. The greater the difference, the faster the rudder will move. Once in the required rudder position, a 50–50 signal-space transmission will hold it there stationary.

Fig. 55 is a detailed constructional plan of both transmitter control box and receiver intergear to follow the receiver relay, of which both contacts are used.

The control box consists of an Electrotor which drives a contact roller via a reduction gearing to give approximately four revolutions a second. The roller carries a tapered metal contact, and a wiper arm traverses its entire contact length. The wiper arm is operated by a lever or knob, which is external. It will be seen that in extreme positions of the lever, either a full signal is transmitted, or no signal at all. These extremes correspond to a permanent movement of the receiver motor in either direction. Intermediate positions of the lever give varying percentages of signal to space. The centre position, that of rest, 50–50. Battery to drive the Electrotor is housed in the box, and externally only a twin wire leads to the normal transmitter keying sockets.

At the receiver, we utilise both relay contacts and *two* batteries to advance and reverse the motor. One battery alone could be used, but only with a two-pole, two-way relay, and the radio relay, which needs to be a sensitive type, is not capable of carrying the extra extension. A subsidiary two-pole relay following the radio relay could be used, but the complication added is hardly worth the slight extra weight of a battery. The reduction gearing needs to be in the region of 2,000 to 1, which will give a rudder movement from full left to full right in about two to three seconds. A double worm gear train of this ratio is very small and light. Finally, limit switches must be fitted at either rudder extremes to stop the motor at full if the control is left in either position.

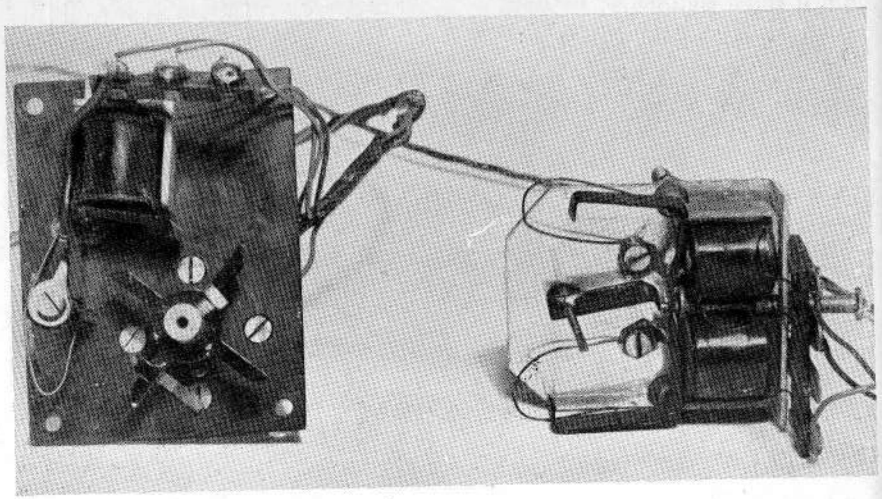
One thing must be taken into consideration, that is in case of radio failure or any other causes, the rudder will go to its extreme movement, therefore, in the case of planes, choose the direction of rudder movement with no signal to be one with which the plane has the least tendency to spin in, or even bring the limit switch of that side closer in. The plane will then be only capable of tight turns in one direction.

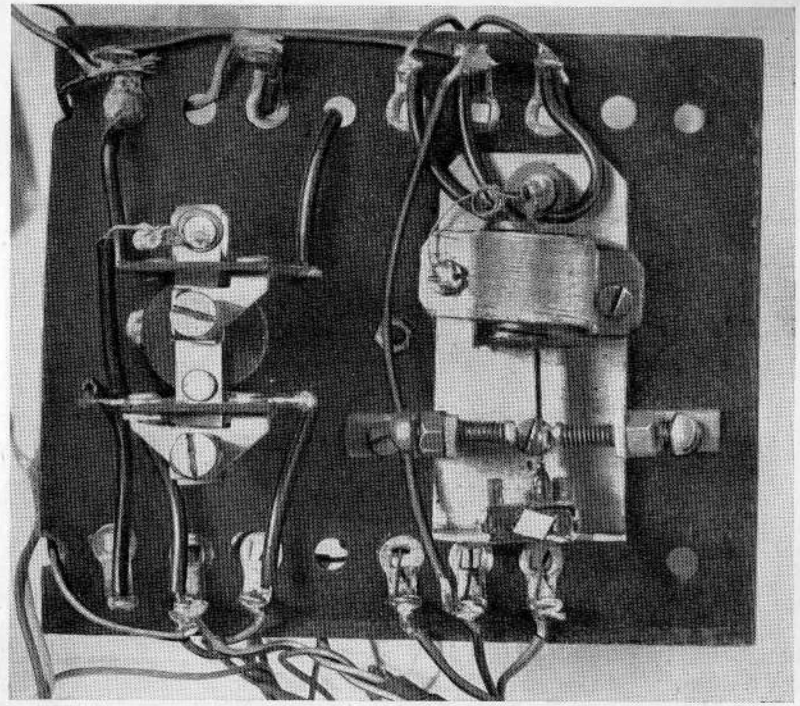
Intergear to give two-rudder positions and advance-retard for two-speed engine

On large scale type planes it has always been a problem to produce a method of giving a progressive or two-position rudder movement with complete reliability. It is fatal in cases of radio failure, either out of range or due to batteries running down or other causes, to see one's work of several months spinning rapidly earthwards. Hence the popularity of the simple self-centring escapement.

The following method has been developed with that in view, and construction is such that in no case can more than half rudder remain due to radio failure. The half-rudder angle should be chosen to give a flat, non-spinning turn.

A switching escapement (left) and a double escapement (right) used to split a normal sequence operation giving a secondary sequence. The memory is not taxed so much by using two superimposed sequences of four in comparison with a sequence of eight.





Polarised relay for engine advance-retard operation with the delayed relay (left) used in circuit of page 70.

In addition, provision is made for advancing or retarding a dual timer ignition engine.

All this is achieved *without* any further sequence than the usual rudder, centre, right, centre, left.

Operation is such that a normal short key impulse only affects the half rudder, a sustained depression of the key operates full rudder, on releasing the key the full rudder goes back automatically to half rudder. One of the midships positions controls the engine advance, the other the retard position, but again only if the key is kept depressed in this position, for one second.

The moment the engine changes speed, the key can be released and used as normal for rudder control.

Put into words this appears complicated, but in actual practice is simplicity itself to control.

Short "dots" control normal half rudder movements, "dashes" control full rudder and in midships positions, engine speed.

The original arrangement was made for a twin boom and rudder fuselage, but of course a split rudder on a normal fuselage can be used.

The total weight of the extra equipment following the normal radio receiver is approximately eight ounces.

Technical description (Fig. 56).

The normal contacts of the radio relay energise a four-position rudder escapement, which in addition to mechanically operating the half-

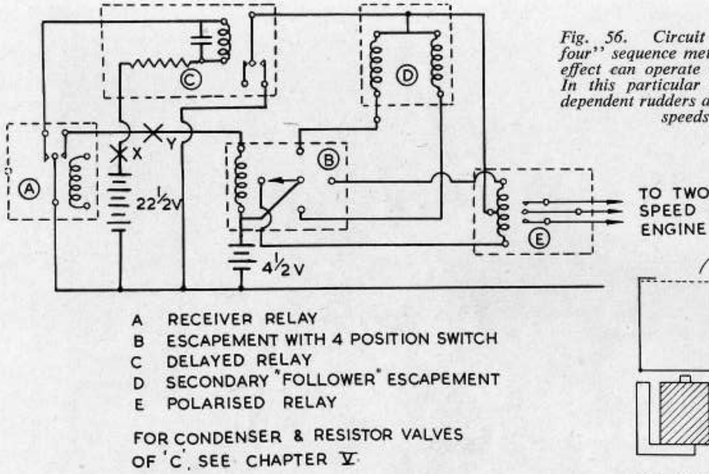


Fig. 56. Circuit of "double four" sequence method, which in effect can operate three devices. In this particular case two independent rudders and two engine speeds.

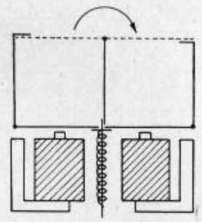
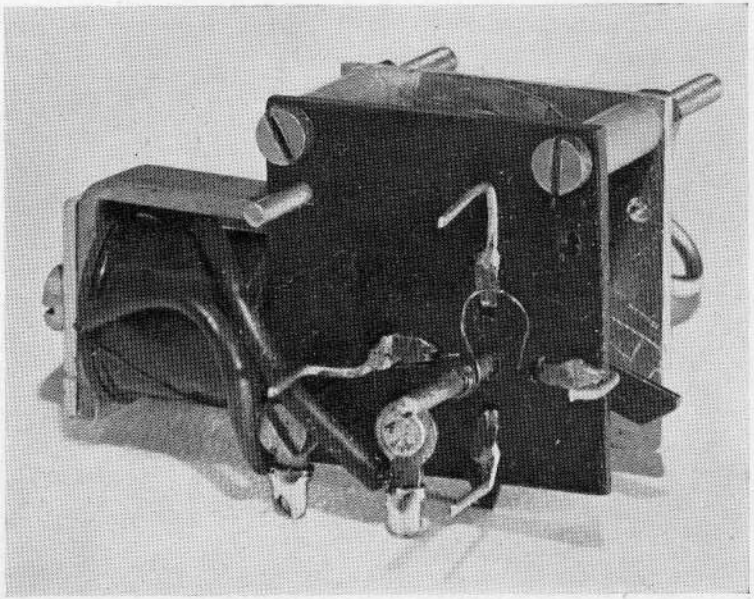


Fig. 57. Layout of secondary follower escapement.

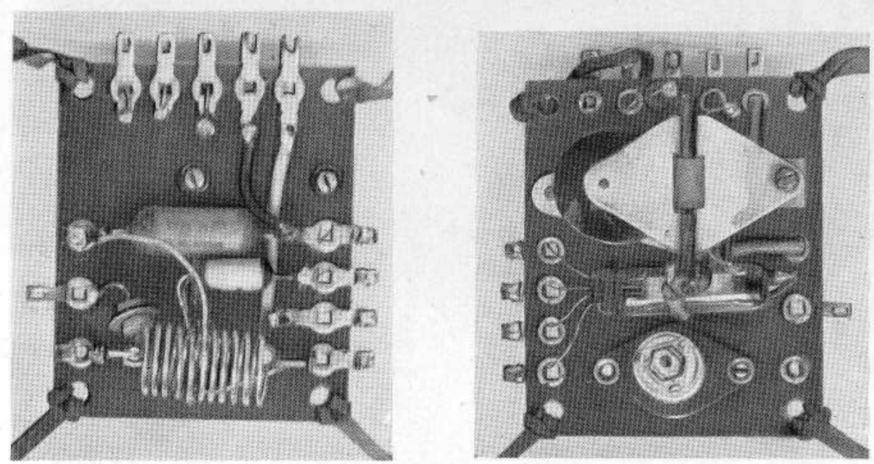
section rudder, rotates a switch wiper arm over four contacts positioned at the four points of rest. The two contacts corresponding to port and starboard energise the port and starboard coils of a special two-position escapement (Fig. 57). The two midships contacts operate in opposition a polarised relay, the contacts of which are connected to the double tuner of a two-speed engine.

Both the auxiliary escapement and the engine speed relay are, however, operated in series with the contacts of a delayed relay, which is controlled by the back contact of the radio relay. The delay period is chosen to be between ¾ and one second. Radio relay A in its rest position closes the current of the delayed relay C, the delayed relay contacts open and both D and E are inoperative. Any short signal operates the half rudder escapement B with its switch. Although on each short signal delayed relay C circuit has to be broken, the relay has not fallen out due to the delay, if however, a sustained signal is sent, then as well as escapement B operating via the contacts of C and whichever switch position B is on the appropriate section of D or E will operate. D will remain in operation as long as the signal ceases, then D self centres. Polarised relay E will click over and remain there until energised by the opposite contact on B by a sustained signal.

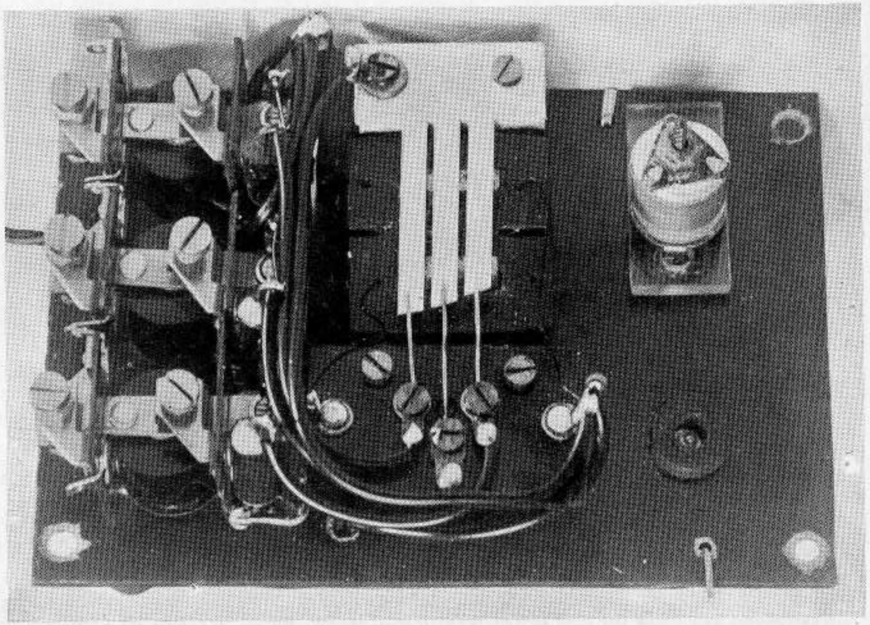
For receivers which are carrier operated an on-off switch is required at Y. For modulation operated receivers a switch is required at X. A plunger, P, held up by a spring, holds the rotor arm R in the neutral position. The rotor arm is tensioned by a rubber skein in the direction of the arrow. Whichever coil is energised, the armature A will depress the plunger and release the rotor arm over to the tip of the armature (dotted). On release the rotor will return to the neutral position at the now raised plunger. Thus, energising coil 1, the rotor describes a ¾ circle, returning a ¼ circle to neutral; coil 2, a ¼ circle, returning a ¾ circle to neutral.



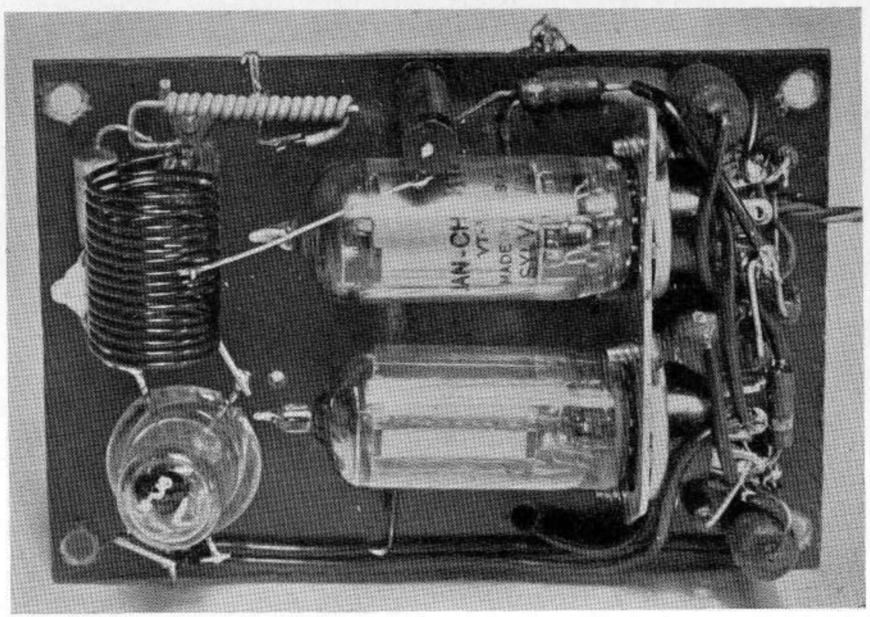
Commercial escapement converted to a switching type. The four contacts are traversed by a phosphor-bronze wire wiper soldered to the rotor spindle.



The new thyratron receiver being produced by Mercury Models, one of the pioneers in the field of commercial radio control equipment.



Three-channel reed receiver. Only the "adjustable" components are mounted on top of the panel, the three relays, reed assembly and beehive tuning condenser. The three-valve receiver is mounted below the panel. In this particular case the detector valve was a 957 acorn. For use on the French 144 M/c band the tuning coil is then the only component to be changed. Weight and size of this receiver is well within the medium-sized plane range.



CHAPTER VIII

SPECIAL INTERGEAR FOR MODULATED CARRIERS

Tuned reeds—L.F. oscillators and switching to modulate transmitter—Reed selectors, direct operation, interposed relays, filter network—Technical requirements—Circuits, choice of frequencies, harmonics, etc.—Conversion of E.D. 3v. modulated carrier to tuned reed reception.

