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Item Description: This is a draft manuscript of a lengthy report compiled by the RAF Bomber Command Operational Research Section, probably some time in 1945. The report was authored by Dr. Basil Dickins, a rising star in the field of physics who served as Section head during the war. Using a thematic approach it explores in excellent detail the challenges inherent in strategic bombing, making it a valuable source for both historians of air power and those studying Europe in the Second World War.

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CHAPTER 11

GEE AS AN AID TO BLIND BOMBING

The Gee Principle

The navigational equipment known as Gee was based on the use of three ground stations, arranged approximately equidistantly and nearly in a straight line, emitting synchronised pulses of high frequency radio energy (20 - 70 Megacycles per second). The central station, called the 'master', emitted pulses which were used to trigger off the outer stations, called 'slave' stations, after suitable phasing adjustments had been made. The signals from all three stations were received and displayed on a cathode ray tube equipment in the aircraft. This equipment was designed to measure the time interval between the receipt of signals from the master and each of the slaves. Considering the master station and one slave, it will be seen that for a given time difference between the receipt of signals from each of the two stations an infinite number of positions for the aircraft receiver were possible, all of which lay on a hyperbola having the ground stations as foci. Further, all possible time differences would be represented by a family of confocal hyperbolae. Similarly, due to the master and the other slave, a second family of hyperbolae would be generated which would intersect the first family. These hyperbolae could be drawn on a 'lattice chart' which was carried in the aircraft. All that was necessary for the navigator to do was to measure the time delays using his Gee equipment, or TR1335 as it was originally called, and to identify the appropriate hyperbolae on his chart. The point of intersection of the hyperbolae gave a fix, the accuracy of which was a variable dependent on the position of the aircraft with respect to the ground stations and the accuracy with which the measurements were made.

The Early Development and Trials of Gee

The first experimental Gee receiver was flown on 19 October 1940, using a two station chain. Trials were carried out to measure position lines and successful attempts were made to home along pre-calculated hyperbolic paths. These flights showed that the basic principles were sound but that more technical development was required before large scale manufacture could be

/considered.

considered. Flight trials of a more highly developed Gee receiver and indicator were made on 27 December 1940, and this new equipment proved much more successful. In the meantime, work had been going on to produce the Mark I Gee airborne equipment and a high power transmitter for use as a ground station. By 15 May 1941 this work had been successfully completed and flight trials showed that the equipment was quite satisfactory and that ranges of the order of 400 miles at 10,000 feet could be expected. Work was immediately begun on six airborne equipments which were installed in Wellington aircraft of No. 115 Squadron at Marham for service trials. These service trials, with which the O.R.S. was closely associated, were carried on for a period of two months. It was concluded that Gee was far in advance of any other navigational equipment in the R.A.F., and that it was extremely simple to operate.

The first Gee chain to be set up was the 'Eastern Chain'. With the master station sited at Daventry and the slaves at Stenigot and Gibbet Hill, it gave the maximum possible accuracy over the Ruhr, where a large number of high priority targets were located and which was just within range of the system. Whilst carrying out trials on this chain over Germany on 11 August 1941, one of the aircraft of No. 115 Squadron unfortunately failed to return. It was very important to determine whether the equipment was likely to have fallen into enemy hands in a relatively undamaged state, and the O.R.S. was asked to investigate the available evidence regarding the causes of the loss of all the aircraft missing on that night. It was concluded that all or nearly all the aircraft which were missing had either crashed in flames or exploded in the air, and that it was therefore unlikely that the Gee set had fallen into the hands of the enemy. (1)

The potentialities of Gee seemed so great that Bomber Command wanted it as soon as possible in large numbers. In order to ease the production problem the O.R.S. suggested a modification to the Gee system which might have reduced the number of valves in the equipment and so speed up production. (2)

/The

(1) Bomber Cmd. O.R.S. Rept. No. S.2.
(2) Bomber Cmd. O.R.S. Rept. No. S.1.

