THE RADAR GROUND CONTROL INTERCEPTION SYSTEM OF FIGHTER COMMAND, ROYAL AIR FROCE.

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(Report by Marconi's W.T. Co. in fulfilment of the Ministry of Supply Contract 6/WT/3645/CB.14a).

Summary.

A critical study has been made of the F.G.C.I. radar equipment, i.e. A.M.E.S. Types 7, 11, 13 and 14. Measurements taken on the various elements of the respective systems, i.e. transmitters, aerials, receivers and displays, have permitted assessment of the loss of performance attributable to a quality of component and circuit technique which is inferior to that of modern radio practice.

The functioning of the R.A.F. Station, Trimley Heath during the course of normal radar operations has been observed by our engineers. Test flights with Meteor and Mosquito aircraft have been made for the purpose of establishing the radar cover of the F.G.C.I. type station and for assessing the improvement in performance produced by certain experimental apparatus changes.

It is shown that the operational requirement for increased cover can be met by modification of the existing equipment. The possible modifications are reviewed in detail and an assessment made of the development effort that would be required to produce them. It is concluded, however, that in order to approximate to gapless cover it will be necessary to use two or more of the available systems simultaneously; a number of possible system arrangements are therefore presented, together with details of the combined cover which they would yield.

The problem of the presentation of the radar information in a multiple system is considered and two Combined Display Schemes are submitted for consideration. With this discussion is included a general specification of the Display Consoles and ancillary equipment that would be required.

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1. Introduction.

1.1 Terms of Reference.

The Ministry of Supply Contract 6/WT/3645/CB.14a calls for a Research Investigation of a number of ground radar stations known as A.M.E.S. Types 7, 11, 13 and 14 respectively.

1 In a D.C.D./M.O.S. letter to the Marconi W.T. Co. dated 25th 1948, under reference 7/WT/723/R.D.C.4 it was explained that the Air Ministry had formulated a modification programme designed to bring the performance of the G.C.I. station more nearly into lin

with current requirements. This programme was stated as follows :-

(i) Improvements to Control Radar Equipment.
Improve without fundamental re-design the performance of Type 7, Type 11 and Type 14 equipment so that jointly they will detect in an optical path a single aircraft of the dimensions and characteristics of a Meteor aircraft at a range of 150 miles and provide gapless cover up to 60,000 feet.

(ii) Combined Displays.
Develop a method whereby information from any two at any time of the following equipments, 1½ metre 50 cm. and 10 cm. can be combined on a common display.

(iii) Improvements to Height Finding Equipment.
Improve without fundamental re-design the performance of Type 13 equipment to determine heights of aircraft of the dimensions and characteristics of a Meteor aircraft at a range of 150 miles and at all heights above optical limitations up to 60,000 feet.

(iv) Increase size of Displays.
Increase size of displays to accord with increase in radar range.

3. In furtherance of this programme the Company were then asked to undertake an engineering study of the equipments concerned and to submit a report which would contain answers to the following questions in respect of each type of station :

" (a) How far can these stations be modified to meet these requirements?

(b) How should this be done (in engineering terms)?

(c) What performance should the modified station give?

(d) To execute the proposed modifications, is it necessary first to solve any physics, as opposed to engineering, problems?

(e) To execute the proposed modifications, is it necessary first to design and make available any new types of valve or component?

(f) How long should a well chosen contractor take to

(i) design the modifications.

(ii) modify a prototype station.

(iii) supply drawings, to WT.1000, of the modifications

and what would be a fair charge for such work (excluding valve and component design)?

(g) Compare the magnitude of the tasks of

(i) designing the modifications.

(ii) designing a new station or stations to meet the requirements as nearly as possible. "

1.2 In a later communication, 7/WT/723/R.D.C.4/A of 3rd September, 1948, the above terms of reference were qualified by the following :

"In amplification of our letter of the 25th May, we have been informed that the target date for the improvements to start going into service should be two years from a decision to go ahead. You should, however, consider the matter on a broader basis, and say in your report whether this is a reasonable time scale. Similarly a 30% improvement in performance is considered to be worth-while with the 150 miles/60,000 ft. figures, as the target to fully meet current needs. "

5. The time scale mentioned in this qualification is important and taken in conjunction with the conditions imposed in Air Ministry's item (i) i.e. "Improve without fundamental re-design etc." renders it imperative that the improvements shall be achieved by designs based on valves and components whose development is complete.

1.3 At the first meeting held at Thames House on September 15th the above terms of reference were confirmed. In addition, and arising out of a Survey Paper on the scope of the investigation submitted by the Company, certain points of detail were clarified, e.g. I.F.F. considerations. These points are set forth under paragraph 4 of the Minutes of the above meeting.

1.4 Collection of Technical and Operational Information.

Full use has been made of the relevant Air Publications loaned by D.C.D., and of the war-time files and reports supplied by Headquarters, Fighter Command and H.Q. No. 90 Group.