Tuned Reeds

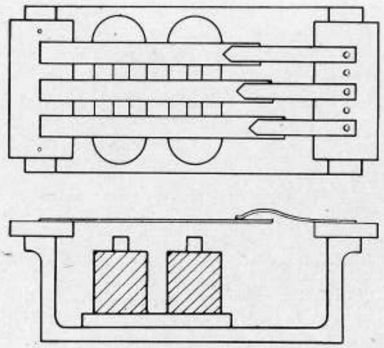
PERHAPS the method which promises most for the future of R.C. both for planes and boats is the "tuned reed" receiver. In very recent times remarkably light, efficient and simple types have been developed by amateurs on both sides of the Atlantic. Rockwood, of California, a manufacturer of "custom made" R.C. equipment, and in France the team of Laederich Ugon and Kuhn have both produced equipment which promises at one stroke to enlarge the field of R.C. as far as number of operations and progressive movement is concerned. One thing appears to be against it at present, and that is the price. Properly constructed, it can be perfect, but a haphazard method of construction can only lead to erratic or negative results. The great advantage is that no sequence or selector switching with its attendant time delay, mechanical difficulties, and use of one operation at a time is required.

The transmitter control box can consist of push-button or levers. Also two, and with careful choice of circuit and design, perhaps three operations can be made simultaneously.

The only drawback, and you will have noticed, there always appears to be one, is its "electronic" complication. Special transmitters and receivers are required, the only commercial equipment at present usable for tuned reeds is the E.D. R.C. In this case an addition to the transmitter and a modification to the receiver is all that is required, a detailed description follows at the end of this chapter.

The theory is simple, a tuning fork or any piece or strip of metal has a resonant frequency, it can be made to oscillate at this frequency either mechanically, by tapping or by alternatively attracting and repelling by an electro-magnet energised at the same frequency. If we alter the frequency of the electro-magnetic excitation then the reed will not vibrate, and at even a small variation of frequency off "tune" it will not respond. Hence it is very "selective", and several reeds can be operated at reasonably close frequencies. The tip of the vibrating reed at resonance covers quite a large arc of movement, and contacts arranged, so that at rest they do not touch it, make contact the moment it vibrates.

One point is that if several reeds



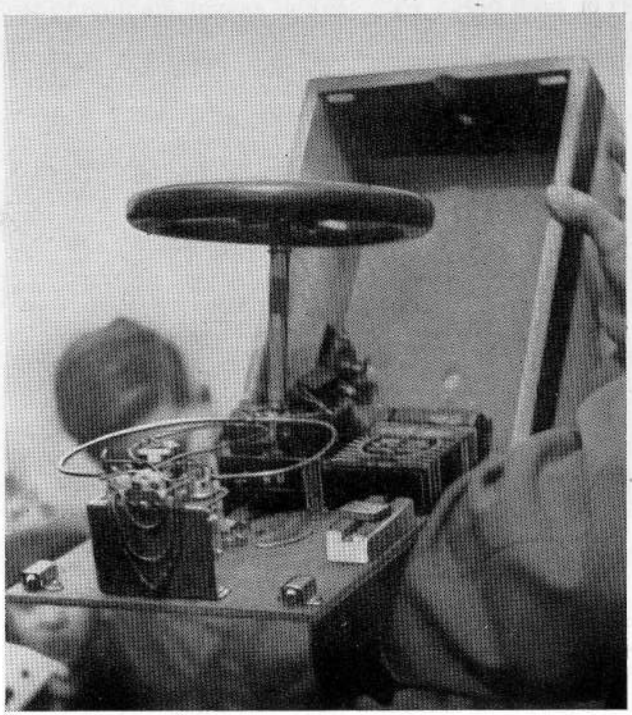
SKETCH OF THREE-REED BANK

Fig. 59. Layout of three-reed bank at full size. Reeds of this size of clock spring steel will resonate at the 200 to 300 cycle per second range.

are used, then the frequencies used are not just a matter of haphazard choice, because the harmonic of one could cause another to vibrate. To explain that in simple words, if a reed is excited at its resonance of say 200 cycles a second, then it would also follow a 400-cycle excitation, not perhaps quite as strongly because it would only be attracted and repelled over a short portion of its movement. It may appear that there is plenty of room for quite an amount of spot frequencies in the audible frequency range, whose harmonics do not interfere with either fundamentals or harmonics of others. But our band is also limited by radio considerations. The receiver is, due to small components, seldom capable of greatly amplifying very low notes, and as interference, background mush and transients which could affect our reeds are at the higher L.F. frequencies, we find that our usable L.F. band is from 400 to 3,000 cycles.

L.U.K. in France have successfully managed to operate a 15-reed receiver on frequencies covered by one octave only. This method eliminates all fear of harmonic interaction, but the mechanical construction of the reed assembly must be very accurate.

To begin as usual at the receiver end, we must have an electrical method of causing the reeds to



Interior of 15-channel reed transmitter of L.U.K. The one-turn large diameter tuning coil for a frequency of 72 M/c's acts as a frame aerial and in conjunction with the three-valve receiver is capable of a range of up to 100 metres, with a power of less than half a watt.

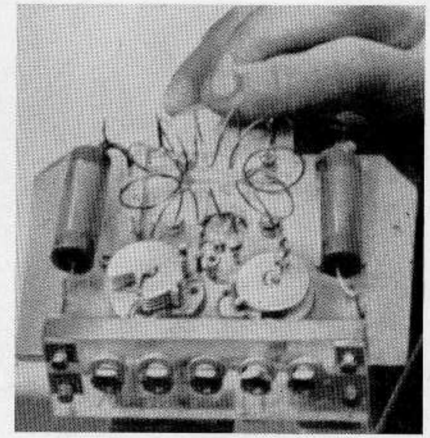
vibrate at the L.F. frequency received from the transmitter.

Our receiver must consist of a detector stage followed by a pure L.F. amplifier with an output to an electro-magnet in whose field the reeds are positioned. The fluctuating magnetic attraction in this field caused by the modulation note received, will cause that reed which is in tune with the frequency to vibrate and to make with its contacts.

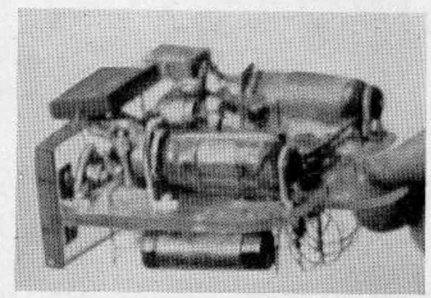
The carrier wave of the transmitter must be modulated by a choice of frequencies which correspond to the various reed frequencies. If only one operation at a time is required then one **single L.F. oscillator** is sufficient, the note of which can be varied by switching. This method is the general one in use, several separate L.F. oscillators would require each a separate valve, associated circuits and switching, etc., the complication and cost of this would put it out of the normal model class.

Having now a theoretical knowledge of the working of reed selectors, we must now apply their output to our controls. It must be realised that, like the relay, the reed is simply a switch with, however, one great difference, in operation it does not "make" permanently, but only for a small fraction of the time of its movement. The amount of current passed therefore is proportional to that percentage of time. We can, however, damp out the current pulses and also increase the overall output by connecting a resistance-capacity filter in the output circuit. The actual size of the reed and contact also determine the current carrying capacity. Miniature reed assemblies which only require a low-powered receiver to operate them, will not be able to switch enough current direct to operate even small motors or selectors. Therefore each bank of reeds will require an equivalent bank of relays to do the final switching. In some cases, light servo equipment or low-powered indicator lamps can be directly operated if the resistance of the filter circuit is omitted and the size of the condenser greatly increased to 100 M/FD. or more.

Fig. 60 gives the circuit of a **three-reed bank** with relays. Vibration of the actuated reed makes contact and passes current through its relay, the



L.U.K. receiver. Toroidal tuning coil acts again as a one turn loop for reception. The five scokets fit on to corresponding plugs in the boat to make a plug in unit.



Reverse view of L.U.K. receiver. Made of perspex, the finger grip makes removal from a small pocket easy.

The outstanding L.U.K. team transmitter, operated by one of its designers. The box contains transmitter, batteries, controls and internal frame aerial. The large wheel operates a progressive "following" rudder, the lever giving forward, reverse, stop and start, including half speeds. The positions make it child's play to operate, lever right forward = full speed ahead, half forward = half speed ahead, centre = stop, and the same movements in reverse. This equipment was the well-deserved winner of the Miniwatt international competition, 1949, in France. Alongside is the R.C. steam freighter of C. Pepin.

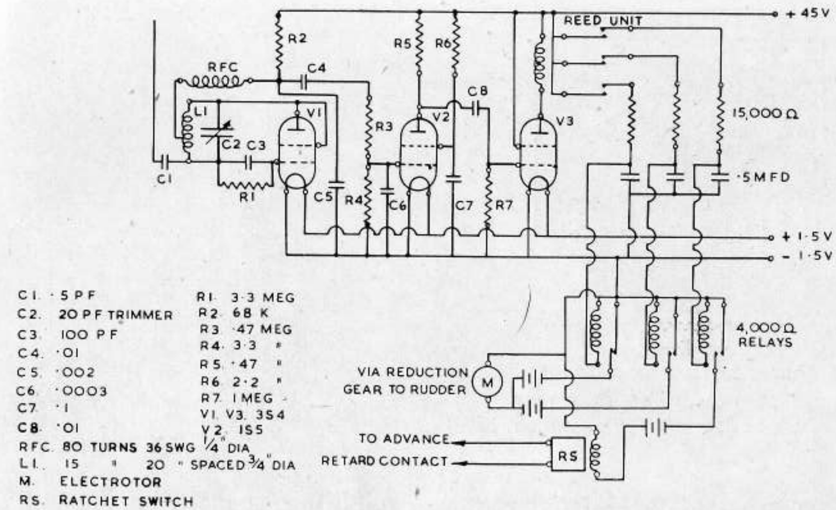
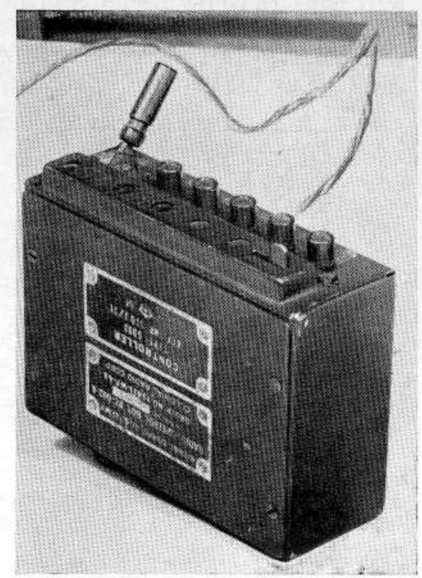
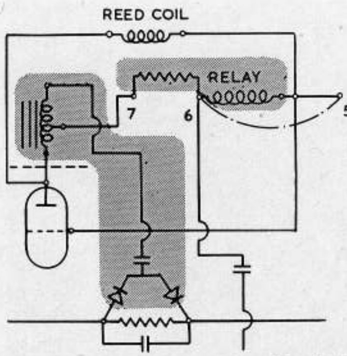


Fig. 60. Complete circuit of a three-channel reed receiver suitable for planes with a two-speed ignition engine. Average values of components are given. But it must be remembered that if less sensitive relays are used then the series resistors must be reduced in value and the reservoir condenser values must be increased.

contacts of which lead to the final operative circuit. The current through the relay is maintained by its parallel condenser even during the period it is not making on its contact, the series resistor helps to dampen out the initial condenser charging surge. As well as the smoothing effect, the resistance-capacity filter also, of course, delays the action of the relay, and values must be chosen to give a smooth positive "click" of the relay. One other point, the current carrying capacity of a switch is also determined by its surface, shape and material. Lightly making contacts should have one smooth flat and one pointed in order to prevent dust accumulating between them. The reeds themselves must of course be of magnetic ferrous material, but the tips which lie under the contact pieces must be quite heavily silvered. This applies also to the contact pieces.

A very handy type of control box of ex-Forces origin. The lever switch is for rudder control, the push buttons for the auxiliary controls.





CUT AT DOTTED LINE ALL COMPONENTS SHADED CAN BE REMOVED. TAGS 5 & 6 SHORTED OVER (SHOWN DOT DASH)

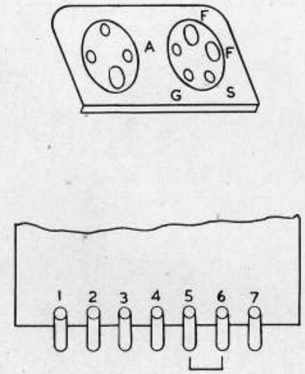


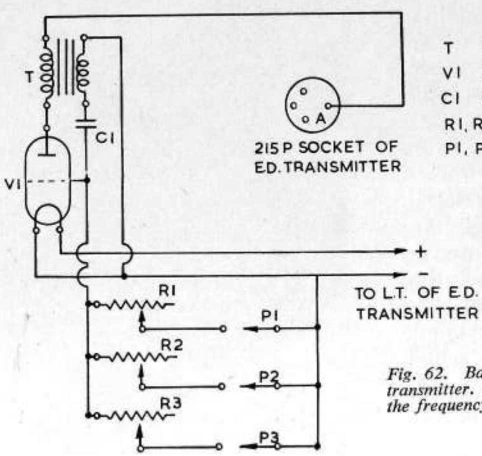
Fig. 61.—Conversion diagram of E.D. three-valve receiver to a multi-channel job. The tags on the panel are as seen from underneath.

Conversion of the E.D. three-valve modulated carrier R.C. to tuned reed reception

Fig. 61 shows the rear view of the valveholder bracket, the panel terminals and a portion of the output stage circuit. Firstly, strip the entire relay from the panel, cutting the associated wiring at the terminal or tag points they lead to. The three-reed bank can now be fitted in the space left by the relay. Now cut the wire soldered to valve socket pin A and tape up the bare end. The reed coil is then connected to A and S of the same valve-holder. Tags 5 and 6 are now shorted over. This leaves the entire positive feed-back circuit isolated from the anode circuit, and if it is required to reduce some weight, then transformer T and the two Westectors W, with condenser C and resistor R, can be removed.

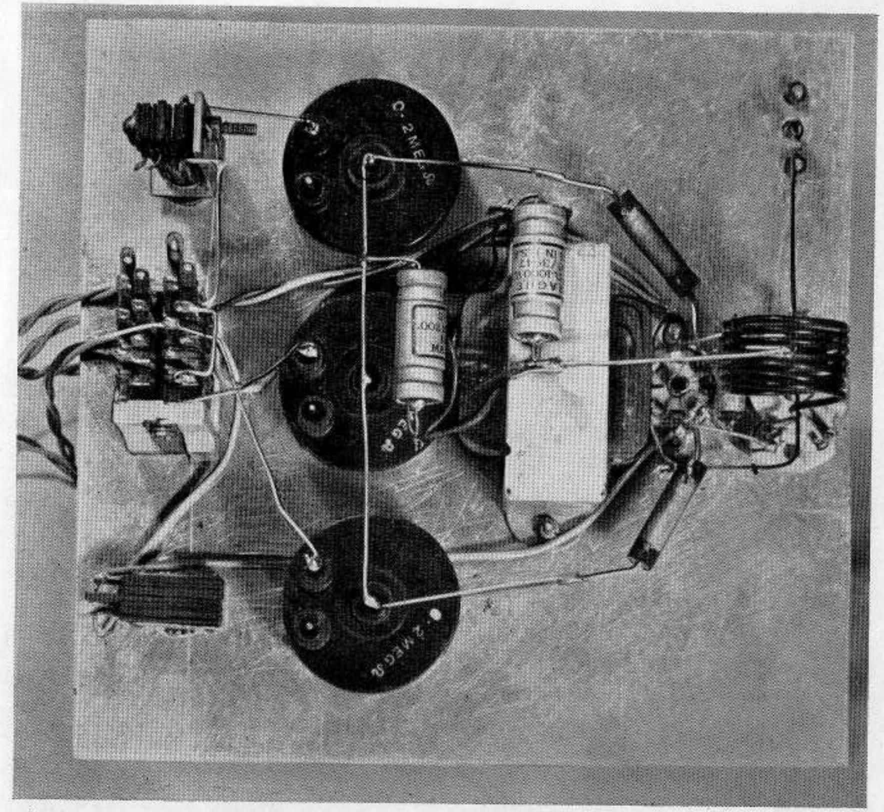
To change the transmitter, remove the modulator valve (215 P) and plug the output lead of the reed modulator unit into the anode socket (Fig. 62).

Operation: With the exception



T 3:1 L F TRANSFORMER
VI 215 P VALVE EX ED TRANSMITTER
CI ·05 CONDENSER
RI, R2, R3, 50 K Ω POTENTIOMETERS
PI, P2, P3, PUSH BUTTONS OR CONTROL SWITCHES.

Fig. 62. Basic modulator unit to be used with E.D. transmitter. A L.F. oscillator of the "blocking" type, the frequency of which is determined by the value of the grid leak.



Under chassis view of three channel transmitter. On the left are the on-off switch, double lever switch, and push-button switch. The three variable grid leaks (pre-set potentiometers) and the L.F. transformer are in the centre. At the right is the tuning circuit, valve holder and associated components.

that the receiver G.B. battery voltage should be reduced to three volts, the normal batteries are used. Switch on the transmitter and the receiver and a rough scratching noise will be heard directly from the reeds, tune the receiver until the normal "silent" spot is found. Then key the first transmitter control and slowly turn its associated potentiometer until reed No. 1 buzzes loudly and its circuit operates. Proceed the same with Nos. 2 and 3.

Overall range will be reduced, due to elimination of the positive feed-back circuit. Range tests should be made to find the best working conditions. Points to note for range are a good earth at the transmitter, an aerial of optimum length and position at the receiver. Above all, an accurate *minimum* spacing of the reed contact gaps, not however too close for engine vibration to cause them to make.