The principle of estimating positions by measuring the differences between the time of arrival of signals from three ground stations was retained, but, instead of using a micro-clock consisting of electrical circuits and employing numerous valves, it was proposed to use a stop watch assisted by a 'time transformer' working on a stroboscopic principle and controlled from the ground. However, it was decided that in the long run it would be better to proceed as originally planned.

It had been suggested in certain quarters that for security reasons it might not be possible to allow navigators to take with them over enemy territory a Gee lattice chart which would reveal the sites of the ground stations. It was therefore decided to carry out an investigation to determine the practicability of using the system with certain numerical data instead of charts. Navigators were actually supplied with the lattice co-ordinates of the target and two or three known positions en route. It was shown conclusively, however, that the great advantages of Gee would be almost entirely lost if navigators were unable to refer to a chart, since not only was it necessary to know certain co-ordinates but also the spacing and direction of the lattice lines.

Research into the Operational Techniques to be used with Gee

By the end of 1941 it was clear that Gee would be available for use in operations against the enemy in the near future. It was thought at this time that the major problem confronting Bomber Command crews was that of target identification since it was considered that dead reckoning navigation was sufficiently accurate to ensure that in the majority of cases aircraft arrived within about 20 to 30 miles of their targets. It was considered that with Gee much more accurate navigation would be possible and much thought was given by the various branches at Bomber Command to the possibility of devising a method of using Gee as an aid to target location. In December 1941, the O.R.S. produced a report outlining some of the possible ways of using Gee.(1) The facilities directly provided by Gee were first discussed, e.g. accurate fixing and homing. The report then went on to discuss the

/operational

(1) Bomber Cmd. O.R.S. Rept. No. S.23.

operational facilities which would be provided, e.g. navigation to near the target, homing to a target, wind determination and blind bombing, and indicated the various tactical uses for the equipment, such as timing of operations and routeing of aircraft etc. Finally, it was suggested that in view of the short life which could be expected from Gee, because of the probability of enemy jamming, it was very desirable to carry out some trials to determine how Gee could be best employed. The service trials, it was pointed out, showed that Gee worked very satisfactorily but did not point out the best way to apply the equipment in the bomber force as a whole. These suggested uses of Gee, and in particular the recommendation for service trials, were approved by the Air Staff and a programme of experiments was drawn up by the O.R.S. in consultation with the Group Captain Operations, Chief Signals Officer and Chief Navigation Officer. These experiments which were given in Bomber Command O.R.S. Report No. S.26 (1) were divided into two main sections (a) accuracy trials, and (b) trials of operational techniques. The Gee Development Flight, later to become No. 1418 Flight and finally the Bombing Development Unit, was formed to carry out these trials. The result of the accuracy trials were presented in a report by the Air Warfare Analysis Section (Report No. BRA3), (2) who had been responsible for the preparation of the charts. It was concluded that the random errors of observation amounted to 0.0115 of a Gee unit (standard deviation) and that there was no systematic error over Galloway, the region where the trials were carried out.

A conference was held at Headquarters Bomber Command on 17 January 1942, under the chairmanship of the Commander-in-Chief, to discuss the operational use of Gee. The agenda for this was drawn up by the O.R.S. At the conference it was decided that Gee-fitted aircraft could only be used by themselves when conditions were such that only blind bombing was possible, on all other occasions Gee aircraft could be used to lead the main force on to the target. It was agreed that only two methods of leading the main force on to the target could be used, (a) by Gee aircraft dropping incendiaries blindly and the main force bombing the fires, or (b) by Gee aircraft

/illuminating

(1) A.H.B./II/69/210.
(2)