Visits have been made to the various Government Establishments, also to many industrial Research Laboratories and much useful and up-to-date information on components and techniques has been gained. These visits are listed in Appendix 6 and references to them are made at various points in the report. The main findings of this report, however, are based upon apparatus measurements and flight tests performed at the R.A.F. Station, Trimley Heath, also upon experimental work discharged in the Company's Research Laboratory, Great Baddow. In view of the period allotted for the contract, i.e. six months, it was clearly not expedient to work at a number of widely separated stations, particularly as they are closely similar to each other in technical detail, and the status of Trimley as the M.S.O.C. would appear to guarantee a level of efficiency and technical maintenance not inferior to that obtaining at the other operational stations. A visit to Wartling confirmed this point.

1.5 Form of the Report.

It has appeared best to present the report as a logical whole and not to deal with the questions raised in 1.1 in an unconnected manner, for certain of the questions are inter-dependent and the answer to any one question, if treated in an isolated manner, could only be conditional and might even be definitely misleading. It would be well to emphasise at the outset that there is not an unique solution to the cover problem as presented by Air Ministry. We are confident that many worthwhile improvements can definitely be achieved but the choice of proposals to be selected for development and incorporation can only be made by the Ministry itself. All our proposals represent possible modifications, but certain ones might not be expedient when referred to the Ministry's long term policy in this matter.

In compiling the report, therefore, we have first presented an appreciation of the present system (Sections 3 and 4) based upon experimental observations which are fully detailed in Appendices 1 - 4.

Section 5 describes the general nature of the apparatus improvements that could reasonably be developed and embodied in the G.C.I. station and therefore covers, in large measure,

the queries (a) (b) (d) and (e) of 1.1. The main points of the present report are contained in Sections 6 and 7. These Sections consider in some detail a number of possible groupings of the various improved equipments, also the associated display arrangements that would be required; they contain answers to questions (b) (c) and, to some extent (g). The remaining questions (f) and (g) are dealt with in Section 8.

2. Equipment and Operation : M.G.C.I. Station.

2.1 The G.C.I. Station.

The present M.G.C.I. station is a development of the 1942 F.G.C.I. station, which, in its turn, had evolved from the "Mobile" and "Intermediate Transportable" systems. The operational role of all these stations is primarily the same, viz. the close ground control of fighter aircraft through the medium of V.H.F./R.T. communication, based on knowledge of position and altitude of target and fighter gained from a 209 Mc/s. radar system.

The technical development of the 1942 - G.C.I. is largely covered by a number of papers submitted to the I.E.E. Radiolocation Convention of 1946 (Ref. 1.2.3); a brief description of the system is included for convenience of reference.

2.2 The 1942 - G.C.I. Station.

This was the first fixed location G.C.I. type station and comprised :

(a) Operations building.

(b) Radar well.

(c) Aerial, mounted over radar well.

The aerial (see fig. 2.2) consisted of four bays, eight stacks of centre-fed full-wave dipoles, and was equivalent to four separate aerials :-

Top array	4	stack,	at	a	mean	height	of 25'.
Middle array	2	"	"	"	"	"	$12\frac{1}{2}$'.
Middle & Bottom array	4	"	"	"	"	"	10'.
Bottom array	2	"	"	"	"	"	$7\frac{1}{2}$'.

Successive pulses of R.F. power were fed to these arrays in turn through the medium of the capacity switch. Common aerial technique was employed and the system always transmits and receives on the same aerial stack. Associated with the capacity switch rotor was the master waveform generator, which not only triggered the transmitter and provided "Sync." for the display time bases but also furnished the blanking waveforms that permitted the signals from two aerials only to be presented side by side on the A-scan display. This was for the purpose of height measurement.

The Radar well housed the transmitter and monitor receiver, Air Publication details as follows :-

Transmitter	T.3079.
P.r.f.	400/sec.
Pulse length	3 - 4 microsecs.
Valves	Pair of VT.98a, lecher tuned, grid - squegg/anode-squegg circuit.
Nominal Peak Power	80 K.W. (Ref. 3).
Feeders	330 ohms, balanced open wire, spark gap unit for common aerial working.

The returned echo pulse was passed via spark gap unit, balance-unbalance transformer, impedance matching unit to the Preamplifier (A,3175) and thence to the R.F. amplifier proper (Panel A) of the monitor receiver (R.3144). The I.F. output was passed through an underground coaxial to the distribution box in the Operations Building.

The Operations Building was designed to provide multiple interception control facilities as well as to permit the presentation of the general picture of aerial activity as derived from radar and Flying Control sources. The main Operations room contained the two plotting maps and Fighter tote. Overlooking this space were the cabins of the Chief Controller, and the supporting liaison officers, e.g. Movement Liaison, Searchlights etc. The organisation of the station centred on the Chief Controller; from the information displayed before him he was able to allocate targets to his Interception Controllers operating in the two interception cabins.

The incoming I.F. signal was fed to a Console Type 4 (Master Console). This unit provided I.F. amplification, detection, video amplification and fed the video signal to the various P.P.I. units (Consoles Type 5) together with Calibration, Sync., and certain blanking pulses. The Height or A-scan consoles (Type 6) were fed directly with the I.F. signal for vertical deflection but also derived "Sync", video for intensity modulation, calibration and blanking pulses from the Master Console. These consoles were present only in the interception cabins and were provided to permit the measurement of angle of elevation and hence the altitude of the aircraft. The Chief Controller and other officers overlooking the Operations room were provided with P.P.I. Consoles only; these were initially Type 5 units, but D.U.54's or D.U.70's were later sometimes employed for space reasons.