The author checking his equipment prior to a demonstration before members of the Dutch Air Force. The model shown is one of the well-tried Electron series developed in various sizes as flying test beds for new equipment.

CHAPTER IX

U.H.F. TRANSMISSION

Special requirements for U.H.F.—Transmitters—Special valves required—Parallel lines and coaxial lines oscillators—Circuit layout and full details for a U.H.F. transmitter and receiver—Transmitters, Receivers, Valves, Tuning Circuits, etc.—Lecher wires: Method of calibration for U.H.F.

R.C. on U.H.F.

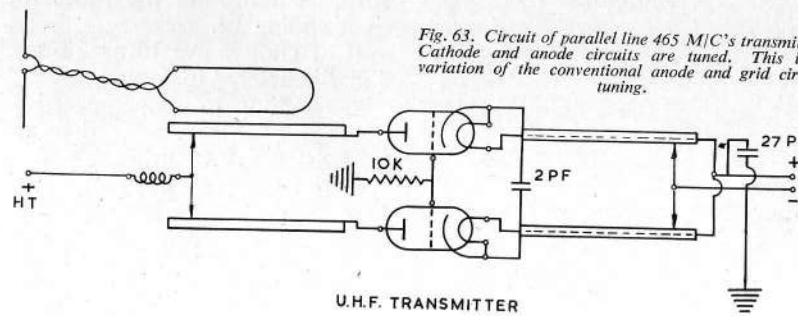
A SECOND radio frequency band which at the moment is also available for R.C. is from 460 to 465 M/C. The very specialised requirements for these short wavelengths restrict its use to purely experimental work, or at the most in the simpler forms to a very limited distance, for example for land models.

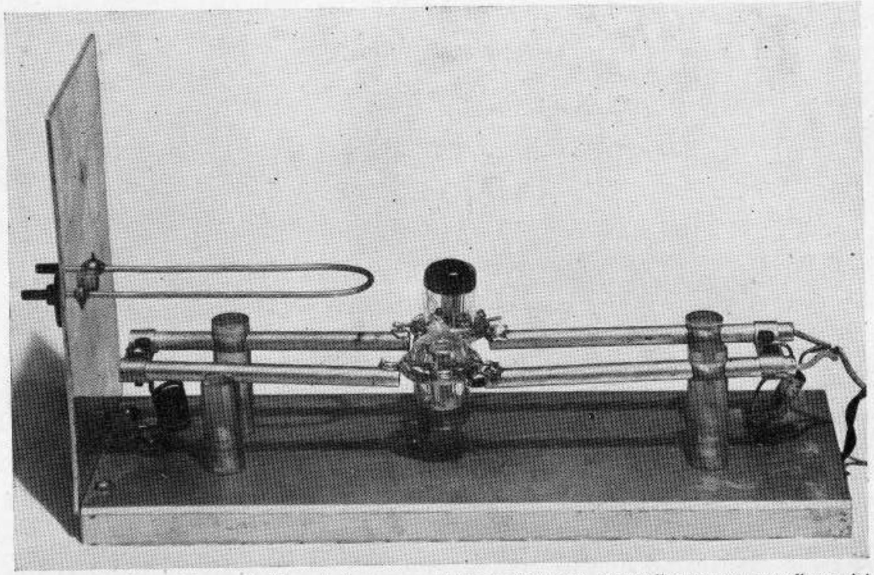
However, there is nothing more stimulating to the mind than to voyage in uncharted waters and however limited the success, a greater amount of knowledge can be obtained from the simplest experiment than by assimilating quantities of words. With this in mind I give a complete diagram with instructions for a push-pull U.H.F. transmitter and a one-valve receiver. The current-change as a pure one-valve receiver will remain too small except for the most sensitive relays. Therefore it would be better to use a modulated carrier and follow the one-valve detector with a conventional L.F. amplifier. The tuned reed equipment described in the previous chapter would be ideal to use in conjunction with it. The modulator section would feed the U.H.F. push-pull oscillator in the same way and the L.F. amplifier and reeds would follow the U.H.F. detector.

Circuit, layout, and full details for U.H.F. transmitter and receiver

The transmitter is a conventional tuned anode-tuned cathode oscillator using parallel lines in place of coils. Tuning is carried out by sliding shorting bars at the ends of the lines. The frequency is determined mainly by the anode lines, and power to the

Fig. 63. Circuit of parallel line 465 M/C's transmitter. Cathode and anode circuits are tuned. This is a variation of the conventional anode and grid circuit tuning.

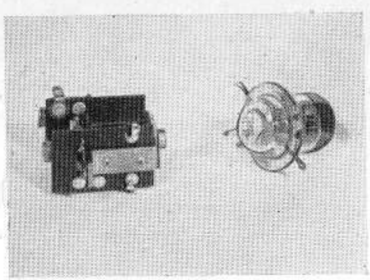




U.H.F. transmitter. Symmetrical layout of valves, parallel tuning lines, etc., are vitally necessary as well as a rigid assembly. A single hairpin loop feeds the aerial.

aerial is taken off there by a loop. The heater current is carried one side by the cathode lines, the other via insulated wires running through the tubes. Directly heated 957 valves (1·4-volt) can be used, also any valve capable of oscillating at 465 M/C. The assembly must be mechanically rigid and dimensions given must be adhered to. Tuned lines, sliders and aerial pickup loop must be silver plated. Assembly must be quite symmetric, R.F. choke, grid resistor

Midget sensitive relay in use for lightweight receivers (left). Acorn valve for use on the 463 M/C U.H.F band (right).



and L.T. line being dead central between lines, which of course should be quite parallel. Distrene blocks are used to hold and insulate the lines and spacing them at least one inch from the chassis. To obtain short, parallel connections, one 955 valve is mounted upside down. Valves are held by soldering direct to the lines.

Anode lines $2\frac{1}{2}$ ins. long, 3/16 in. o.d. copper tubes, $\frac{7}{8}$ in. apart.

Cathode lines 3 ins. long, 3/16 in. o.d. copper tubes, $\frac{7}{8}$ in. apart.

Shorting strips, $\frac{1}{4}$ in. flat brass strip, bent around the tubes for a tight sliding fit.

R.F. choke, five turns 20 s.w.g., $\frac{1}{4}$ in. diameter, $\frac{1}{2}$ in. long.

Aerial loop 16 s.w.g., spaced $\frac{3}{4}$ in. above anode lines, coupled to aerial by twisted P.V.C. flex.

Aerial 16 s.w.g., each arm 6·4 ins. long.

Operating circuit, either carrier keying or modulation, would be in series with the H.T. + line.

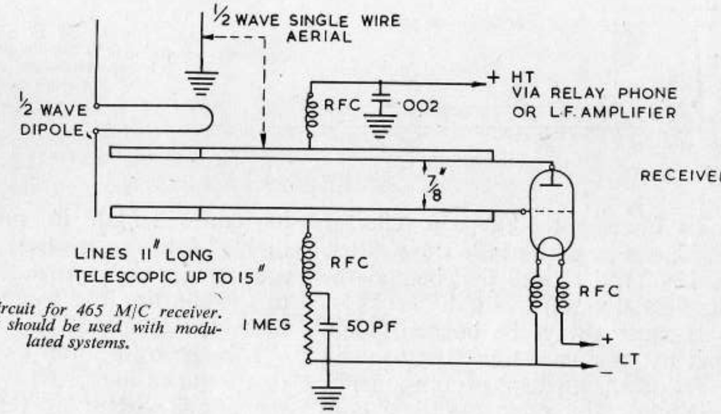
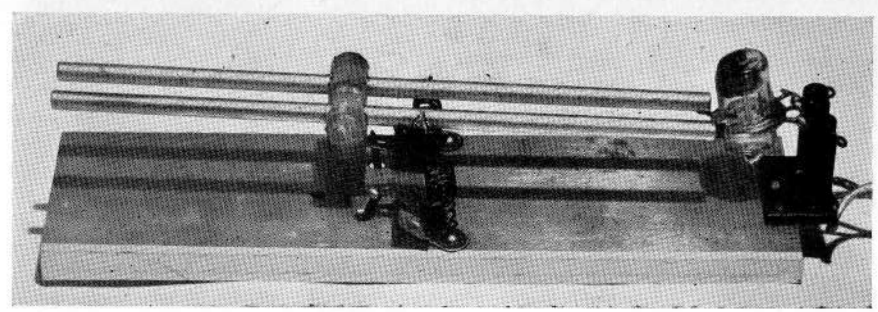


Fig. 64. Circuit for 465 M/C receiver. This receiver should be used with modulated systems.

A low-consumption flash-light bulb connected to the aerial loop will glow brightly if the circuit is oscillating, and adjustments made to give the greatest light will indicate correct operation.

The receiver detector stage is a parallel line super-regenerator. In this case the lines are half wavelength long and are tuned by telescopic ends which can extend them from 11 to 15 inches. R.F. chokes are fitted in the anode, grid and heater circuits. Aerial loop and dipole aerial are the same as in the transmitter. All precautions already mentioned, silvering, symmetry, rigidity, etc., are just as necessary. An alternative half-wave aerial 13 ins. long can be used as shown dotted. As this super-regenerator also radiates quite a strong signal, tuning is perhaps easier by adjusting both receiver and transmitter with a lecher wire system as accurately as possible. Then only slight readjustments will be necessary to match one to the other. As mentioned before, these U.H.F. circuits function best if modulated systems are used, but preliminary checks and tests can be made with either a meter or a pair of phones in the H.T. + line of the receiver. The RK 61 type of gas-filled valve can, unfortunately, not be used at these frequencies.

465 M/C receiver. On U.H.F. the actual layout follows the circuit diagram very closely. Only the ·002, ·50 pf condensers and the 1 meg grid leak are under the chassis.



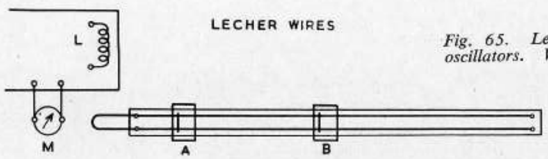


Fig. 65. Lecher wires used to calibrate U.S.W. oscillators. Wavelength is visually measured on the lecher wire batten.

To increase the range a reflector aerial can be used at the transmitter. A 12·8″ rod spaced 6·4″ behind the dipole and parallel with it.

It must always be borne in mind that extreme care must be taken in every detail. Spacing of components, insulation and good electrical connections, all of these points are vital. Wherever possible all metals in H.F. circuits should be silvered. This means all coils, tuning lines, variable condensers, etc., also earth return wires which are part of an H.F. circuit. The range of "acorn" valves and also some types of the miniature seven-pin button-base types are usable up to 600 M/C.

At these frequencies the wavelength is easily measured with a very close accuracy by actually visible methods. Known as **"lecher wires"** the following method with care will be accurate up to 2 or 3%. The example given is for the 465 M/C band, but if used for any other band then the overall length of the wires must be at least one wavelength long. Two bare wires, spaced 5 cm. apart, are tightly stretched upon a batten, leaving a loop at one end and open at the other. A shorting bar upon a slider runs smoothly upon the batten. The batten is marked accurately on its entire length in meters, subdivided into centimeters. An index mark on the slider permits movement of the shorting bar to be accurately measured (Fig. 63).

L is the transmitter oscillator coil or the tuned lines. M is a meter in the anode circuit of the oscillator valve. The loop end of the lecher wire batten is placed about two inches from L. The shorting bar is slowly moved from the loop end outwards until a sudden dip is noticed on the meter. The distance between the loop and L should be adjusted to produce a definite, easily read movement of the meter. Noting accurately the position of the shorting bar (A) it is now moved further along until a second dip is noticed (B). The distance between A and B is one half of a wavelength in meters. The frequency is obtained by the formula:

$$\text{Frequency in M/C} \quad \frac{150}{\text{length in metres}}$$

or

$$\text{Frequency in M/C} \quad \frac{1{,}500}{\text{length in cm.}}$$

The most accurate readings result only when the lowest possible coupling is used between the loop end of the lecher wire and L.

CHAPTER X

MODELS

Various methods of propulsion and suitability for R.C.—Planes—Size and weight considerations—Strength, springing—Controlled surfaces, engine control, cut outs—Boats—Scale models, speed boats, etc.—Land models—Wheeled, tracked—Amphibious types.

Propulsion of Models

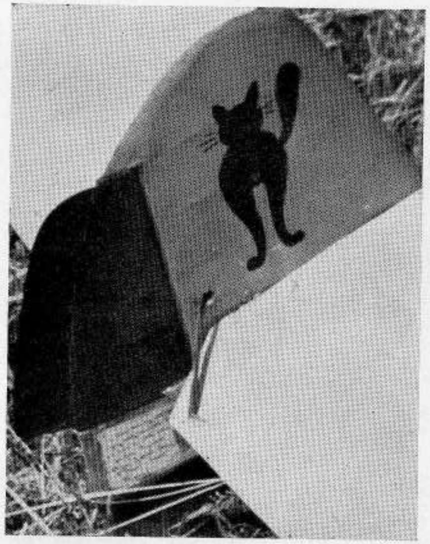
METHODS of propulsion for R.C. models have seldom been given great thought. As far as planes are concerned, in early days **large, powerful diesel or ignition engines** were considered absolutely necessary. The last year, however, has shown that even with the additional weight of radio, planes down to engines of ·75 c.c. can be, and are, very good performers. Attention to flying capabilities, airfoil section of both wings and fuselage, long moment arm, lifting tailplanes, etc., can put up a performance greatly in advance of many standard types of free flight (non-pylon, competition type) planes. For low engine powers, a cross between a **normal free flight** job and a glider is to be aimed at. The nearly full-scale type plane will, however, require a larger engine, but seldom over 5 c.c. unless the wing-spread is over eight feet. **Twin tandem engines** are an interesting idea, the larger one with only a short engine run to gain height, and then the greater part of the flight can be carried out with only the smaller one in operation. This method gives non-vicious scale type manoeuvres which are a joy to behold.

Finally, I have yet to see a **jet (rocket type) assisted glider.** This would eliminate the necessity to have the usual glider team plus the R.C. operator, and by using several jets flights of various duration could be made.

Propulsion for boats can be split into two categories. **Diesel or ignition engines** for speedboats with steering only (plus two speeds with dual ignition engines). **The electric motor,** however, gives a greater scope to the R.C. enthusiast who wishes to give rein to his ingenuity in the choice and construction of the intergear. Reason, of course, is that the main propulsion electric motors can be started, stopped, reversed, and speeds changed by simple methods. One thing, however, must be borne in mind, electric motors run most efficiently at full revs. Reduce the speed and not only does the power fall off but the *battery consumption rises*. In all cases, even with small motors, gear well down. The "innards" of an old clock are often suitable for small motors.

Planes, size and weight, etc.

In the majority of cases, an existing plane or a standard free-flight kit has up to now been used for R.C. Right away a vicious circle of adding weight and strengthening has taken place, and it is usually found that such planes seldom last more than a few flights due to weight and strength being in the wrong places. Before building get a good idea of the action of the forces and weights,



Tail of French R.C. glider. The artistic touch as well as the trimtab on the rudder itself should be noticed.

especially at the moments of landing. The radio and batteries will exert a forward-downwards force, and the undercarriage a backwards-upwards force. Arrange that these points of attack on the fuselage cancel each other out and where they meet put all of the reinforcing, ply gussets, hard balsa sheeting, nylon covering, etc., in the correct places, and that plane will still be flying in two years' time.

One further point I always stress, whenever possible fit a **sprung under-carriage.** This will definitely pay dividends. Even the most simple type, a bent or coiled rear wire is better than a rigid under-carriage.

The amount of controlled operations one can make on a plane are quite limited. The limitations being imposed by considerations of weight and simplicity. The chart below gives the majority of controls in order of priority. The priority being governed by ideas of pure flying and reliability.

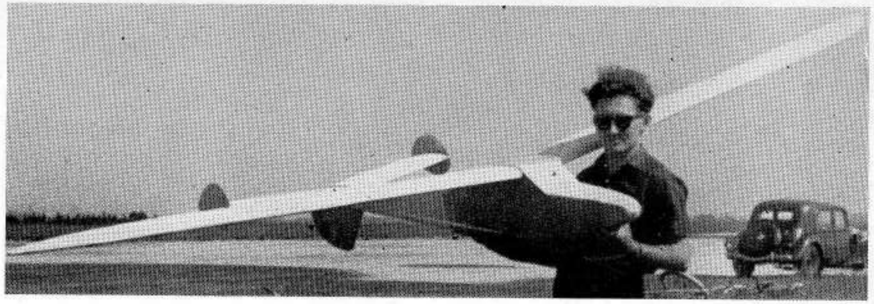
(1) **Rudder Control**
  (*a*) Escapement operated (simple or ruddevator).
  (*b*) Servo motor operated (progressive or semi-progressive)
(2) **Engine Speed Control**
  (*a*) Dual timer engine.
  (*b*) Servo operated timing lever.
  (*c*) Steering by offset two-speed engine.
(3) **Aileron Control**
  (*a*) For steering purposes.
  (*b*) In conjunction with rudder.
(4) **Elevator Control**
(5) **Auxiliary Controls**
  (*a*) Engine cut out.
  (*b*) Retractable under-carriage.
  (*c*) Bomb dropping, parachutes, flares, rockets, etc.