illuminating the target with flares. An alternative suggestion that non-Gee aircraft should fly in formation with Gee aircraft was considered impracticable for night operations. In view of the uncertainty of the technique of operation to be carried out by the follower and leader aircraft in the flare method, it was decided that trials should be carried out under conditions comparable to those over the Ruhr, as soon as the accuracy trials were completed. To implement this decision the O.R.S. wrote a paper on 'The Use of Flares in Conjunction with Gee',(1) outlining the proposed experiment which was given the code name Crackers and was carried out by No. 3 Group. Selby railway station on the Isle of Man was selected as the target, since the Gee lattice lines were similar to those over the Ruhr. The experiment was carried out on the night of 13 February 1942, and at a conference held at No. 3 Group on 15 February 1942, at which several O.R.S. representatives were present, it was decided that the experiment must be considered a failure due to a technical breakdown. However, valuable experience was gained which was used when the outline of Crackers II was drawn up. This was carried out on the night of 19 February 1942 using Brynkir (North Wales) railway station as a target. This experiment was much more successful, and No. 3 Group were able to make recommendations on the use of a flare technique suitable for actual operations. In this type of operation, which came to be known by the code name Shaker, the general idea was that selected crews should drop flares blindly on Gee over the centre of the target at the beginning of the attack. Provided enough crews were detailed for this duty it was considered that the area so illuminated would include the aiming point in spite of the relative inaccuracy of the fixes obtainable at long range. Other specially selected crews were then to search for the aiming point in the light of the flares, and bomb it with incendiary bombs. The remainder of the force would then bomb the fires so created. The operation was, of course, dependent on clear weather. Under cloudy conditions blind bombing attacks on Gee could be used and were designated Samson attacks. It is of interest to note how closely these original proposals by the O.R.S. for the use of Gee were followed in the techniques that were adopted later for the Pathfinder Force.

/The

(1) Bomber Command O.R.S. Report No. S.30.

The Results Obtained by Gee in Operations

The first Gee operation took place on the night of 8/9 March 1942 using the Shaker technique. Flares were dropped blindly on Gee to illuminate the target which was a marshalling yard south-east of Krupps in the old town of Essen. An incendiary force followed with instructions to navigate to the target area using Gee, and then to identify and bomb the target in the light of the flares. The main striking force was then to bomb the fires which it was hoped would be large enough to make the target unmistakable. From an analysis of the operation carried out by the ORS (1) there is little doubt that the majority of Gee aircraft passed close to the target and built-up areas were sighted and bombed but, unfortunately, these were not always Essen. However, having regard to the fact that it was the first operation, it was considered that the results were encouraging and provided valuable lessons both for the aircrew and planning staff. A report on the technical performance of Gee (2) was also written about this operation, and this and other similar reports are discussed later in this chapter.

The attack on Essen was followed by a second and more successful one on the next night, using the same technique. The third attack on Essen on 10/11 March 1942 was, however, carried out without the use of flares. The target was blind-bombed by Gee using incendiary bombs, the fires caused by these bombs were then to be attacked by the main force. Photographic evidence showed that little success was achieved by the main force due to the small concentration in time achieved at the target by the Gee aircraft together with the small and quite insufficient illumination produced by the 250 pound incendiary bombs. These attacks were also reported on in Report Nos. B.102 (3) and B.103. (4)

/Other

(1) A.H.B./II/39/1/2 (Bomber Cmd. O.R.S. Rept. No. B.101).
(2) A.H.B./IIH/241/10/89 (Bomber Cmd. O.R.S. Rept. No. S.35).
(3) A.H.B./II/39/1/2.
(4) A.H.B./II/39/1/2.

Other Gee attacks of interest were on Kiel 12/13 March 1942,(1) Cologne 13/14 March 1942,(2) Essen 25/26 March 1942,(3) Cologne 5/6 April 1942,(4) Essen 12/13 April 1942,(5) Cologne 27/28 April 1942 (6) Bremen 2/3 July 1942,(7) and Duisburg 21/22 July 1942.(8) Most of these attacks were carried out using either Shaker or modified Shaker techniques.