2.3 Performance of the 1942 - G.C.I.

The performance diagram of the 1942 - G.C.I. Station is shown in Fig. 2.3.1. This figure has been reproduced from the H.Q.F.C./ORS Memo. No. 17, dated 14/7/42. The cover is that which would be yielded by a station fitted with R.L.37 preamplifier and corresponds to a Station Constant (K) of 15,000 - a figure usually established for the centre of the first lobe. The cover envelope is drawn for a Signal/Noise ratio of unity; the cover represented would only be realised under the most favourable conditions of performance and aircraft aspect. A more realistic cover diagram would be that corresponding to a pick up Signal/Noise ratio of $^{3}/_{2}$ and this has been included in dotted line on the figure.

From an examination of the O.R.S. files, in particular O.R.S. 9/2/29, it is clear that this K-value was a very variable quantity and that stations could vary greatly in their average performance figure. Thus K values of 25,000 appear for occasional test runs, but the figure frequently falls as low as 6,000. The figure of 15,000 would appear to be a better than average performance; its variation with time at a given station is a point particularly to be noted.

The system was capable of yielding altitude measurements on aircraft within a range of approximately 60 miles. The height accuracy was very variable but from a war-time analysis by one of us (E.E.) a deviation of ± 10% was regarded as acceptable.

2.4 Later developments of the 1942 - G.C.I.

During 1944 it was operationally necessary to improve the low cover of certain of the G.C.I. stations. Two modifications were introduced :

(a) Doubling the aperture of the 25' aerial. This arrangement still obtains at Trimley and is shown in Fig. 2.2.1.

(b) Increased power : this was supposed to be achieved by increasing the voltage of the H.T. and bias supplies. It is no longer employed at Trimley, but is considered further in Section 3.

2.5 System additions to the 1942 - G.C.I. Station.

The 1942 - G.C.I. station was protected against equipment failure by providing a stand-by transmitter and by a multiplicity of spare panels capable of substitution in the various consoles Types 4, 5, 6 and the monitor receiver. There was no stand-by aerial nor even Panel A, but since the G.C.I. operations did not at first extend over 24 hours there appeared to be ample time to effect repairs. Consideration, however, was given to the provision of complete stand-by facilities, partly against the contingency of major breakdown but mainly to cope with the operational requirement of a change of frequency during conditions of jamming. The Type 19 system was intended for this latter purpose but never came into general service; the Type 11 (Fig. 2.5.1) was also employed on some occasions in this manner and is considered below. Provision for its installation was made at many stations in the shape of installation of all the necessary cables terminating at a hard - standing. The height finding counterpart of Type 11, namely Type 20 or DMH, did not come into general service.

The major system additions to the 1942 - G.C.I. were made in 1943 and consisted of the Type 14 - 10 cm. plan position equipment and the Type 13 - 10 cm. height finder.

These were fixed equipments and are shown at Figs. 2.5.2 and 2.5.3 respectively. Their primary operational role at installation was to cope with window-jamming and to provide low interception cover.

2.6 Type 11 System.

The Type 11 system in all its Marks has been essentially a mobile, general purpose equipment. In its most useful operational form to date, viz. Type 11 Mark 4, the equipment possessed the features of variable frequency (500 - 600 Mc/s), narrow horizontal beam width ($4\frac{1}{2}^{o}$), tiltable beam, comparatively high power (100 K.W.; 2 μ secs. - two CV.92 triodes in push-pull with anode modulation). A large measure of immunity from jamming was therefore enjoyed, which property, coupled with a free space range of 45 miles, rendered the system quite useful. It might have been profitable to consider the significance of this equipment to the present G.C.I. but since the Type 11 Mark 7 was approaching the production stage, it was ruled by Air Ministry that only this later Mark should be considered.

The Type 11 Mark 7 possesses the M.T.I. facility which not only reduces Permanent Echo difficulties but should also help materially to combat window jamming. It will be seen later that the Mark 7 also lends itself to modification to a high powered system. This equipment has not yet been field tested so that no indication of previous performance is possible; a technical appreciation is reserved for Section 3, and the probable cover is discussed, based upon the existing Mark 4 aerial system. Further modifications are considered in Sections 5 and 6.

2.7 Types 14 and 13 Systems.

The 1943 additions to the G.C.I. stations comprised a Type 14 Mark 3 and a Type 13 Mark 2, these two latter systems together constituting a Fixed Type 21 installation. The units at present situated at Trimley Heath are shown at Figs. 2.5.2 and 2.5.3. Both systems are based on the naval 10 cm. equipment - Type 277, which is housed in the cabin and rotates with the aerial. This cabin contains the 180V. 500~ rotary convertor, the 9R transmitter and its associated 3 AT modulator,

the SE2 gas switch unit feeding the crystal mixer, preamplifier and L.25 Indicator Unit (Type 53 Monitor) and I.F. amplifier. The intermediate frequency signal at 45 Mc/s. is fed over a coaxial to the Operations Building.