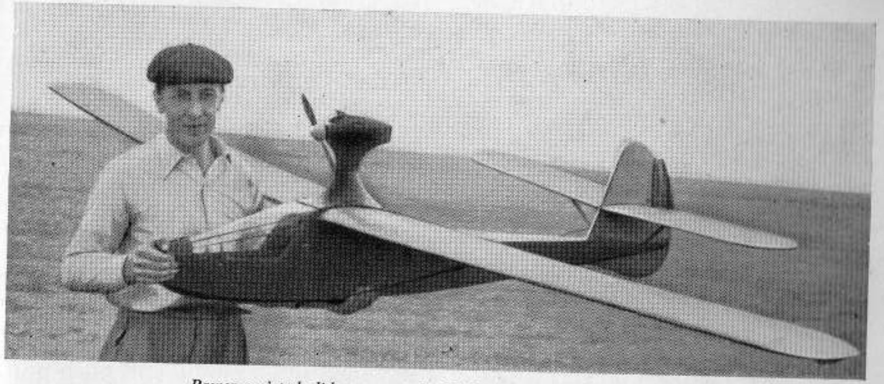
You will notice that I have not mentioned elevators at all. Elevators require to be operated in conjunction with a progressively variable engine speed, which at the moment in reasonably-sized models is out of the question. A short "flip" of an elevator would of course raise or lower the nose of the aircraft, but held on would only result in a stall or dive. It therefore remains nearly at the bottom of the list. In Chapter 12 we shall see that rudder and engine controls not only perform their main functions but also cover the rôle of the elevator.

Auxiliary controls, or perhaps operations, can often be used in conjunction with others, and as such are not purely radio controlled. For example, it can be arranged that the slackening tension of the escapement rubber will release a pin to the engine cut-out after a predetermined number of rudder movements. It can still be called "radio controlled" because if required before its time one can quickly run through a score of rudder rights and lefts to cut the engine, without materially affecting the flight of the plane.

The escapement, either clockwork or rubber driven, will be found in the majority of R.C. aircraft. It has long been popular for rudder control due to its simplicity and reliability. Failures have been mainly traced, not to the escapement itself, but to the mechanical coupling to the rudder. Great care should be taken

Eleven-foot R.C. glider at the Miniwatt competition. Their weight and perfect airfoil finish gave them a speed which enabled them to combat the high wind.





Power-assisted glider seen at the 1949 Miniwatt competition.

Steamer of C. Pepin and the launch of L.U.K. in operation together. Use of the two French bands 72 and 144 M/C make dual operation possible.

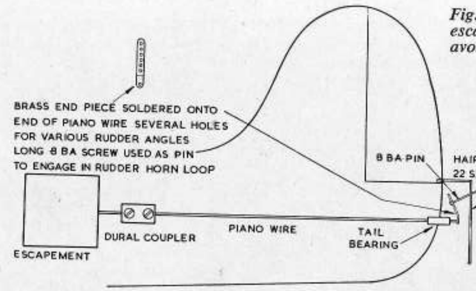


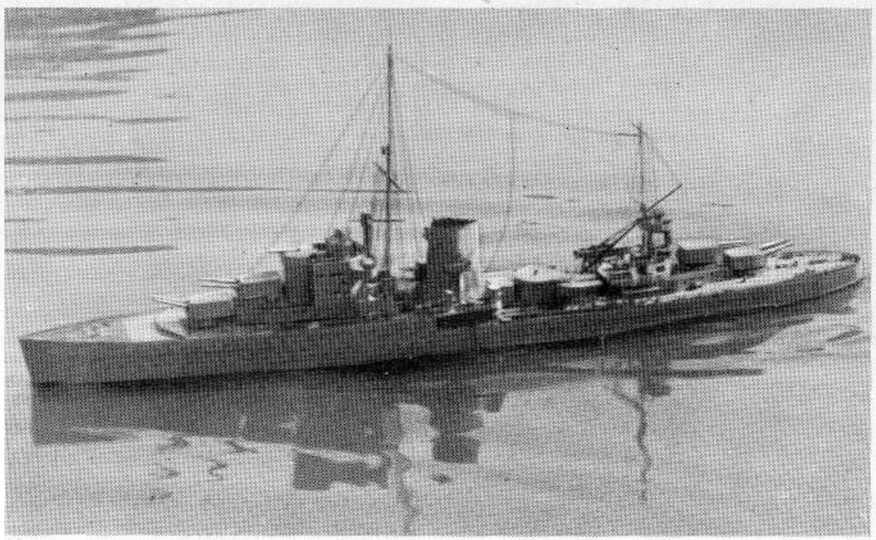
Fig. 66. Method of connecting rubber-operated escapement to rudder. All bearings should be free to avoid jamming if the fuselage warps due to strain in turns.

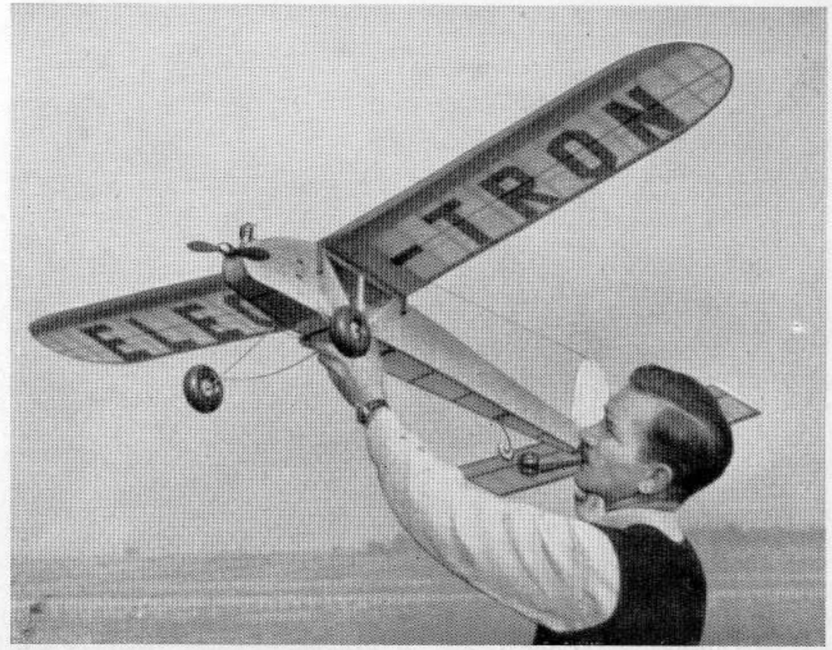
to ensure that control wires or cords do not bind and that the least amount of power is required to move them. Disconnecting the escapement itself, it should be possible to lightly blow the rudder from side to side. More than any other type of coupling used is the direct drive type. Here the escapement spindle is extended right back to the trailing edge of the rudder, where it ends in a crank. The crank handle engages in a hair-pin loop of piano wire fixed to the trailing edge of the rudder. In either neutral position, the crank is up or down. In rotation to right or left it carries the rudder with it. The crank handle should be bent at less than 90° otherwise it will tighten up in the hairpin loop as the rudder angle increases. In order to be able to adjust for various angles of rudder movement, it is wise to fit a crank of adjustable handle length (Fig. 66).

The next method, used in larger planes, is to employ a stiff push-pull coupling link instead of a rotating one. In this case a crank handle is fitted directly to the escapement, and a stiff link, usually light aluminium tubing, operates another crank at the rudder hinge. This can all be fitted inside the fuselage and does not mar the appearance of scale models.

The last method is to fit a "T" yoke to the escapement crank pin. Cords from the tips of the "T" run

H.M.S. Ajax. A perfect scale model by F. H. Mitchel. Powered by twin electric motors and operated by E.D. R.C. with delayed relay reverse, it might well be the real thing.





The author with Electron 6. A 30-ounce lightweight with a three-valve receiver and a Mills 1·3 engine. Now fitted with an E.D. 1 c.c. Bee engine and thyratron R.C. with an all-up weight of under 20 ounces. A glider type with large tail area which has a glide of longer than the normal three-minute engine run.

to a crossbeam on the rudder. Cords however have a habit of shrinking which can cause a great deal of trouble. The last two methods have one drawback, the escapement spindle is vertical and unless one resorts to a bevel drive, only a short elastic is possible, as even in a large plane the depth of the fuselage seldom exceeds eight inches. Clock-work-driven escapements are, how-ever, ideal in this position, both from the point of view of accessibility and means of winding up.

Motor-driven rudder servo's have always been the dream of the "gadgeteer". Well constructed, they can score on the point of reliability, a motor-driven reduction gear overcoming any control linkage stiffness. In weight it need not exceed that of the escapement by more than the weight of the driving motor.

The first type has the advantage of being self-centering, also it only consumes current whilst moving the rudder, and not when the rudder is being held in either right and left. This permits the use of quite a small capacity driving battery. Thirdly, by giving only a short impulse one can hold the rudder in an inter-mediate position (Fig. 67).

The next method could be used in conjunction with various systems. The "Knupple" and tuned reeds are the two main examples. Selector switching systems a third, but not advised for planes due to the unavoidable time lag of sequences. Again, we need a reduction gear, and this time, of course, limit switches. Fig. 55 explains the construction of

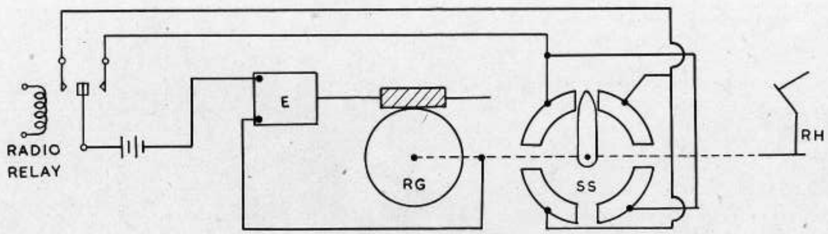


Fig. 67. Semi-progressive, self-centring, motor-operated rudder servo. Battery consumption of this type is negligible and will run for hours on a lightweight battery.

the rudder servo in detail.

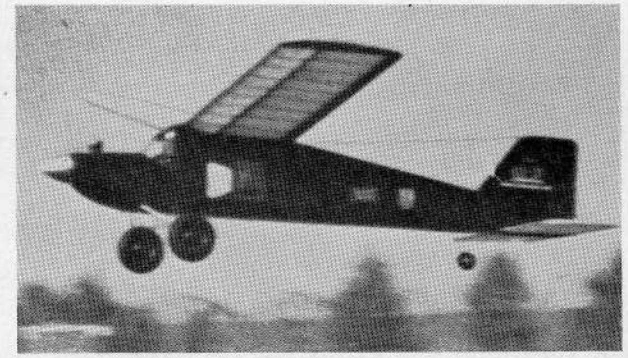
Engine speed control will without doubt enjoy great popularity as a second control, and in fact in some cases as a first and only control. Several methods can be used to give a second operation usable for engine speed control, of dual timer engines. The method described in Chapter 7 either with or without the double rudder control, or the following simple method using the two midships escapement positions for advance and retard. This method, in conjunction with the delayed relay system of Fig. 44, is quite easy to construct. (Fig. 66.)

Even a single timer ignition engine can be used, the timer arm being moved by a crank driven through a high reduction gear by an Electrotor. Reduction should be chosen to give one complete crank rotation in about five seconds. The beauty of engine speeds as a secondary control is that there is very little danger of serious prangs, either by failures or mistakes in operation. Providing, of course, that the plane is in normal trim with the engine at full speed.

The third use of an engine speed

The AEROMODELLER version of the Rudderbug in its original spotless trim. After serving as a testbed for sundry receivers and various members of the staff trying their hand at control it still exists in a much repaired condition.

Pete Cock's 40 m.p.h. reduced scale Radio Queen with E.D. three-valve receiver.



control is not a secondary one, but a primary one and also the only control on the plane. The plane is trimmed, by engine offset and fixed rudder setting, to fly left under torque of an advanced engine, and right when the engine is retarded. With a dual-timer engine, straight flight is achieved by "blipping" the engine. With a motor and reduction gear driven timing lever quite progressive steering can be obtained.

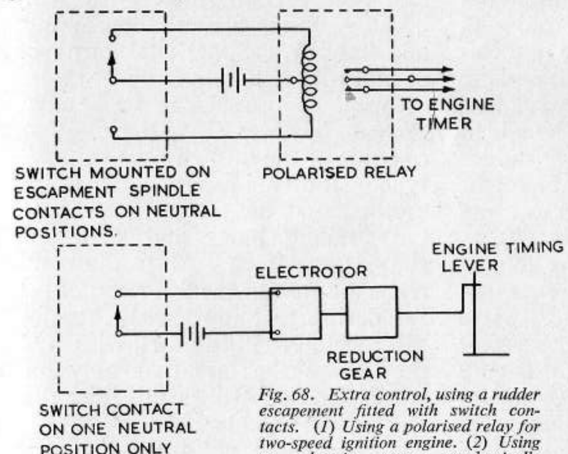


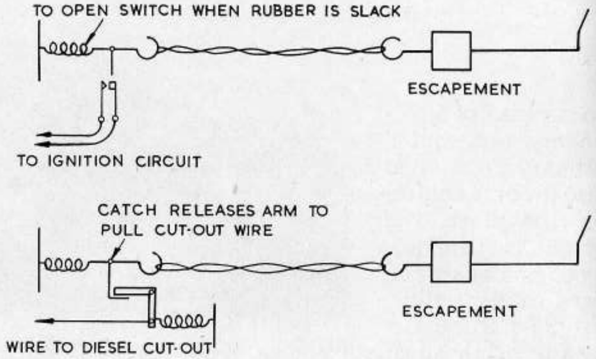
Fig. 68. Extra control, using a rudder escapement fitted with switch contacts. (1) Using a polarised relay for two-speed ignition engine. (2) Using an electric motor mechanically moving the timing lever.

Aileron control has not up to now been in great evidence. Its advantage as an only control for steering will be appreciated when one sees the spinning tendencies of rudder control. However, the great difficulty of fitting the mechanism to operate ailerons, when, due to transportability, wings have not only to be detachable but even in two halves, have caused the majority to think of it only at the moment. But with a reasonably-sized wing of deep section, there is no reason why an escapement could not be accommodated: this would require only an electrical connection to the radio in the fuselage. Ailerons again could be of use in conjunction with a controlled rudder, either mechanically connected or electrically by a switching rudder escapement connected to solenoids operating the ailerons.

There are two types of auxiliary controls, useful ones and those which can be termed "stunts". My advice is to keep clear of the latter, as you will have your hands full enough with only two controls. However, in order to complete the picture I shall include them, if only in a form which is least likely to cause trouble to other controls by complication.

The first really useful one is an engine cut-out, both for diesels or ignition engines. The type which is operated as one step in a sequence system (usually escapement type), it being necessary to skip quickly over it until it is required, is in my opinion of no use at all. The

Fig. 69. Simple method of cutting engines by R.C. without introducing a further sequence to the rudder operation. The cutout must be made to operate—leaving enough rudder movements to bring the plane in on the glide.



memory, especially in an emergency, will not cope with any even slightly complicated sequence of events. In the majority of cases an engine cut-out is required towards the end of the flight, therefore a system which will operate after a certain number of rudder movements appears to be the ideal. The method is an old one often used by rubber plane enthusiasts to give a "turn" to their plane when the rubber skein was running down. In our case it has the added warning that only a few rudder movements are left. Do not forget to arrange for enough turns to bring the plane in on the glide (Fig. 69).

A control which can be left to the "stunt" class is the retraction gear for the undercarriage. Here again it will only apply with safety to the large plane. In fact it is very nearly out of the model class. Again, electric motors and reduction gears are the answer. To operate it would presumably require a multi-channel R.C., tuned reeds being the most likely method, because a plane with radio controlled retractable undercarriage would have at least two other controls of primary importance.

Now to the useless ones (bombs, flares, parachutes, leaflet dropping, etc.), take my advice, fit a timer to operate them ! If you really want to radio control them, then sandwich them somewhere in time with a sequence operation as for engine cut-outs.

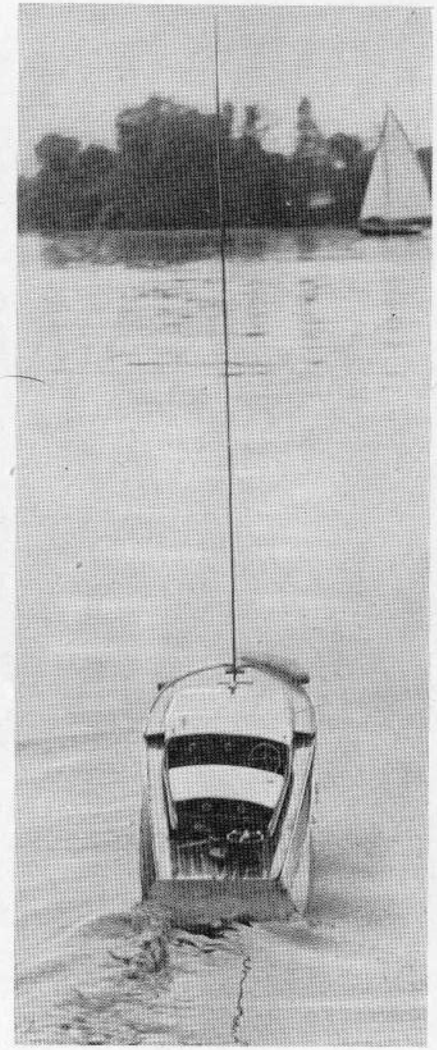
Boats

It is quite impossible to suggest a best type of hull suitable for R.C. because, unlike planes where weight and stability, etc., are vital, any type of hull with either mechanical means or wind as propulsion, is suitable. We can, however, make one division, one side of the line we have the scale type boat driven generally by electric motors, and on the other we have both sailing boats and pure and simple speedboats. I can already sense the fury of the followers of sail for daring to lump speedboats and sail together. But in fact, with R.C. they share the fate that only one worthwhile control is possible, that is of course rudder. In the case of sail, R.C. will go a long way to change the trend of design of model yachts. Direction, instead of relying upon fixed rudder and sail settings, and then upon the vagaries of the wind, will depend upon how close a well-built hull will sail into the wind. There is no point in further controls than rudder, for as long as the boat has way, she will follow the rudder and the boom will swing over. One point is worthwhile to mention, an easily visible vane should be

fitted to the tiller, otherwise due to the time lag of following the helm, one may be misled as to which rudder position one has chosen. Once you have seen the vane click over to either port or starboard, you can wait patiently knowing that she will follow.