An attack of particular interest was that on Cologne on 22/23 April 1942, when some 80 aircraft were detailed to blind-bomb the city on Gee. Night photographs were to be taken for the purpose of analysis. Unfortunately, however, the evidence obtained was inconclusive and the degree of success of the raid could not be accurately assessed. Such evidence as was available, however, appeared to indicate that the attack was scattered over an area round Cologne and within ~~5~~ five to ~~10~~ ten miles of it, and that in all probability only a small proportion of the bombs dropped actually fell in Cologne itself (Report No. S.44 refers).(9) In view of the importance of determining the accuracy of blind-bombing by Gee, the O.R.S. analysed the available evidence from all operations in an attempt to get a broad picture of the operational accuracy of this method of bombing. The results are given in Bomber Command O.R.S. Report No. S.47,(10) which concluded from the evidence available that when operational crews blind-bombed heavily defended targets in the Ruhr and Rhineland the accuracy obtained was more than three times worse than that obtained by expert crews of No. 1418 Flight over this country. In particular it was estimated that in a blind attack on Essen 5 to 10 per cent of all bombs dropped would fall in the town and about 2 to 3 per cent in Krupps works. A memorandum was prepared on the ten raids which had been carried out on Essen up to the end of May 1942 (Report No. B.111) (11) The evidence from these operations was examined, and it was concluded that the best results were likely to be achieved by

/blind

(1) Bomber Cmad. O.R.S. Rept. No. B.104.
(2) A.H.B./II/39/1/2 (Bomber Cmd. O.R.S. Rept. No.105)
(3) A.H.B./II/39/1/2 (Bomber Cmd. O.R.S. Rept. No. B.107)
(4) A.H.B./II/39/1/2 (Bomber Cmd. O.R.S. Rept. No. B.108)
(5) A.H.B./II/39/1/2 (Bomber Cmd. O.R.S. Rept. No. B.109)
(6) A.H.B./II/39/1/2 (Bomber Cmd. O.R.S. Rept. No. B.110)
(7) A.H.B.2 unindexed (Bomber Cmd. O.R.S. Rept. No. B.112)
(8) A.H.B./II/39/1/2 (Bomber Cmd. O.R.S. Rept. No. B.114)
(9) A.H.B./II/39/1/2.
(10) A.H.B./II/69/157
(11) A.H.B./II/39/1/2.

blind-bombing attacks in view of the difficulties of visual identification of the target through the Ruhr haze.

Concurrently with these intensive investigations into the operational performance of Gee, the O.R.S. was engaged on investigations into the accuracy with which fixing and homing could be carried out. In particular, attention was paid to the reduction and possible elimination of systematic errors introduced by the slave station operators attempting to maintain accurate phasing, and to the monitor stations ability to detect the correctness or otherwise of the phasing delays actually applied at the slaves. The disappointing operational results obtained with Gee led to a concentration of effort to reduce both these errors introduced on the ground and those introduced in the air. Much of this work was purely technical and is discussed in detail in a later section of this chapter, but it was clear that every available opportunity for training crews in the homing technique would have to be seized if the maximum improvement in the operational results was to be obtained. Since practice flights carried out by operational squadrons could provide much data valuable both to the crews and to planning staffs, if the flights were properly organised, the O.R.S. wrote Report No. S.56 (1) on how these could best be carried out. The report described the kind of flights which should be carried out and gave a list of suitable areas for them. Micro-lattices were drawn up for these areas, and it was then easily possible to check the position of ground photographs against Gee fixes. It was arranged for all the data, photographs etc., to be sent to the O.R.S. and a return-of-post system was organised whereby crews were told with the minimum of delay what their errors were.

In view of the failure of Gee as a blind bombing device which it was, of course, never intended to be, a second memorandum was written on the attacks on Essen with a view to analysing the causes of the poor results. This was finally published as a Bomber Command Air Staff Note, dated 26 July 1942. It was concluded that although blind bombing on Gee would

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(1) A.H.B./IIH/1241/10/89.

not 'blitz' Essen, it was likely to achieve better results than any other method. Various other ways of achieving success were suggested, i.e. firstly improvements on the present techniques using extreme concentration of aircraft and special preparation of the crews; secondly, use of a nearby landmark from which aircraft could make timed runs; thirdly, blind bombing using an expanded time base on the navigators' indicator and special phasing of the ground stations (Bomber Command O.R.S. Report No. S.55) (1) and the use of marker bombs and selected target marking aircraft.