The Type 14 signals have been displayed on various types of P.P.I. consoles but on first visiting Trimley in September last, they were being presented on D.U.54's in the close control cabins, on a Type 16 console in the main Operations Room, and on a D.U.70 in the Chief Controller's cabin. The Type 13 elevation scan display was presented on one Type 15 console only; this was situated in the main Operations Room, immediately beside the Type 16 display of the Type 14 signals. The D.U.5 unit thus formed constituted the only Centimetric height finding system the station possessed. Located at this same point and operated by the P.P.I. reader was the Control Unit Type 154. This unit permits the slow turning of the Type 13 array until its line of shoot passes through a target selected from the P.P.I., the position of correspondence being noted by the condition that a radial beam of light - the 'linolite' whose orientation is selsyn controlled from the control unit - passes through the selected target. This process of Type 13 orientation control is termed "azication" and is considered more fully later. Due to frequent failure of the Type 14 gear at Trimley the Type 7 signals were apparently often displayed on the D.U.5 unit and azication performed on these much larger paints; the results were not always very satisfactory. Azimuthal turning of both Type 14 and Type 13 aerials was achieved by use of the Turning Gear Type 3; this unit was $1\frac{1}{2}$ h.p. only and at best would only rotate the Type 14 at 4 r.p.m. Lashing the aerial was necessary in high wind and failure of the turning gear has been, unfortunately, a common occurrence. The Type 13 was tilted in elevation between -1° and 20° at the rate of six cycles per minute by a $\frac{1}{8}$ h.p. motor via a crank drive. Incorporated in the rocking arrangement was a magslip with 3 Kc/s tone fed into one of the stator windings; the voltage picked up from the rotor varied as the sine of the angle of tilt and after rectification provided the run down voltage for the vertical time base of the Type 15 console.

All Marks of Types 14 and 13 equipment, in common with other systems employing the Type 277, possess the features :-

Frequency	-	3000 Mc/sec (approx.)	;	Wavelength	- 10 cm.
P.r.f.	-	500 c/sec	;	Pulse width	- 0.6 μ sec (narrow) 1.9 μ sec (wide)
Nominal Peak Power	-	500 KW	;	Magnetron	- CV.76
T.R. cell and T.B. cell	-	CV.83 or CV.193	;	Local Oscillator	- CV.35.
			;	Modulator	- CV.12.
Crystal	-	CV.101	;		

2.8 Type 14 : Aerial and Performance.

The aerial of the fixed Type 14 Mark 3 consisted of two double cheeses (24' x 3'6") which yielded a beam of $3/4^{\circ}$ width in the horizontal plane.

In order to increase the vertical coverage, the energy could be fed to either the upper or lower aerial; between these two aerial elements was a fixed angle of $3\frac{1}{2}^{\circ}$ while the system as a whole was capable of being adjusted to a preset elevation between 0° and 10°. In practice these facilities were hardly ever employed. The upper aerial itself soon fell into disuse, partly because of attenuation trouble with the wave guide switch, but mainly because this switch could obviously be controlled by one officer only and arbitrary use of the switch proved rather bewildering to controllers using the parallel Type 14 displays.

It has already been ruled that the Type 14 Mark 3 will be replaced by the Type 14 Mark 6 and therefore no tests were conducted on the Trimley Mark 3 channel.

The Type 14 Mark 6 in its mobile form is shown at Fig. 2.8.1 but for fixed station application the unit is to be mounted on the concrete plinth at present occupied by the Mark 3. The aerial is of rod construction in the form of a parabolic cylinder and is fed from a slotted wave guide. Full details of the aerial, and of the apparatus checks and results of test flights conducted with such a mobile system at Trimley, are presented in Appendix 2. A maximum range of 87 n.m. (100 statute miles) was claimed by T.R.E. for this

equipment, as is shown in the performance diagram of Fig. 2.8.2 taken from T.R.E. memo. E.3./3/GHRS (1946?). The same diagram is also contained in A.P. 2899F.

2.9 Type 13 : Aerial and Performance.

The centimetric height finding equipment as installed on the F.G.C.I. stations was the Type 13 Mark 2. In this system the aerial consisted of a divided parabolic cheese of overall aperture 20' x 3'1", which was tilted in elevation between the angles of -1° and 20° at the rate of six cycles per ~~second~~ MINUTE as noted above. In later Marks the aerial was changed to a parabolic cylinder of 20' x 5'6" aperture the feed being a slotted guide - Fig. 2.9.1. The performances of these two equipments are quoted in A.P. 2899F as approximately 70 miles for the Mark 2 in its mobile version (Chapter 1 paragraph 18) but between 90 - 110 miles for the Mark 5 (Chapter 1 paragraph 18 and Chapter 2 paragraph 2). 110 miles appears to be too great an improvement to attribute to increased aerial gain alone. It is not known whether any other change of equipment was involved.

The experiments at Trimley have had to be conducted on the fixed Mark 2 system, since the new Mark 5 was still not functioning at the termination of the contract; details of the measured performance are contained in Appendix 2.