A very popular type of model speed boat is the air/sea rescue launch, which is to be seen in large numbers upon our lakes. The majority of R.C. enthusiasts have taken to this boat, using both electric motors and diesels for propulsion. Rudder control by escapement seems to be the order of the day. The progressive steering systems, "Knupple", etc., give a far better performance, especially if the boat is really fast. The only secondary control would be an engine speed control on the lines already explained for planes. Of course, there is no necessity to worry about weight or size of components, in fact a more robust construction would be more suitable.

Scale models, cruisers, motor-yachts, steamers, aircraft carriers, etc., open a new vista for R.C. Here, with their relatively low speed and slow turns, one can let oneself go and wallow in multiple sequence systems. Up to ten operations is not out of the ordinary and presents little difficulty either to construct or to operate. Figs. 53 and 54 are types suitable for scale models. For land models and amphibious types there appears to be little interest. Possibly the attraction of R.C. is to control a model which is out of one's reach. With only *terra firma* between you and your model the achievement of perfect R.C. appears a little flat. Perhaps for exhibition purposes there is more interest, or even during an inclement winter to instal one's gear into the young hopeful's pedal car.



Model powered launch under radio control. The "mast" is of course the aerial. Even quite small model boats can be adapted for radio control, including sailing craft—though this is another story.

General arrangement of receiver, batteries and engine on this model designed and built by Squadron Leader E. D. Cable could hardly be bettered. Adequate access to the "works" is given without in any way weakening the basic fuselage, and extreme forward position of H.T. and L.T. batteries prevents them from damaging radio equipment or wiring should anything go amiss. Last minute adjustment can also be made with mainplane in position—a matter not always considered.

CHAPTER XI

INSTALLATION OF RADIO GEAR

Planes: Wiring, Aerials, Fitting of components, Screening and other anti-interference methods—Boats: Ditto—Land models: Ditto.

Installation of Radio Gear

THIS is perhaps the most vital stage of the construction of a R.C. model. Many times have I seen well-constructed receivers and intergear, also standard manufacturers' equipment, installed and wired in the model in a fashion which is calculated to introduce every possible source of failure from vibration effects to range.

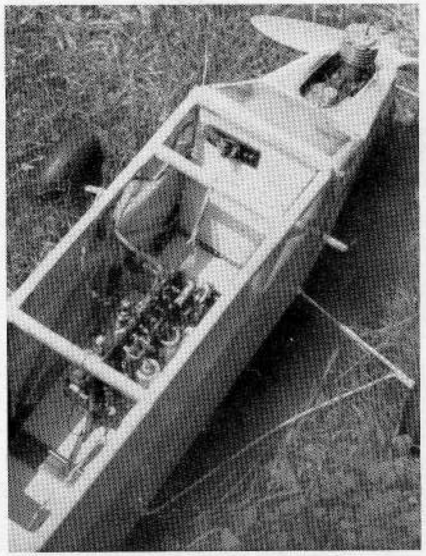
Dealing with planes first and beginning with general wiring.

One thing must be understood first. With normal radio on the ground, we often disregard the earth connection, which with short waves is often not necessary because the capacity of our equipment (case, batteries and leads, etc.) to earth is large enough to give an adequate earth connection. But off the ground, that is missing, and we know that the best aerial is a dipole. The earth connection merely permits our aerial to mirror itself in the earth to produce a dipole.

In the plane our only earth half of the dipole aerial system is the battery, escapement, etc., and their wiring. Now all of this wiring functions as a receptive aerial just as much as the aerial itself. As it is generally known that an aerial which hangs loose and moves about can cause signal fluctuations, so the rest of the wiring in the plane can have the same effect. Not only signal strength fluctuations but also detuning of the signal. One other point, if on a normal dipole we bend the two halves together until they run parallel and close to each other then the aerial system will lose efficiency.

Conclusions to be drawn are: All wiring neatly cabled or twisted together, and run the aerial as far away from the general wiring as possible. Even better, run the aerial at right angles, either inside one wing or at the trailing edge. Finally, if the wiring looks neat and tidy, then it is correct. Wire breakages nearly always occur at the point of connection. As the majority of connections will be soldered on to tags it is advisable to slip a sleeve over the wire and tag to prevent bending at the point of connection. Either plastic sleeving or cycle valve rubber is suitable.

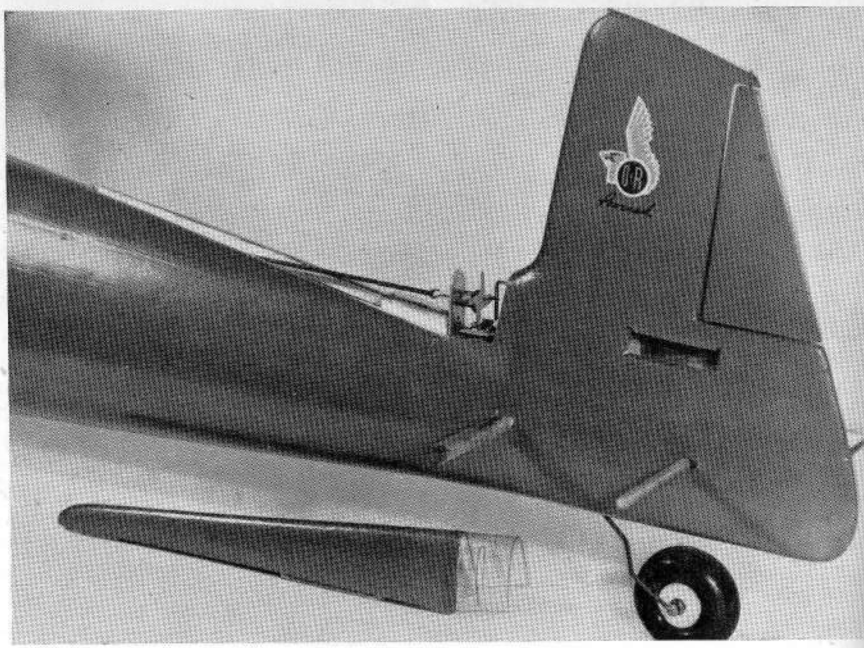
Batteries should never be soldered directly on to the set wiring. A separate battery box should have a plug and socket connection to the general wiring. Miniature four or five-pin plugs and sockets are easily obtainable. This method has the advantage that the entire battery supply can be easily disconnected from the set wiring and also the box can be taken bodily out of the plane or boat to check voltages or for replacement of batteries. Flexible

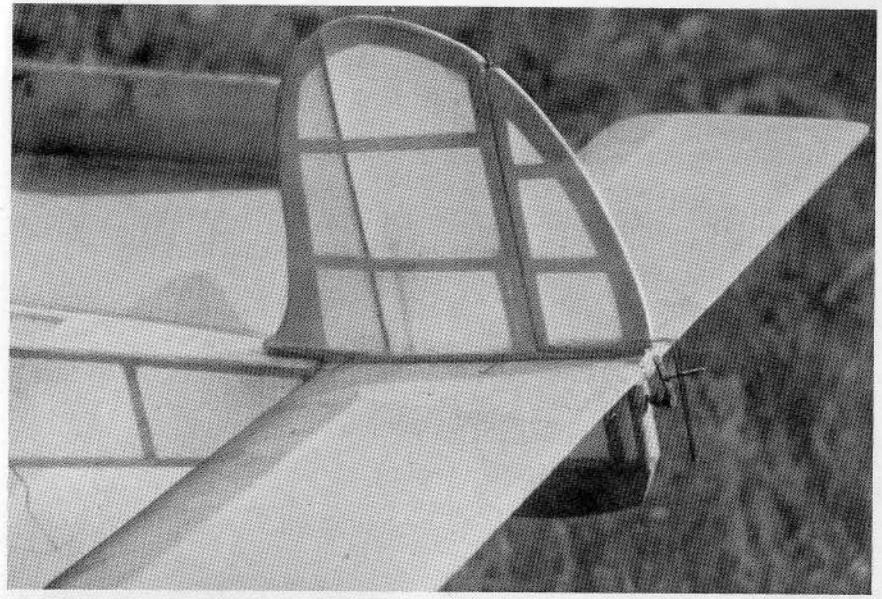


Above: Neat installation of 3 valve receiver in the E.D. Radio Queen, a popular commercial kit model for R.C. use. Below: Squadron Leader Cable's "Cats Whiskers", showing rubber operated relay system and neat perspex fairing that clips over it.

insulated wiring should of course be used throughout.

The fitting of various components requires a fair amount of thought and preparation. The centre of gravity point, of course, has to be maintained, but also the major weights must be clustered around the C.G. otherwise the flywheel effect of widely spaced weights would cause the plane to swing past the given rudder position turn. For example, centring from a turn, there would first be quite an appreciable time lag before the plane began to straighten, and then it would swing over the centre position to the other side. I had this happen in a large, heavy plane; the plane wallowed from side to side after a turn, only achieving straight flight after ten or more seconds. Regrouping of the receiver and batteries towards the C.G., and also fitting a lighter escapement in the tail, cured the trouble at once. This is one reason

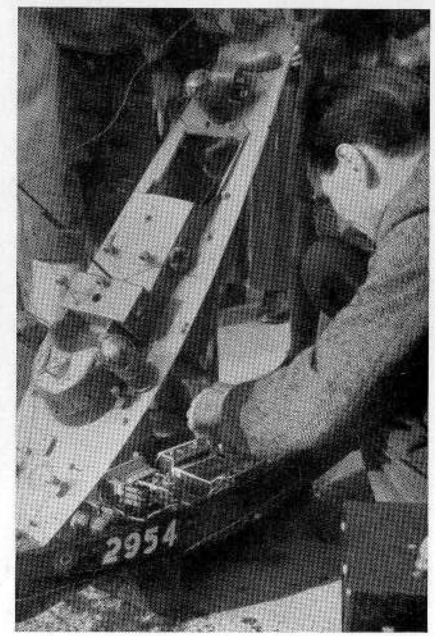




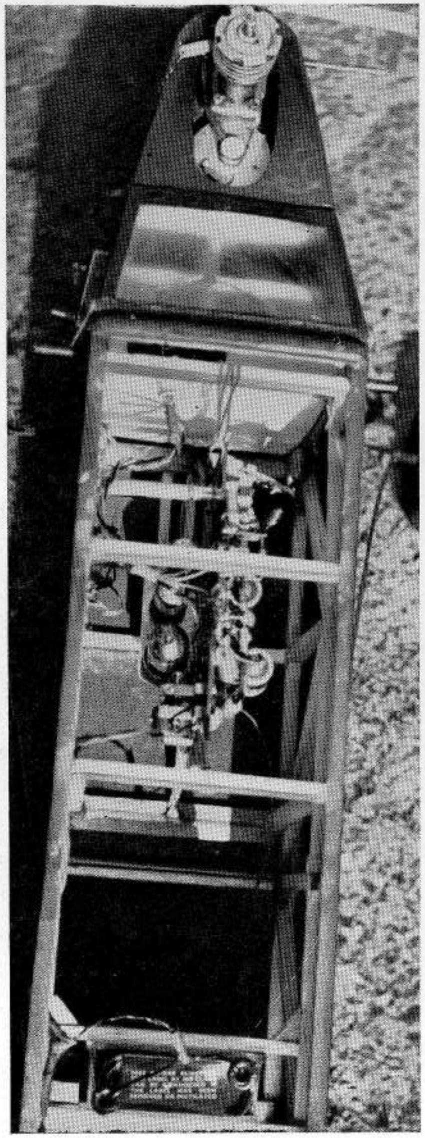
(Top) Tail of Electron 6, showing easily adjustable rudder horn. Note slight angle of pin for free movement in loop at right angles.

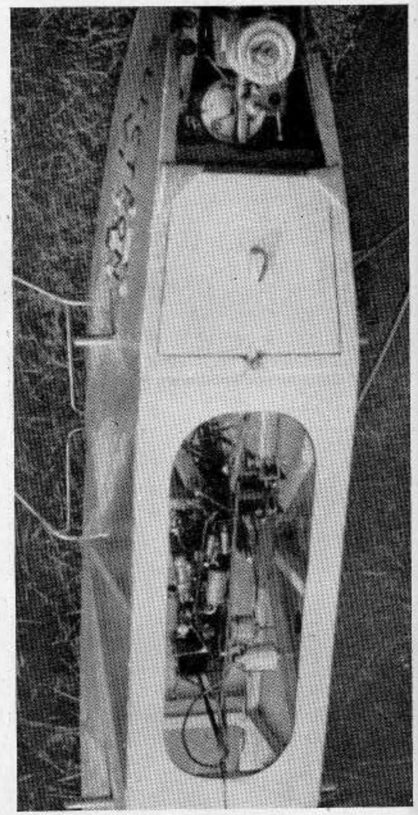
why I advise fitting the escapement just forward of the fin, and not at the extreme end of the tail. The radio receiver itself should be suspended on elastic bands to avoid the effects of vibration. The suspension should not be only in two directions, but up, down, fore and aft. The elastic should be quite strong, as on a hard landing the receiver may jolt forward for more than an inch, springing back again nearly the same distance past the rest position. For this reason see that there are no obstructions within reach which could damage the receiver. Tuning controls on the receiver panel should be quite accessible without having to remove parts of the plane, wings, etc. On-off switches, 'phone or meter sockets, etc., should be clear of the wings, so that a meter reading can be easily seen without lifting or tilting the plane. Switches should be seen, not fumbled for.

The super-regenerative receivers used in one form or the other practically universally have a limiting



View of installation of E.D. receiver in a "Radio Queen". A roomy fuselage makes it easy to connect up and fit sockets and accessories. (Right) Miniaturised version of E.D. receiver installed in Electron 6. Sheeted fuselage top gives added strength to this lightweight.





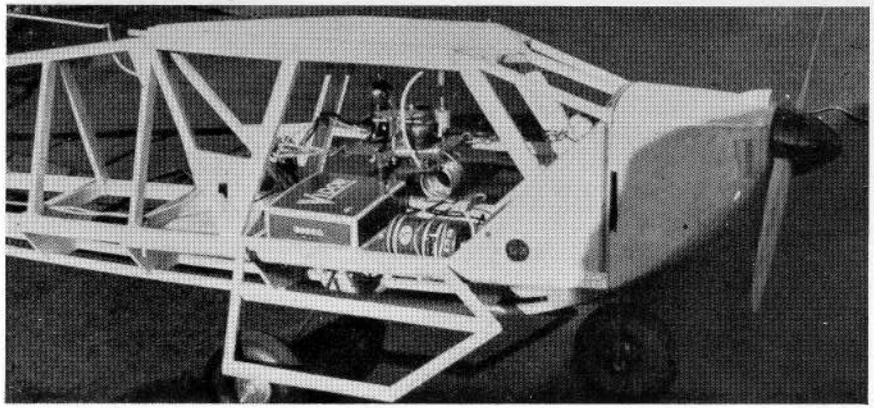
effect to the sudden peak voltages of ignition interference, but all wiring of an ignition engine should be kept clear of the radio equipment, aerial, batteries and wiring. For example, the ignition battery should not be placed close to the radio batteries. The majority of the interference is radiated by the coil and H.T. lead, and these, especially, should not approach the radio or wiring by less than six inches. I have never found it necessary to either screen components or wiring, or to fit suppressors, providing that the above precautions are adhered to. Finally, a faulty ignition condenser, or one of incorrect value, increases the radiated interference. Small electric motors

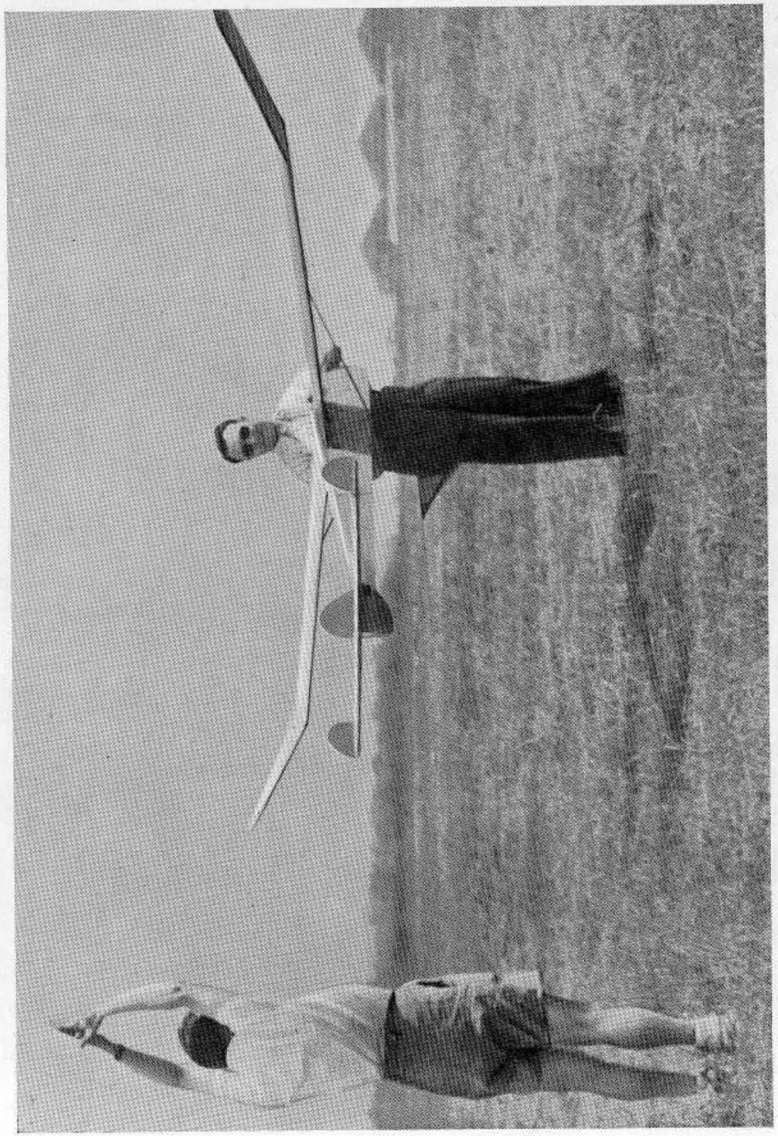
used for servo purposes can cause really disturbing interference. However, a small ·1 condenser connected direct to the motor terminals will smooth it out.