The operational performance of the Gee Equipment

One of the functions of an O.R.S. is to analyse the performance of new devices as they are brought into service. Accordingly, a pro-forma was devised, in conjunction with the Radar Branch of Bomber Command, which could readily be filled by crews returning from operations, and at the same time give sufficient data in the best available form for analysis. The pro-forma was designed to allow as many questions as possible to be answered merely by placing a tick in the appropriate space, and it was divided into three main sections with the following headings (a) Technical, (b) Navigational, and (c) Target. Each of these sections was sub-divided into a number of sub-divisions dealing with the ranges at which the signals faded, data dealing with found winds, and data dealing with the way the target was identified and bombed etc. The information obtained from these pro-forma formed the basis of Bomber Command O.R.S. Reports Nos. S.35, (2) S.36 (3) S.37, (4) S.38 (5) S.39 (6) and S.40, (7) each of which dealt with a particular night's operation. When the technical performance of the system became more stabilised these reports were discontinued and only published when there was something of definite interest. Reports in this category include (a) unusual low range of stations Type 7,000 (No. S.42) (8) and (b) range and operational performance of Gee in raids on Stuttgart (Bomber Command O.R.S. Report S.49 (9) The point of interest of the first report is obvious, whilst that of the second was that Stuttgart was well outside Gee cover, which could therefore be used for only part of the flight. An omnibus

/report

(1) A.H.B./IIH/241/10/89
(2) A.H.B./IIH/241/10/89
(2)-(7) A.H.B./II/69/157.
(8) A.H.B./IIH/241/10/89.
(9) A.H.B./IIH/241/10/89.

report (No.552)[1] was written which summed up the evidence on the range of Gee over the period 8 March 1942 to 20 May 1942.

Enemy interference with Gee was first encountered in August 1942 when various reports of 'lost signals due to much grass' were received from navigators. Bomber Command O.R.S. Report No. S.60[2] summed up the information to hand at the time and gave an account of certain investigations which were carried out by the Bombing Development Unit. It was concluded that Gee had been effectively jammed over Germany by means of modulated C.W. signals, and that the range from Daventry (the site of the Master station) had been reduced from about 400 miles to 250 - 300 miles. A report was written by the Bombing Development Unit on a flight carried out over Germany on 17/18 August 1942 to test an anti-jamming circuit. This report was included as an appendix to Bomber Command O.R.S. Report No. S.61[3] dealing with the interference experienced up to 19 August 1942. Experience of latter raids confirmed the interference on earlier ones, and the report stated that the anti-jamming circuits showed great promise. A number of Gee sets were fitted with the anti-jamming modification and by 25 August 1942 three more attacks had been carried out. The O.R.S. analysed the data collected on these attacks in Bomber Command O.R.S. Report No. S.62[4] and it was concluded that the modification was a successful countermeasure to the enemy jamming effort. Bomber Command O.R.S. Report No. S.63[5] dealt with three more attacks which took place at the end of September, and it was noted that the enemy appeared to be experimenting with a new type of jamming in the form of locked and unlocked pulses.

Beginning in September 1942, a careful analysis was made of the ranges obtained using Gee, and the O.R.S. published a series of tables known as 'Range Analysis Tables'. Copies of these were sent to groups and distributed down to squadrons, and it was possible for any squadron to compare its results with all the others. Bomber Command O.R.S. Report No. S.69[6] reviewed the range of Gee since the start of enemy jamming in early

/August

(1) A.H.B./IIH/258/3/12A
(2) A.H.B./II/69/210
(3) A.H.B./II/69/210
(4) A.H.B./II/69/210
(5) A.H.B./II/69/210
(6) A.H.B./II/69/210

August, and compared it with the ranges obtained prior to the jamming. It was shown that the range fell sharply when jamming was first experienced, and that after a recovery brought about by the use of countermeasures the the range decreased again. This was possibly due to increased effort on the part of the enemy or possibly to the change in climatic conditions. A supplement to this report showed that up to December 1942 the decline in Gee ranges continued until 31 December 1942, when the range was only 280 miles. At the same time the Southern Gee chain, in an unjammed state, was giving ranges of the order of 400 miles. The Range Analysis Tables proved of value to various sections in T.R.E. which used them to carry out investigations connected with the effect of enemy jamming and propagation conditions on Gee ranges (T.R.E. Reports T1339 and T1496).(1)

This work by the O.R.S. and T.R.E. was continued in 1943 when a series of monthly reports was written on the operational ranges obtained with Gee (Bomber Command O.R.S. Report Nos. S.86,(2) S.85,(3) S.87 (4) and S.93(5).) It was shown that enemy jamming was increasing in severity and that the Mark II receiver which had been introduced was showing little promise of materially increasing the ranges obtained.