2.10 Recent modifications to the F.G.C.I. Station.

2.10.1 Extension of Function.

During the war years the F.G.C.I. station had a specialised and limited function; the few stations which remain operational, however, have a much greater scope and potential responsibility in air operations generally. While the commitments for Crew Training (both operators and maintenance personnel) and certain supervisory duries on Ground Signals Equipment are not inconsiderable and certainly reduce the effectiveness of the station by reason of the preoccupation of the senior technical staff, it is the assumption of many of the old "Sector Operations" duties that has produced the most obvious change in the character of the station. In addition, the presence of the Raid Reporting Crew has further increased the demand on the Station's accommodation and technical facilities. The

Fighter Command and 90 Group Stage IIa Modifications Programme is intended to provide the increased accommodation and multiplication of radar facilities that are demanded by this enhanced operational responsibility of the old G.C.I. station.

Even before the end of the war, considerable thought had been devoted to a defence scheme based on a few Master Radar Control Centres. It was recognised that with the increasing tempo of air operations the old technique of radar observing, telling to Filter Room, filtering, retelling to Group and Sector Operations etc., must prove inadequate. The solution was seen to lie in the provision of first-hand, comprehensive radar information at the very spot where it was to be used. Thus even in 1945 the concept emerged of a Master Station, strategically sited, equipped with improved radar gear which would permit the direct display in the station operation's room of the air activity (in plan position and altitude) over an extended area. Fighter operations were to be marshalled from this same operations room and the close control of interceptions was to be conducted at the same station and in association with the same radar gear that was providing the operations room information. The present Stage IIa programme has, presumably, some connection with these earlier considerations; it will certainly assist greatly in the organisation and housing of the elements of such a Master Station, but the full realisation of the Master Station plan is obviously dependent upon the provision of radars with the required performance.

2.10.2 Provisions of the Stage IIa Programme.

The form and organisation of the G.C.I. station after completion of the Stage IIa programme is clearly relevant to the present investigation, since the possible improvements suggested by this study must be considered with reference to the station in its Stage IIa form. A brief summary of the Stage II changes is therefore included.

(a) Interception Rooms.
These are increased from two to three. The size of the room is increased in order better to accommodate the Display consisting of :-

Console Type 5) - for Type 7 information.
" Type 6)

Console Type 16 - for Type 14.

Console Type 15 - for Type 13.

Console Unit 154 - for azication of T.13 from T.14 console.

D/R plotting tables, R/T etc.

(b) Raid Reporting.

Provision of separate cabin for Raid Reporting Crew and equipped with the same display facilities + A band I.F.F.

(c) Liaison Rooms.

Provision of separate cabins overlooking main operations room for Searchlights, Fighter Marshall, Sector Controller, as well as for Chief Controller and Deputy Chief Controller as at present.

(d) Buildings.

To accommodate these changes an annexe is to be built on to the present operations building; a complete reorganisation of R/T, Teleprinter and Domestic rooms is also involved.

(e) Displays.

The Master Console for Type 7 is removed to the basement; the master console for Type 14 is the Type 16 housed in yellow cabin; no D.U.54 units are to be used; two D.U.70's are to be used in each of the cabins of the Chief Controller, Sector Controller and Fighter Marshall for the display of Type 7 and Type 14 information respectively; a skiatron is to be used in the searchlight cabin presumably accepting Type 7 only.

(f) Height Finding.

Type 7 height finding is still provided in the Interception and Raid Reporting cabins, but in addition a separate Type 13 Mark 5 is scheduled for each of these four cabins.

(g) Type 14.

The present Type 14 Mark 3 is to be replaced by a Type 14 Mark 6 mounted on the same plinth.

(h) Power Supplies.

The present mains transformer (135 KW) is adequate but the standby supply of 68 KW. is to be increased to the same figure.

2.10.3 Comments on the Stage IIa Programme.

Certain of the stage IIa provisions are very significant from the point of view of this report. In particular we notice :

(i) Increased reliance upon centimetric height finding equipment :- this policy queries the need for retention of Type 7 height finding, and is discussed in Sections 5 and 6.

(ii) The recognition of the need for simultaneous use of both Types 7 and 14 information :- substantial progress in this direction is clearly dependent upon the development of a really comprehensive Display System (Section 7 refers).

(iii) Use of master consoles in the role of partial information generators. - This suggests the desirability of completing the process and locating all the resulting master units in one Station Radar Office in order to permit central monitoring and control and the provision of adequate stand-by facilities.

(iv) Extension of use of essentially mobile equipment to fixed station application with all the limitations that result therefrom, e.g. treatment of the 180V 500~ supply problem.

(v) Vulnerability.

This problem is not dealt with by the Stage IIa programme. Radio vulnerability demands careful study and incorporation of antijamming techniques. The aerials must necessarily remain exposed to enemy action but some measure of protection should be provided for the operations building which at present is obviously too vulnerable. It would therefore have appeared more profitable to reduce this vulnerability rather than to add to the present buildings in the Stage IIa manner.

Appendix 6. Record of Progress.