The installation in boats or land models does not differ from that of planes greatly. Of course the C.G. question is not so vital, also vibration, even if a combustion engine is used, is not nearly as great. The flywheel, also the extra rigidity of the hull dampen it out. The radio here need not be suspended, but can rest in its box or in chassis form on a sponge rubber, mat or feet, lightly held down by rubber bands. Having a stable and good earth handy, a connection should be made from the L.T. tag of the receiver direct to a small brass plate (screwed to the hull at a point which is always under water, whatever the speed or turn of the boat). A piece of brass two inches long and one inch wide, streamlined shape, is quite large enough. It can be painted over, the capacity effect to the water is quite sufficient. With metal hulls the L.T. tag should be connected to the hull at the nearest point. Interference problems are the same as for planes, and should be tackled in the same way. Propulsion electric motors should be smoothed by ·1 condensers, as all servo motors. A special type of intermittent interference which causes escapements, etc., to pass more than one point at a time, can be caused by erratic earth connections to the water via rudders and prop-shafts. If the prop-shaft's coupling is of the pin and crank type, then a piece of insulating sleeve should be slipped over the pin insulating the prop-shaft from the motor, or a definite earth connection should be made from prop-shaft to motor frame with a heavy flex. In the same way, the escapement should be insulated from a metal rudder, or bonded together. These interference problems are usually not noticeable until the boat is in the water with engines running.

Boat aerials will usually tend to conform with the scale effect of the vessel. The receiver should be positioned as near to the foot of the aerial as possible. With carrier-operated receivers, which usually require longer aerials, rigging or stays can be a portion of the aerial without the boat losing its scale appearance.

Conveniently located elastic-band sprung receiver unit, with heavy batteries mounted as low as possible — though the ideal is to separate them entirely from the receiver and so avoid possible crash damage.





Final take-off check by French competitors of Miniwatt competition. The excellent team work is demonstrated by this method of semaphore signalling to the operator.

CHAPTER XII

OPERATION

Planes—Manœuvring on rudder control only—Rudder and motor speed control—Multiple sequence control—Advanced multiple controls—Boats—Rudder control—Rudder and engine controls, stop, reverse, half speed—Further non-operational controls—Land models—Steering and reversing for wheeled and tracked models.

THERE is a fair amount of controversy as to the correct procedure for test flights of R.C. planes. One school of thought prefers to strip the plane of all radio gear and substitute equivalent weights of wood. Then to make all test and trimming flights as free-flight jobs. The other school, and my personal idea also, makes the first flight a fully radio-controlled one. Providing the plane is of good design, entirely symmetrical construction, correct engine offsets for given power, etc., then a few test glides should suffice to trim the plane with reasonable accuracy. Note the word "reasonable" because that is my reason for a R.C. first flight. Inaccuracies of turn trim can be corrected by rudder control and noted for alteration of trim tab. Power stalls can be easily corrected by giving alternative right and left rudders. A bad spinning tendency can also be corrected by the giving of opposite rudder. The main thing is to get the plane off the ground and well up. There you can correct at leisure. Do not adjust your engine cut-out for a short first flight. A relatively heavy plane is not a fast climber, so get it up there.

A certain drill is required which should be studied, practised and remembered, so that in the excitement of your first R.C. flight it can be completely forgotten.

Check the radio on the ground at a distance of at least 100 yards, then check it with engine running. For the first few flights obtain the help of two assistants. One to start the engine, switch on the radio and launch the plane, the other to semaphore signals to you at the transmitter, as the launcher will be unable to signal himself.

The launcher will start the engine, switch on the radio and pick up the plane ready for launching. You will have the transmitter already switched on and will operate the key. The semaphore man standing behind the plane will signal what the rudder is doing. Arm up, left and right. At a wave of your arm the plane is launched. By this drill you will know which rudder position your first signal will make. Unless there is any instability, the corrections of which have been already dealt with, let the plane gain height. Then key for the first rudder movement; if for a moment nothing occurs, don't frantically key again. Just hold it there, a fraction of a second may seem like hours during this first flight. When the plane begins to turn, let the rudder go to centre, wait again for a few seconds and then key opposite rudder. Do not at first attempt complete circles, just hold the plane in the general direction of the wind. When the engine cuts, again make no complete turns but weave slowly right and left to lose height and hold generally into the wind to the point of landing. Whatever the position of the plane to the wind, just before touch-down leave the rudder central, never land with a rudder turn. Several flights of this description should be made before venturing further. Full circles should only be made with the plane at a reasonable height, and the amount of loss of height should be noted and remembered. This is important for turning into the wind for spot landings. Too often this is neglected. Spot landings right up to your feet are the most convincing manœuvre to demonstrate the perfection of R.C.

Up to now we have taken for granted a rudder setting to give only mild turns. If, however we set our rudder movement to the extreme, not only do our turns become more vicious, but the plane will rapidly spin down in an ever-tightening circle. Keying opposite rudder will whip the tail down and the plane will either stall, or if there is sufficient power, go into a loop. If the opposite rudder is released to centre at the top of the loop, then the final half of the loop will be quite normal. If, however, rudder is held on, then the plane will roll out of the top of the loop. This is quite spectacular as a change of direction in the vertical plane. It will be found that a loop is more easily achieved from a spin in one direction than the other. The best direction is hotly argued about. I have found that, according to type of plane, engine offsets, etc., that one cannot make a definite rule.

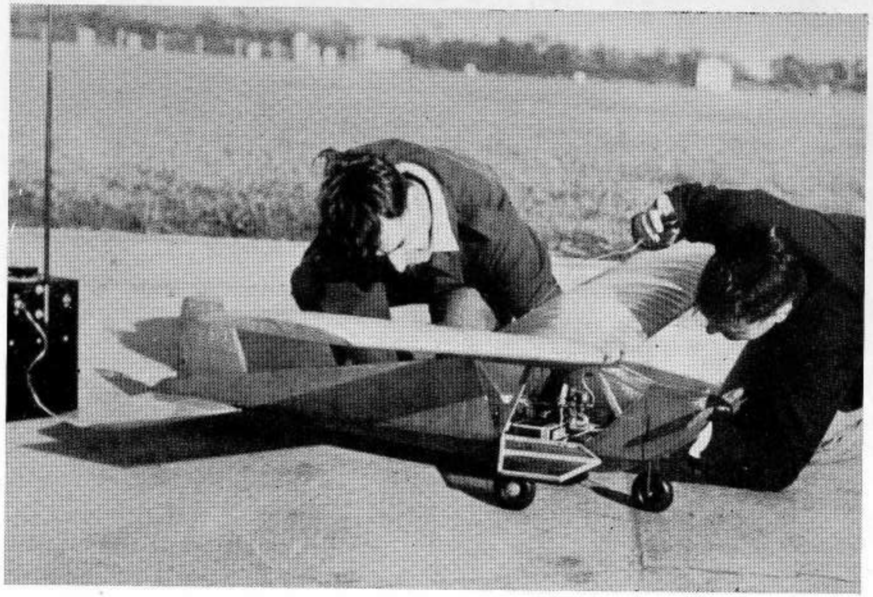
"Weaving" can be used for two purposes. Firstly, a very wavy weave with definite rights and lefts is used to jockey for position for spot landings. Secondly, a hardly perceptible weave into the wind, opposite rudder being given the moment the plane just begins to turn, will prolong the glide and give the nearest thing to a dead straight flight. The keying should only produce a swaying of the wings, hardly a turn. The tail drops slightly, increasing the angle of incidence of the wing, and the speed drops. During a hot summer day I succeeded in holding a plane up with cut motor for over ten minutes, only bringing it down by spinning it. This plane had a wing loading of 12 ounces per square foot. It will be appreciated that a R.C. glider, correctly manoeuvred, could be kept up indefinitely.

Combined rudder and engine speed control bring us into the class of scale flying. The manœuvres just described can be done with half or full engine speeds. At half engine speeds we have nearly flat turns and little stalling tendency when going into opposite rudder. If the retarded engine speed is arranged to give a loss of height, then one can actually touch down with engine running and taxi up to the operator, or after taxiing open up again to a spectacular take-off.

I am loth to describe manœuvres with either multiple sequence controls or any type of advanced intergear. These are hardly in the model airplane class, also I know of no example up to date of a "flying" plane with more than two controls. The photographs of large model planes capable of doing everything, which we have seen in the past year or so, do not seem to have fulfilled their promises. Those who will make a name in R.C. flying are those who are prepared to walk before running, and spend a long time walking.

There is no great difficulty in manœuvring boats by R.C. The turns are comparatively slow and any mistake does not lead to disaster. However, with only a rudder control it requires quite a great deal of practise to accurately estimate the turning circle of your model. Set yourself the task of approaching the shore at right angles and then turning to come dead alongside. You will be surprised at the amount of times you hit the bank or miss by yards. Having mastered this, practise turning around a stake or any floating object about 100 feet out. Distance over water is very deceptive, and if aiming at an object, approach it in line with you, either away or towards you. Boats with engine stop, reverse or half-speed controls, require a knowledge of how long their movement persists until they stop or reverse. Also their steering qualities will require a great amount of practice to master. Whereas with electric motor propelled boats, one can go directly into reverse (the motor will reverse at once even though the boat is still moving forward), with land models, due to the wheel grip, the motor will still be rotating forward even with the current reversed. This applies practically a short circuit to the motive battery and a very heavy current flows in the entire circuit. Even if wiring will stand up to it, relay contacts and motor commutator and brushes will suffer. Therefore arrange for a half-speed and stop position before reverse and then on the other side a half reverse before full. The opposite half-speed positions will act as a brake and limiting resistors in the half-speed positions should be chosen to permit only a safe current flow at the change over.

Better safe than sorry! Testing of equipment before each flight will do much to ensure that whatever else may happen the model is receiving and acting upon signals sent out. Illustration shows members of the Aeromodeller *Research Group performing this desirable safety precaution.*



The attractive Telecommander flown by Wallace of Barnes in the first British National Radio Control Event staged at the 1949 Nationals at Fairlop. Fitted with E.C.C. equipment, and a Wildcat 49 engine, the model was placed seventh.

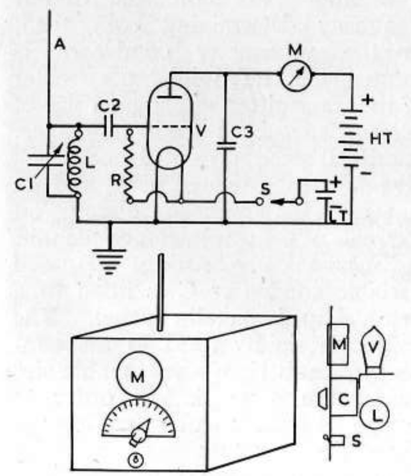
CHAPTER XIII

Simple Absorption Wavemeter—Simple Field Strength Meter.

Field Strength Meter

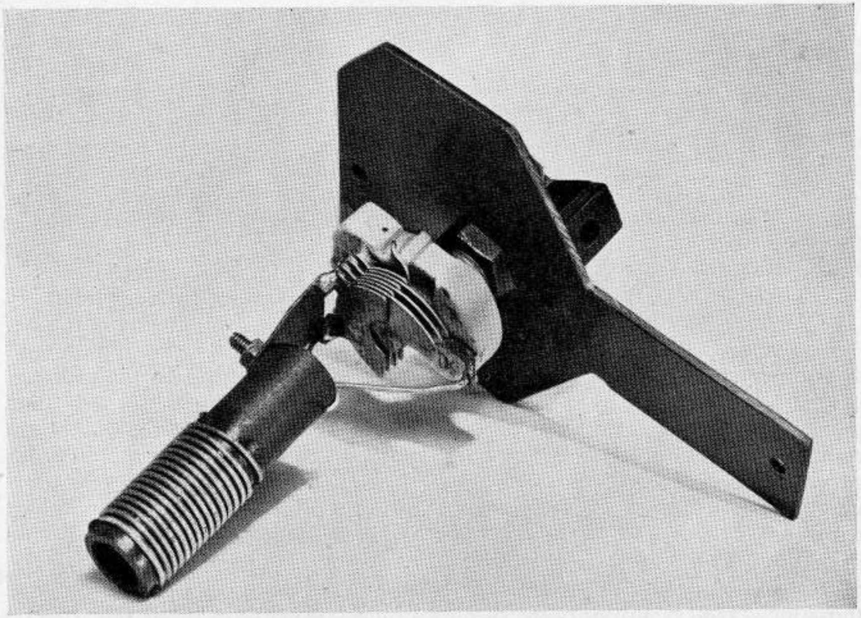
A CALIBRATED field strength meter is not only a means of checking the relative strengths of transmitters, but a better method of calibration than by absorption meter. It is vital to check the actual radiation of your transmitter in order to obtain the optimum by varying aerial lengths, aerial coil couplings, grid leak values, etc. But in making relative tests, the positions of transmitter and F.S.M. must be the same. That is, not only the same distance apart, but the same position relative to adjacent structures and earth conditions.

It will be noticed that when you remove your hand from the tuning knob, the meter reading will change, therefore, note the readings from the same position every time, preferably from a few feet away from the F.S.M. The meter rises on switching on, and drops when tuned in to the radiated carrier of the transmitter. Rotate the knob slowly past the minimum position and then back again in order to accurately position it. Assemble all components on an aluminium panel which will be the front of the case. A small bracket fixed to the tuning condenser holds the XP valve holder. The dural tube aerial can be pushed on to a tight fitting plug soldered direct to the fixed vanes of the condenser. All wiring except for battery leads should be 18 s.w.g. tinned copper, fitted rigid, and the shortest possible connections. In



R. 2 MEG Ω
C1. 50 PF VARIABLE
C2. 100 PF CERAMIC
C3. ·001 M.F.D
L. 1" DIA 1" LONG 10 TURNS
20 SWG WELL SPACED
A. 10" DURAL TUBE 3/16" DIA
S. ON-OFF SWITCH
M. MILLIAMPERE METER APPROX
2 MA FULL SCALE
V. HIVAC XP 1·5
LT. U2 CELL
H.T. B 122 22½ V

Fig. 70. Circuit and layout of Field Strength Meter. Good mechanical layout is more important than component values.

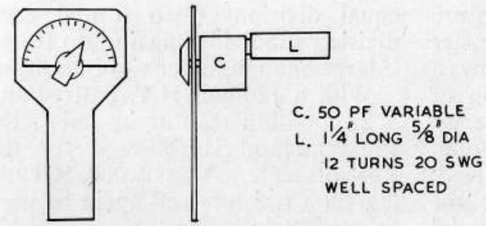


Simple portable absorption wavemeter for rough check of transmitter frequency.

order to maintain accuracy of calibration, components and wiring must be perfectly rigid. Batteries should be held in position at the back of the case by straps or in pockets. Battery leads should be short and cabled. Once calibrated, neither aerial length or valve should be changed. If a valve is replaced it will be necessary to recalibrate. If a calibration of only the allocated R.C. spot frequency is required, it can be done from a manufactured transmitter of reputable make, by the normal method of tuning the F.S.M. to the lowest dip at a distance from the transmitter and then marking the scale. All measurements should be made at a distance which gives only a small, well-defined dip. With a normal one to $1\frac{1}{2}$-watt transmitter this will be in the region of 30 feet.

Simple Absorption Wavemeter

A rough check of frequency can be made with a tuned circuit consisting of coil and condenser in parallel. If the coil is held in the field of the transmitter tank coil (the output frequency determining coil) then, as the wavemeter condenser is rotated, the H.T. milliampere meter of the transmitter will show a rise of current when both are in resonance. A critical separation of the coils will give a sharply defined peak, and we can read the frequency directly off the scale of the wavemeter condenser. A mechanically strong airspaced variable condenser C is fitted to a brush-shaped paxolin panel. The coil L is rigidly fixed to the condenser, knob K of a reasonable size covers the scale S. In order to ensure accuracy after calibration the entire structure must be quite rigid, any bending of coil or condenser must be avoided, a case should be made to protect it when

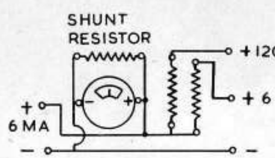


The simply made absorption wavemeter shown diagramatically.

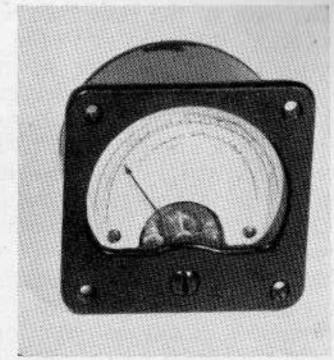
not in use. Calibration can be done by any radio engineer or amateur possessing an accurate signal generator or communication receiver which covers the 27 M/C band.

Simple Test Meter

The only measuring instruments we require is a voltmeter with which to test our batteries, and a milliampere meter to check receiver current flow or to use as a tuning indicator. One meter can be used to cover all of our required ranges. A 0–6-volt scale for L.T. and G.B., 0–120-volt scale for H.T. and 0–5 M/A scale for the receiver current change. With quite reasonable accuracy we can construct and calibrate one ourselves from an inexpensive ex-Services meter. The meter itself must be a "moving coil" type. This is usually recognisable by an evenly divided scale. It is quite immaterial for what the meter was originally calibrated, it might be marked for volts or amperes. The movement itself must be capable of at least a 6 M/A full scale movement, preferably lower. In order to test



Circuit of shunt and series resistances for a general test meter.



Ex-services meter re-calibrated and adapted for use as a test meter.

for this, take the meter out of its case and carefully take off the scale. All series or shunt resistances inside the meter should be removed, and wires from the two terminals should lead direct to the moving coil via the hairsprings. To test for full-scale deflection current a $1\frac{1}{2}$-volt cell (half pen cell) is connected to the terminals in *series* with a 1,500-ohm resistor. By Ohm's law this resistor will pass 1 M/A. The angular movement of the meter needle is noted, and the full-scale deflection is worked out. 1/6-scale movement = 6 M/A full scale, $\frac{1}{2}$-scale movement = 3 M/A full scale, etc. Fitting a shunt (parallel) resistance to the terminals will bring the needle down to a 1/6-scale position. The value of shunt resistor is according to the type of meter and its coil resistance—it will be between 10 and 100 ohms. It is best to procure some approximately 36 s.w.g. resistance wire and connect about one yard across the meter terminals. Reduce or increase the wire length until a 1/6-scale movement is obtained. Of course with the 1,500-ohm resistor still in series with the $1\frac{1}{2}$-volt cell. Then carefully wind the wire spaced upon a piece of $\frac{1}{4}$ dowling or paper tube.

The ends of the resistance wire are soldered to tags on the meter terminals. Our meter has now a fundamental full-scale deflection of 6 M/A. For our six-volt scale we shall now require a 1,000-ohm resistor in series with the meter lead, and a 20,000-ohm resistor for the 120-volt scale. As commercial resistors have high tolerances, it is best to calibrate in the following manner. For the 6-volt range, connect a 6-volt battery (four pen cells) in series with an 800-ohm resistor to the meter, and then add resistors in series until a full-scale pointer movement is obtained. Two 100, two 50, and two 20-ohm resistors should between them enable you to find a correct total value. The scale can now be divided into equal divisions 0 to 6 and each division subdivided again into tenths if large enough, otherwise into fifths.

With a 120-volt H.T. battery and a 22,000-ohm resistor in series, the same method is followed for the 120-volt scale. A few 1,000, 500 and 200-ohm resistors will again be used to accurately calibrate.

The meter should be fitted into a case and terminals fitted and wired up as Fig. 70. The negative terminal is common to both volt ranges and the milliampere range. The shunt resistor is permanently in circuit, and the voltage series resistors only in their respective circuits. A piece of stiff white card stuck over the original scale is used for the new markings.

Perfectly-built slabsider, silk covered, seen at 1949 Nationals. These large planes with roomy fuselage are very suitable for experimental work. Radio and motors can be easily changed without spoiling the appearance of the plane.

CHAPTER XIV

FUTURE OF RADIO CONTROL

Tendency of design—Flights of fantasy.

Future of Radio Control

NOBODY but a politician would lay down fast rules for the future, but with the knowledge of the facts a fairly accurate forecast can be given for a subject of technical nature. A certain human element however creeps in. The trade, with whom, after all, final development rests, will obviously try to cater for the great majority. And unfortunately the majority of those taking up a hobby drop it after a short time, either they lose interest, or, they get married. But in order to cater for these, the reasonably cheap, simple R.C. equipment will be the first consideration of the manufacturers. This is as it should be, providing however that constant research is carried on, and also that specialised equipment and components are made available for the minority. After all, these serious hobbyists are the advertisement for the trade, and their efforts more than expensive advertising, bring new buyers into the market.

Now whither our two trends of design ? Taking the simple equipment first: The thyratron will reign supreme for a great number of years, mainly due to its simple associated circuit. Price reductions will come only with quantities, and the subsequent possibility of mass production tooling for panels, escapements, etc. Do not for the moment expect that the escapement for example should be pressed out like a cheap toy. Here especially, engineering perfection should be aimed at ; good bearings, for example, are an absolute necessity. Receiver weight, which even now can only be pared by fractions of ounces, is mainly determined by the batteries, and will not materially change from the 7½ ounce average. Frequency allocation is in the hands of the G.P.O. here, and the equivalent ministry of other countries. But however much we like to believe in the perverse inhumanity of government departments, they do after all slowly but surely sift the evidence and come to the correct conclusion. Therefore I expect that the frequency for the simple receivers will remain for some time at 27 M/C, perhaps rising to the 60 M/C region. This frequency has the advantage of shorter transmitter aerials, which in turn will make for really portable equipment. After all, our present large transmitter cases are mainly a support for the present 8½ feet aerials. To go materially higher than 60 M/C would bring in various difficulties, valves, circuit stability, etc., and we are still talking of the cheap, mass-produced article. There is a remote possibility of U.H.F. equipment being produced in a simple and cheap form, but here without increased transmitter power, range

F. Borders in thoughtful mood with his eleven-foot wingspan scale Dakota. Steering is to be by variation of engine speeds. Automatic variable pitch props will feather or even go negative at the low speed. It is intended to control the motors by two separate receivers on different frequencies.

will be sacrificed, also the present thyratron is not usable at 465 M/C. You will note that I have said ''the present thyratron'', but there is no indication that the idea of a 465 M/C thyratron is even thought of at the moment.

Now to the specialist: although he also will begin with a one operation job, he will stage by stage advance to multiple controls. Here the boat and plane men will divide. The necessity for lightness and absolute reliability will bring the multi-channel receiver, tuned reeds in my opinion, to a state of perfection. This method has the advantage that even with present-day available valves it can be used beyond the 465 M/C band. Transmitters will remain non-portable and of a reasonable power, mainly due to the greater expense of multi-operational planes and receivers, and a range safety margin of several hundred percent. is advisable. Methods of operating controls will be mainly a matter for the individual—widely differing principles will be seen. But even the expert will remain true to the escapement method in some form or the other, for some time to come. We shall find the beginners alongside the experts using a simple thyratron with boats. The more advanced following the receiver with multiple sequence systems. But even here the multi-channel systems may encroach

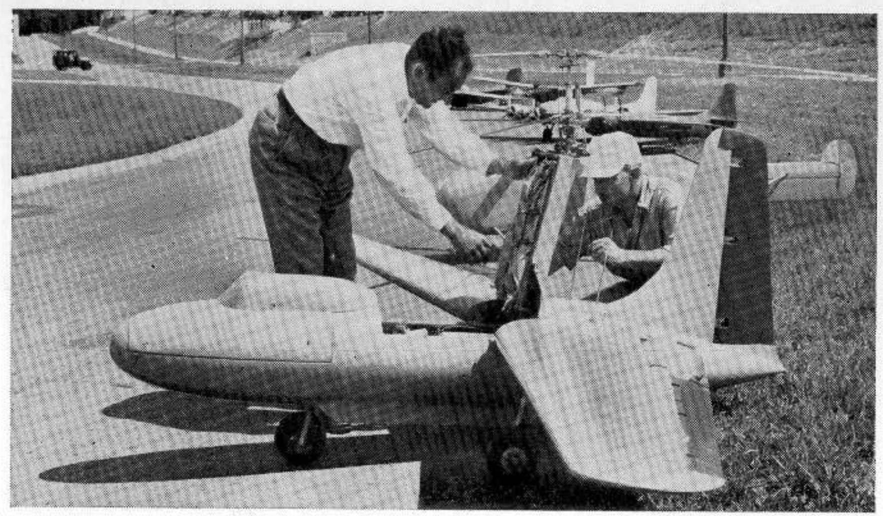
and finally lead the field. Here, especially, the U.H.F. band will hold sway. Range of more than a couple of hundred yards is not quite so necessary and the slower movement can be followed by a directional U.H.F. aerial on a camera-sized transmitter.

We shall undoubtedly also see the super plane, a scaled down job complete with all the controls of the real one, and even reacting like it. But I still maintain that it will not be a model in the hobbyists sense. Time and money would be required in large lumps and it would either be the ''piece de resistance'' of a manufacturer, or the combined efforts of the members of a club or association.

Whichever the case, I think that the majority of its time would be spent in a glass case and its life in the air would be very rare.

Let us for the moment imagine that we could knock up such a plane ourselves alone. The possibilities are immense, not only could we operate it from pilot's ''cockpit'' on the ground, but there is no reason why a small transmitter in the plane itself could not radiate intelligence back to us again, and instruments in our ground-based cockpits would give us direction, elevation, airspeed, engine revs, and even fuel level. This is not exactly a dream; I have in my mind's eye all of the details required. 16 feet wingspread, etc., etc. . . . down to even the colour scheme. Spend that drowsy winter evening in front of the fire with pencil and paper and see what you can do.

This ambitious model designed and produced by the American Dynamic Model Unit under the direction of Captain A. J. Stolzenberger shows the high importance attached to radio control by the American authorities. Span is 13½ feet, weight 131 lbs., and a 24-ft. safety parachute ensures its safe return to earth. Two separate receivers are installed, working on 68 and 73 megacycles respectively, and each with five channel control. Data gained by the use of this model was borne out by identical characteristics predicted for a full-size project to the extent of a fatal spin without recovery.



APPENDIX I

GLOSSARY OF TERMS

A

A.C. Alternating current.
Accumulator. Rechargeable voltage producing cell.
Aerial. (Transmitter) energy radiator; (Receiver) energy collector.
Ampere. Unit of current.
Amperemeter. Instrument to measure current.
Anode. Collector plate of valve.
Armature. In electromagnetic gear, the moving or rotating portion.

B

Battery. Primary or secondary cells connected in series.

C

Carrier. Fundamental wave radiated by transmitter.
Cathode. Indirectly heated electron emitter of valve.
Choke. Coil (iron or air-cored) which opposes A.C. current flow.
Condenser. Permits passage of A.C., opposes flow of D.C. In conjunction with coil, forms tuned circuit.
Conductivity. Ease with which current flows in conductor.
Conductor. Material permitting easy flow of current.
Converter. Vibrator or rotary, to step up low voltage D.C. sources.
Crystal. A section of a Rochelle salt crystal which, when ground to definite dimensions, will react as a tuned circuit of great frequency stability.

D

D.C. Direct current.
Detector. Valve or crystal used to rectify an H.F. signal.
Dipole aerial. Two-arm aerial requiring no earth connection.

E

Earth. (1) Used in conjunction with aerial to increase radiation.
(2) Term used to denote common wiring or metallic chassis of receiver and transmitter.
Electron. Fundamental "portion" of electricity.
Escapement. Method of releasing a mechanical energy with an electro-magnet.

F

Farad. Unit of capacity of a condenser.
Field. Sphere of radiation of a coil carrying an A.C. (L.F. or H.F.) current, or of a radiator of H.F. (aerial).
Field Strength Meter. Instrument to determine relative radiation of transmitter.
Filament. Heater of, or electron emitter of valve.
Frequency. Quantity per second an A.C. current flows a full cycle.

G

G.B. Grid bias voltage source or battery.
Grid. Control electrode of valve.

H

H.F. High frequency above 100 K/C.
H.T. High tension voltage source or battery.
Henry. Unit of inductance of coil.

I

Inductance. Quality of a coil to oppose an A.C. current.
Insulator. Non-conducting materials.
Intergear. Electro-mechanical equipment used to translate and sort out received signal "intelligence".

K

K/C, Kilocycle. 1,000 cycles (per second).

L

L.F. Low frequency, under 15,000 cycles per second.
L.T. Low tension voltage source or battery.
Lecher Wires. Method of measuring U.H.F. waves.
Limit Switch. To restrict motor-driven movement by switching off motor.

M

Megacycle. 1,000,000 cycles per second.
Microfarad. 1/1,000,000 of a Farad.
Modulation. A secondary signal impressed upon an H.F. carrier.
Monitor. Instrument to give visual or audible indication of transmitted wave. Can be frequency calibrated. See also Field Strength Meter.

O

Ohm. Unit of resistance.
Oscillator. Producer of H.F. or L.F. oscillations.

P

Parallel Lines. Tuning circuit for U.H.F.
Primary Cell. Voltage producing cell (unchargeable).

Potentiometer. Resistor with fixed or variable tapping.

R

Rectifier. Permits passage of current in one direction only.
Relay. Electro-magnetically operated make and break switch.
Resistance. Inverse of conductivity.
Resistor. Fixed value resistance in commercial form.

S

Secondary Cell. See Accumulator.
Selectivity. Quality of a tuned circuit or vibrating reed to reject frequencies other than its natural.
Selector Switch. Electro-magnetically operated stud switch.
Servo. General term for electro-mechanical gear to operate controls.
Solenoid. Electromagnetic coil.

T

Thyratron. Gas-filled relay valve.
Transformer. To step up or down A.C. voltage.
Transient. Short-peaked interference impulse.
Transmitter. Producer and radiator of H.F. or U.H.F. waves.

U

U.H.F. Ultra high frequencies over 100 M/C.

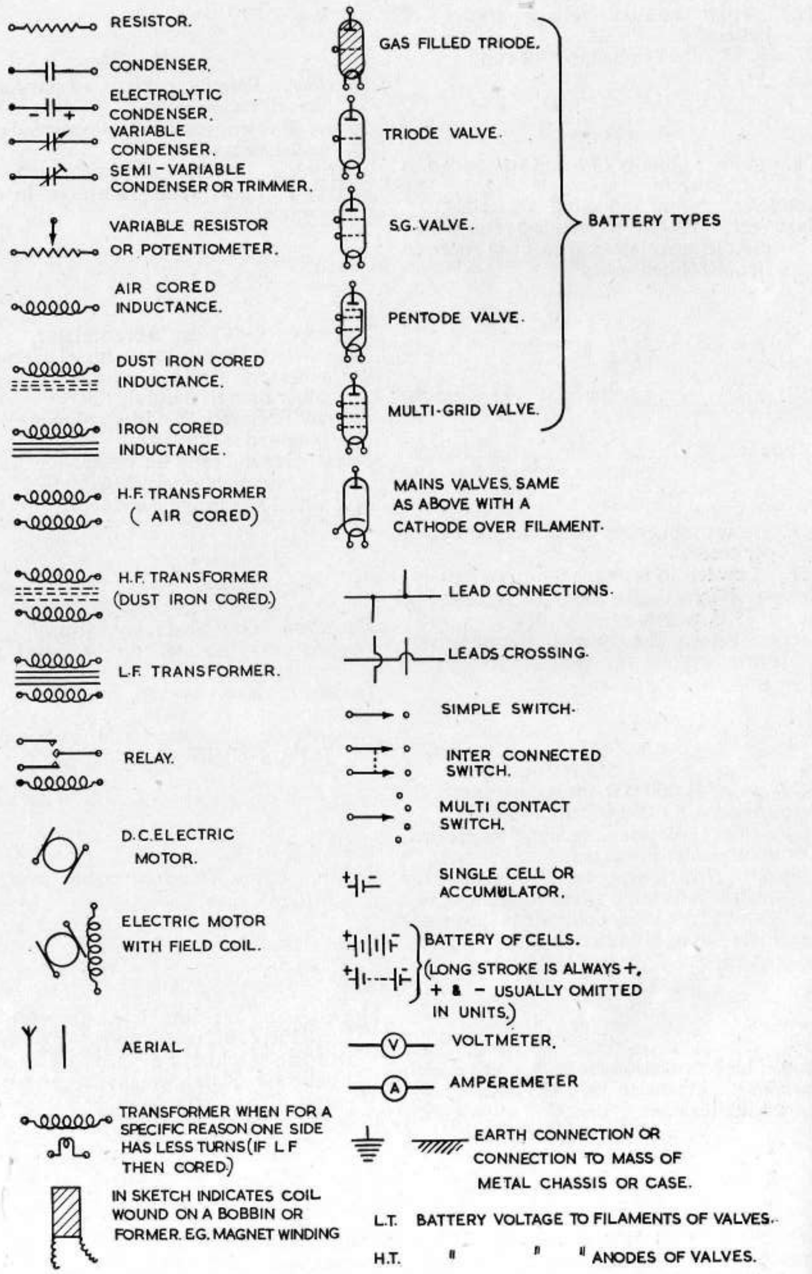
V

Valve. Used as amplifier, detector, or producer of oscillations. Consisting of an emitter of electrons and a collector plate, usually separated by one or more control grids.
Volt. Unit of electrical pressure.