A 6.1 Collection of information : details of visits.

In order to obtain special information on apparatus and techniques we have consulted a number of commercial firms and have visited certain of the Establishments. These visits are detailed on page A.63 and a brief indication is included of the purpose of each visit. The information gained from these sources has been considered at the various appropriate points in the report but it is a pleasure here to acknowledge the assistance we have received from the firms and establishments listed.

A 6.2 Test Flights.

The test flight programme extended over the period 17th November, 1948 - 4th March, 1949.

The Meteor IV aircraft piloted by F/L. Clarke, performed eighteen flights at various altitudes ranging from 2000' to 37,000'. Rapid fulfilment of the programme was not possible due to the usual incidence of unserviceability periods, either of the equipment or of the aircraft, but weather was of course the main limitation, the high altitude flights being particularly difficult to perform during the winter months.

Thirty four flights were made by Mosquito aircraft operating from the R.A.F. Station, Shepherd's Grove and ranged in altitude from 2000' to 25,000'. Observations on the various flights were made by both the Type 7 and Type 14 channels; track tracings from the P.P.I's and complete records of the flights were maintained for the later performance analysis.

Apart from the inevitable delays occasioned by weather and aircraft unserviceability (including I.F.F. fitting and special servicing), a certain amount of difficulty was experienced from the unfortunate coincidence of the investigation with both the Stage IIa modification programme and the B.29 affiliation exercises. The earnest cooperation of all R.A.F. personnel concerned permitted the work to be completed before the target date of 15th March.

A 6.3 References.

The Air Publications relevant to the equipments studied have been used throughout the investigation, also certain old files and reports loaned from O.R.S./H.Q.F.C. and H.Q. No.90 Group.

In addition the following special papers have been consulted; they are distinguished by the reference numbers used in the text.

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15. Rice, S.O., B.S.T.J., Vol.23, p.282 and Vol.24, p.46.
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18. Jesty, L.C., Moss, H and Puleston, R., J.I.E.E., Vol.93, Part IIIa, p.149.
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21. Andrew, E.R., J.I.E.E., Vol.93, Part IIIa, p.1559.
22. Levy, M., Wireless Engineer, Vol.24, p.349.

To.	Date.	By.	Purpose.
D.C.D.	15.9.48	R.J. Kemp. E. Eastwood.	Initial meeting.
Trimley.	(various)	All workers.	Collection of data by apparatus and air tests on Types 7, 13 and 14.
H.Q.F.C.	6.10.48	E. Eastwood, C.D. Colchester,	To discuss radar requirements with O.R.S. and to collect any available information on the war time performance of G.C.I. Stations.
H.Q.90 Group.	8.10.48	E. Eastwood. C.D. Colchester	As above, + technical details on modifications and reviewing defects.
Heath Row.	13.10.48	E. Eastwood. C.D. Colchester. B.J. Witt. R.P. Shipway.	To inspect the American M.E.W. and discuss details of its performance and technical spec.
Metro-Vic.	26.10.48	E. Eastwood. C.D. Colchester.	To hold a discussion with Dr. Dodds on the history of T.3079.
A.S.R.E.	27.10.48.	E. Eastwood. C.D. Colchester. R.P. Shipway.	To hold discussion with Mr. Moxon on the noise characteristics of Cm. Head Amps. and to learn of Admiralty tendencies in Head Amplifier design.
B.T.H.	29.10.48	E. Eastwood.	To attend discussion on Microwave Crystal converters.
T.R.E.	3.11.48	R.P. Shipway.	Discussion on display equipment for Types 13 and 14 (D.U.70) and on low noise I.F. amplifiers 10 cm. noise factors and 10 cm. noise generators (Mr. Holding of T.R.E.)
D.C.D.	15.12.48	E. Eastwood. C.D. Colchester.	Meeting + discussion with Mr. Howes, R.D.C.8 re valves.
A.S.R.E. (Witley)	7.1.49	R.P. Shipway.	Discussion with Mr. Oberman on 10 cm. Noise Generator.
B.T.H.	10.1.49	R.P. Shipway	Discussion on Crystals, 2 M.W. magnetron and CV.12 behaviour and

To.	Date.	By.	Purpose.
A.S.R.E. (Eastney, Witley & Waterlocville)	13.1.49	E. Eastwood. C.D. Colchester. R.P. Shipway.	Details of 277P modifications; 980/81 cm. equipment technical and operational details (Messrs. Ratsey, Drury, Oberman and Benjamin).
E.E. Co.	17.1.49	E. Eastwood.	Details of VX.387 Modulator Switch (J.M. Ferguson).
A.S.R.E. (Witley).	26.1.49	R.P. Shipway.	Calibration of 10 cm. Noise Generator.
Cinema Television.	31.1.49	E. Eastwood. C.D. Colchester.	To discuss developments in C.R.T's suitable for P.P.I. displays (Mr. Daniels).
G.E.C.	4.2.49	C.D. Colchester. B.J. Witt.	To gather information on valve developments, VX.3071, E.1714, CV.240, CV.12 (Mr. Bell and Mr. Warren).
R.A.E.	7.2.49	E. Eastwood. C.D. Colchester.	To discuss R.A.E. - R.A.F. policy on P.P.I. tubes (Mr. White).
Wartling.	8.2.49	E. Eastwood. C.D. Colchester.	To view a G.C.I. station alternative to Trimley.
Heath Row.	7.3.49	R.P. Shipway.	To examine in detail the Display of the M.E.W.
P.P.I. Comparison.	10.3.49	R.J. Kemp. E. Eastwood. C.D. Colchester. R.P. Shipway. B.J. Witt.	To observe comparative performances of C.R.T's on Meteor Test Flights i.e. VCR X.208, VCR.140, C.T.V. magnesium fluoride and aluminised. Discussion with Mr. White of R.A.E.
R.R.D.E.	19.3.49	R.P. Shipway	Standardisation of 10 cm. Noise Measuring Equipment.