W

Watt. Unit of power.
Wavemeter. Instrument to check and calibrate radiated wave frequency.

APPENDIX II. CONVENTIONAL SIGNS.



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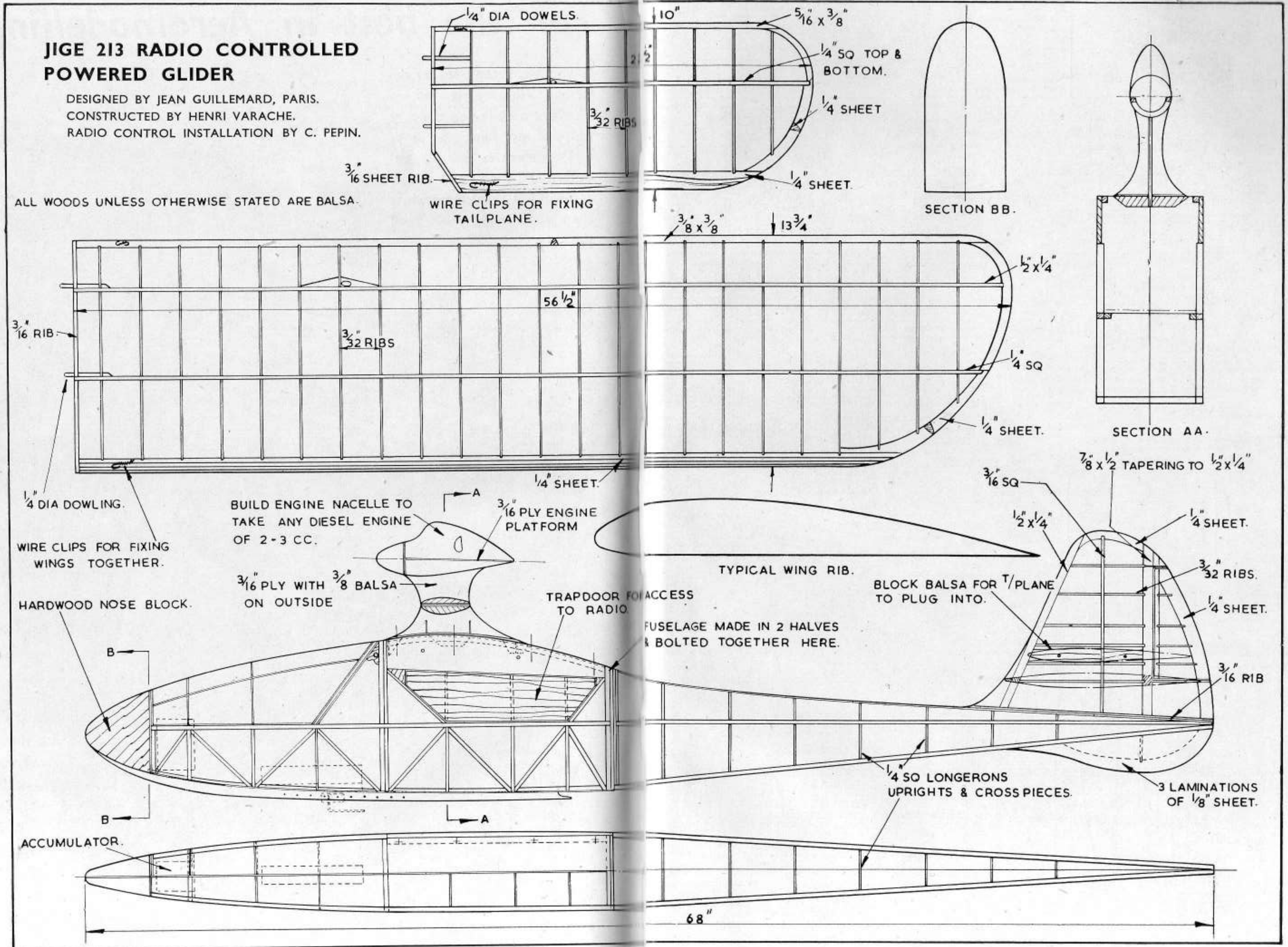
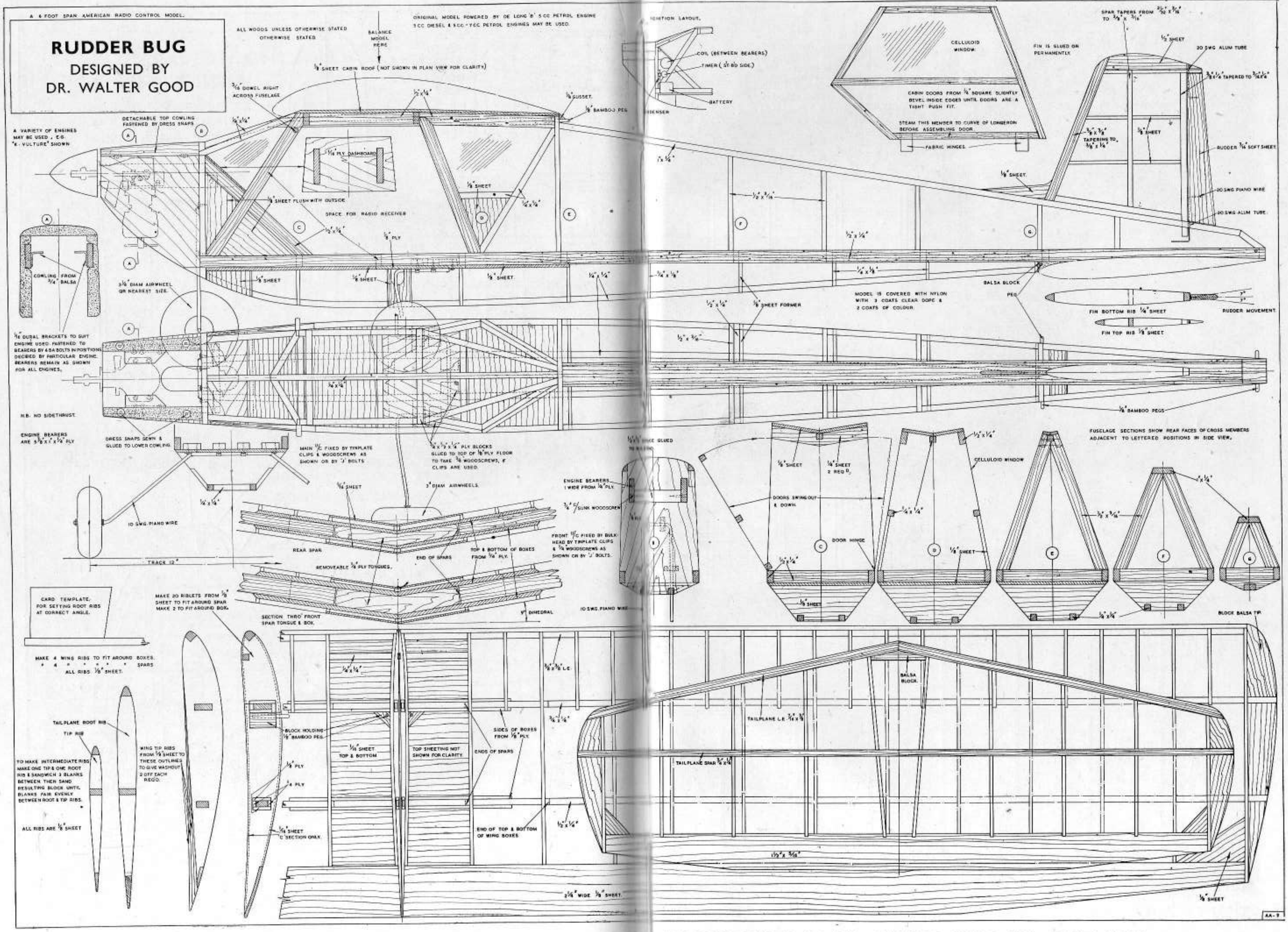
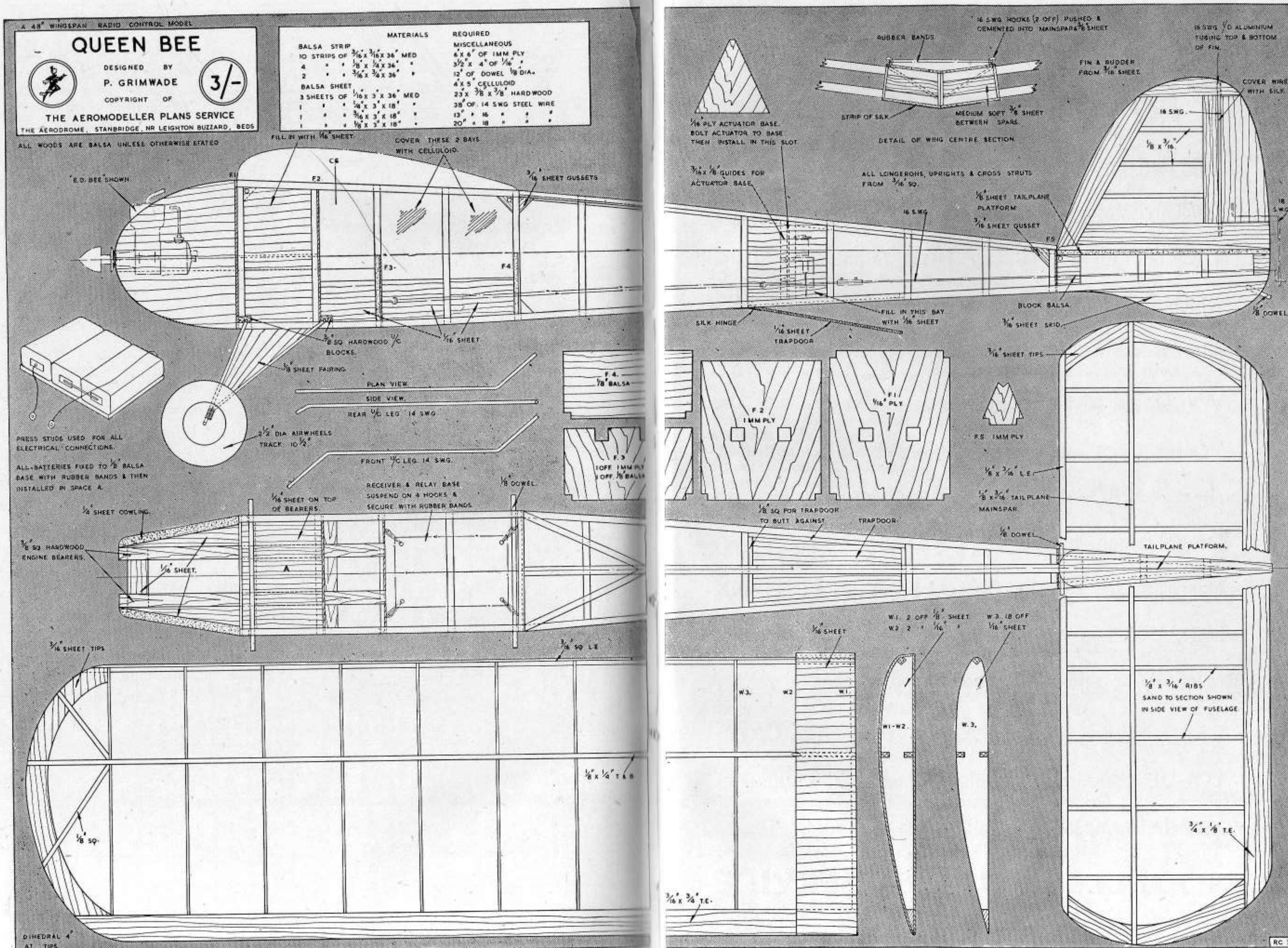

JIGE 213 RADIO CONTROLLED POWERED GLIDER
DESIGNED BY JEAN GUILLEMARD, PARIS.
CONSTRUCTED BY HENRI VARACHE.
RADIO CONTROL INSTALLATION BY C. PEPIN.
ALL WOODS UNLESS OTHERWISE STATED ARE BALSA.
1/4" DIA DOWELS.
10"
5/16" X 3/8"
2 1/2"
1/4" SQ TOP & BOTTOM.
3/32" RIBS
1/4" SHEET
3/16" SHEET RIB.
1/4" SHEET.
WIRE CLIPS FOR FIXING TAILPLANE.
SECTION BB.
SECTION AA.
3/8" X 3/8"
13 3/4"
1/2" X 1/4"
56 1/2"
3/16" RIB
3/32" RIBS
1/4" SQ
1/4" SHEET.
1/4" SHEET.
1/4" DIA DOWLING.
WIRE CLIPS FOR FIXING WINGS TOGETHER.
7/8" X 1/2" TAPERING TO 1/2" X 1/4"
3/16" SQ
1/2" X 1/4"
1/4" SHEET.
BUILD ENGINE NACELLE TO TAKE ANY DIESEL ENGINE OF 2-3 CC.
A
3/16" PLY ENGINE PLATFORM
TYPICAL WING RIB.
3/32" RIBS.
3/16" PLY WITH 3/8" BALSA ON OUTSIDE
BLOCK BALSA FOR T/PLANE TO PLUG INTO.
1/4" SHEET.
HARDWOOD NOSE BLOCK.
TRAPDOOR FOR ACCESS TO RADIO.
FUSELAGE MADE IN 2 HALVES & BOLTED TOGETHER HERE.
B
3/16" RIB
1/4" SQ LONGERONS UPRIGHTS & CROSS PIECES.
3 LAMINATIONS OF 1/8" SHEET.
B
A
ACCUMULATOR.
68"


A 6 FOOT SPAN AMERICAN RADIO CONTROL MODEL.
RUDDER BUG
DESIGNED BY
DR. WALTER GOOD
ALL WOODS UNLESS OTHERWISE STATED
BALANCE MODEL HERE
ORIGINAL MODEL POWERED BY DE LONG 'B' 5 CC PETROL ENGINE
IGNITION LAYOUT.
COIL (BETWEEN BEARERS)
BATTERY
CELLULOID WINDOW
FIN IS GLUED ON PERMANENTLY
DETACHABLE TOP COWLING FASTENED BY DRESS SNAPS
SPACE FOR RADIO RECEIVER
CABIN DOORS FROM 1/8 SQUARE SLIGHTLY BEVEL INSIDE EDGES UNTIL DOORS ARE A TIGHT PUSH FIT.
STEAM THIS MEMBER TO CURVE OF LONGERON BEFORE ASSEMBLING DOOR.
FABRIC HINGES.
RUDDER MOVEMENT
BALSA BLOCK
MODEL IS COVERED WITH NYLON WITH 3 COATS CLEAR DOPE & 2 COATS OF COLOUR.
FIN BOTTOM RIB 1/4" SHEET
FIN TOP RIB 1/8" SHEET
N.B. NO SIDETHRUST.
DRESS SNAPS SEWN & GLUED TO LOWER COWLING.
FUSELAGE SECTIONS SHOW REAR FACES OF CROSS MEMBERS ADJACENT TO LETTERED POSITIONS IN SIDE VIEW.
CELLULOID WINDOW
DOORS SWING OUT & DOWN.
DOOR HINGE
10 SWG PIANO WIRE
TRACK 12"
REAR SPAR
END OF SPARS
REMOVEABLE 1/8" PLY TONGUES.
CARD TEMPLATE FOR SETTING ROOT RIBS AT CORRECT ANGLE.
SECTION THRO' FRONT SPAR TONGUE & BOX.
BLOCK BALSA TIP.
BALSA BLOCK.
TAILPLANE ROOT RIB
TIP RIB
ALL RIBS ARE 1/8" SHEET
TOP SHEETING NOT SHOWN FOR CLARITY.
ENDS OF SPARS
END OF TOP & BOTTOM OF WING BOXES
AA-9



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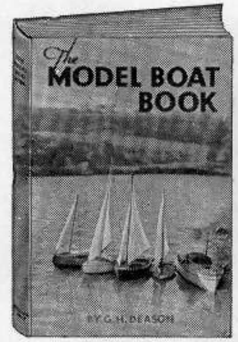

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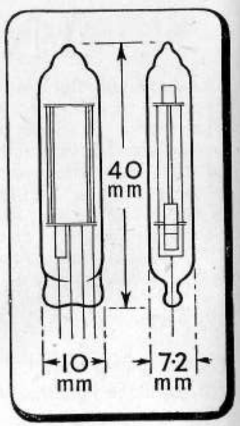
Anode Voltage ...	*45v*
Max. Anode Current ...	*2·5mA*
Weight	*4 grams*



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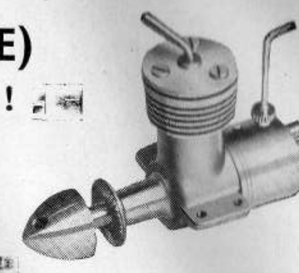

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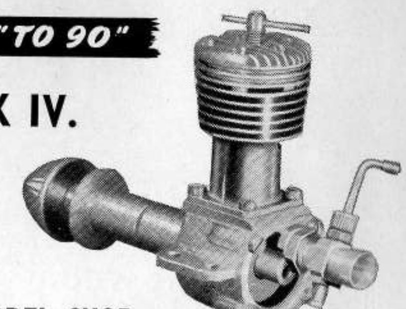

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