(JOB).

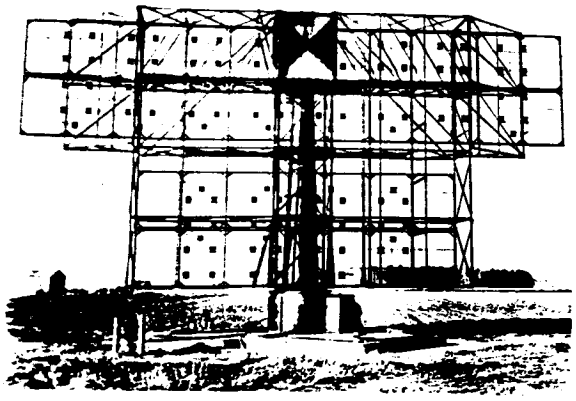


FIG. 2.2.1.

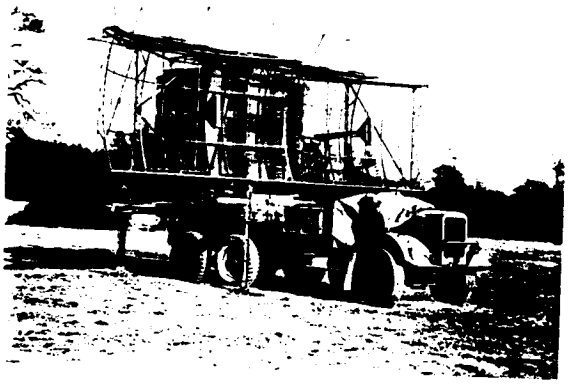


FIG. 2.5.1.

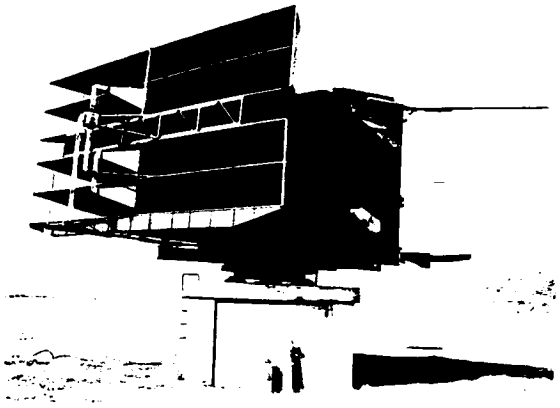


FIG. 2.5.2.

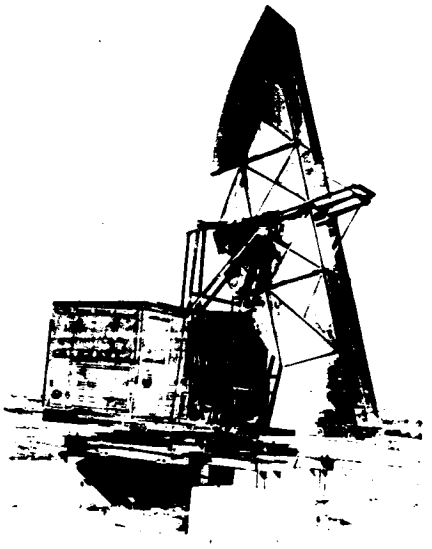


FIG. 2.5.3.

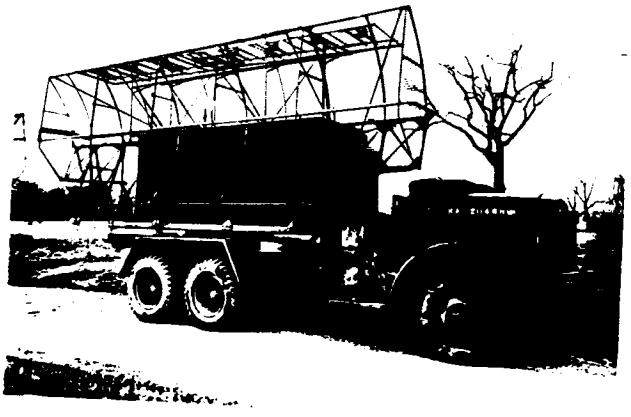


FIG. 2.8.1.

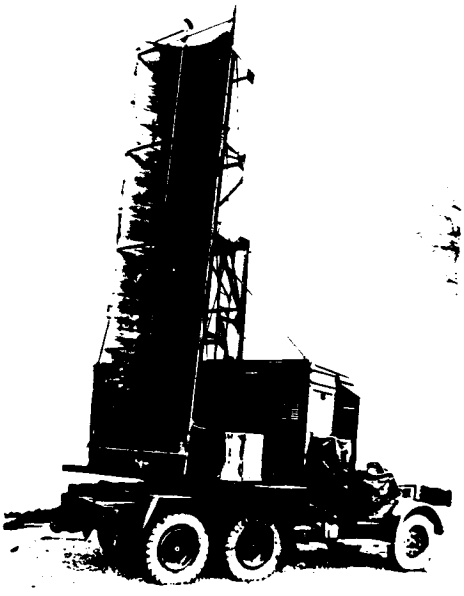
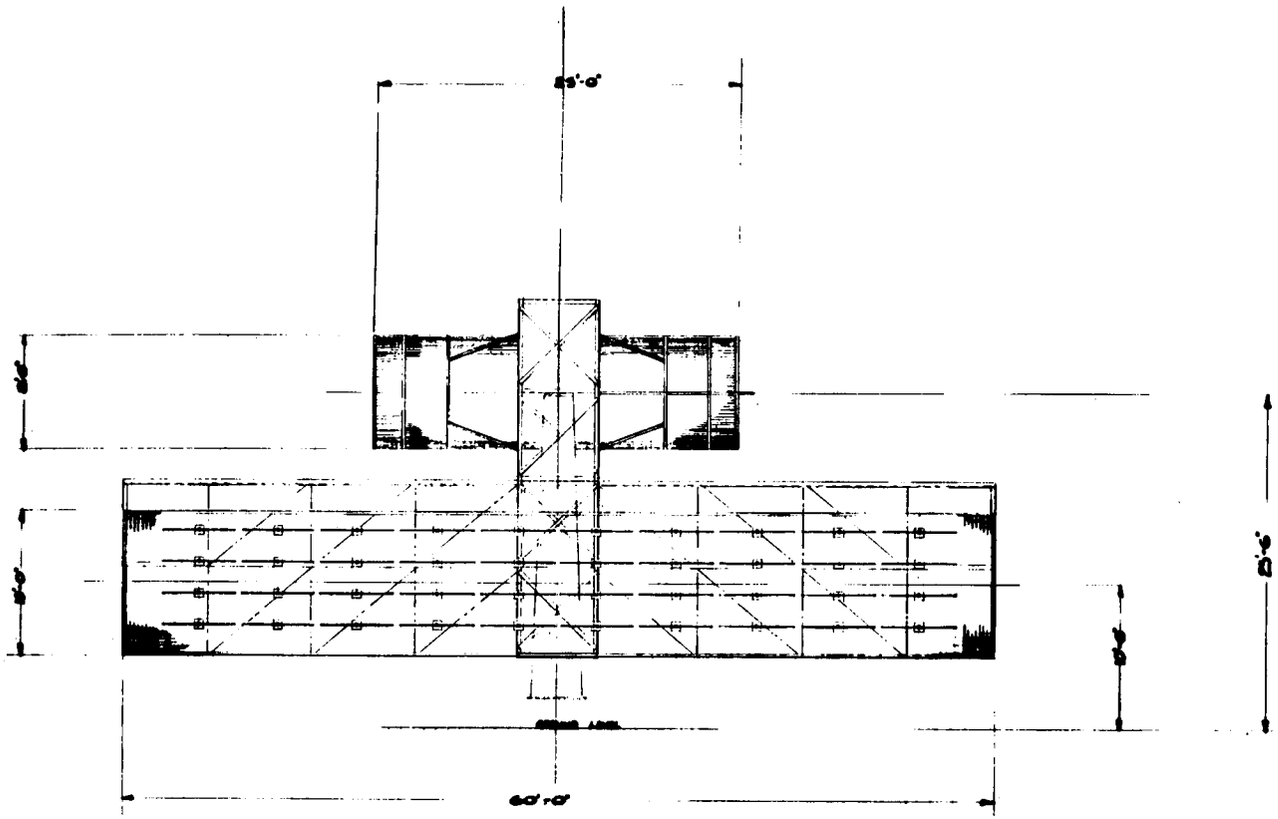
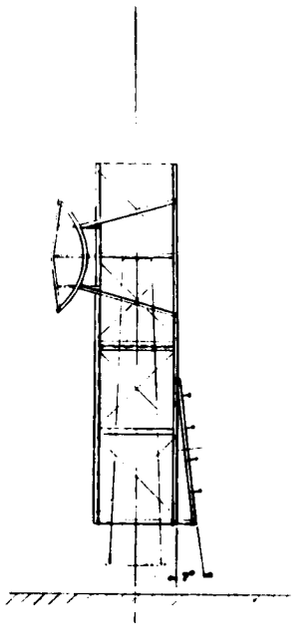


FIG. 2.9.1.





TYPES 14 & 7 COMBINED
AERIAL SYSTEM PROPOSED
FOR RADAR SCHEME 2A.

RD 5242/7