Suggestions were made in various quarters that the effectiveness of enemy jamming could be reduced, even within the existing frequency band, by the introduction of decoy transmissions and other means of misleading the enemy as to the actual frequency which was being used for fixing. Eventually at a meeting held at Air Ministry on 2 March 1943, it was decided to use an extra frequency which would be available only from about 15 minutes before to 15 minutes after the critical period of an attack. The target frequency scheme was used from 8/9 April 1943, and although it did not work well at first, due to inexperience, things settled down, and by 26/27 April 1943 some fixes were obtained on all targets in the Ruhr area. The mean ranges obtained and the percentage of aircraft obtaining fixes were not nearly so high as in the pre-jamming period, but this may have been partly due to the fact that the use of the Pathfinder Force made intensive use of Gee in

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(1)
(2) A.H.B./II/69/168
(3) A.H.B./IIH/241/2/547
(4) A.H.B./II/69/210
(5) A.H.B./II/69/210.

the target area less essential (Bomber Command O.R.S. Report No. S.93 refers).

Research into the accuracy of Gee

Phasing of the Ground Stations

At the beginning of 1942 and before Gee was used on operations, it was realised that the accuracy of a Gee fix was not only dependent on the ability of the navigator and the position of the aircraft relative to the ground stations, but also on a number of systematic errors which could be introduced at the ground stations. A visit was paid to Great Bromley monitoring station, and as a result it was possible to form an estimate of the nature and magnitude of the systematic errors which might arise due to:-

(a) errors due to incorrect manipulation

(b) fundamental limitations of the monitoring equipment

(c) discrepancy between calculated and observed co-ordinates of Great Bromley.

These errors ~~are~~ were discussed in Bomber Command O.R.S. Report No. S.25.(1) It was found that from the first cause errors as great as 0.02 of a lattice co-ordinate could occur as the operators were unaware of the high accuracy required and were not making the best use of the equipment. It was recommended that operators should be provided with detailed instructions describing the most accurate way of using the equipment and that these should be rigorously enforced. The monitoring equipment had the same time base as was fitted to the aircraft receiver, and it was considered that since the ground personnel worked under very much better conditions than the navigators, an expanded and therefore more accurate monitor time base would be advantageous. It was found that there was a discrepancy between the calculated and observed co-ordinates of Great Bromley which was alleged to have constant values between 0.01 and 0.03 Gee units. This was most probably the result of incorrect phasing due to a number of causes, and it was recommended that the slave stations should be phased in such a way that the correct readings were given at Great Bromley. The recommendations made as a result of this investigation were carried out, and an improved monitor for Great Bromley was produced on high priority. A second

/investigation

(1) A.H.B./II/69/210.

investigation (Bomber Command O.R.S. Report No. S.27 (1) was carried out in conjunction with T.R.E. on the new equipment, and it was considered that the change permitted much greater accuracy in reading and therefore more careful monitoring. However, the modified equipment was not completely satisfactory and it was recommended that the possibility of eliminating the unsteadiness of the trace and improving its brightness should be investigated.

Following substantiated reports by navigators of Bomber Command, rendered in January and early February 1942, that Gee lattice co-ordinates were inaccurate to the extent of 0.1, 0.2 and even 1.0 units, a meeting was held at No. 60 Group under the chairmanship of the Air Officer Commanding No. 60 Group. Various possible causes were discussed, and it was decided to send representatives of Headquarters No. 60 Group and the O.R.S. to investigate the matter at the monitor station at Great Bromley. As recorded in Bomber Command O.R.S. Report No. S.32, (2) it was found that the monitoring operator was required to carry out a complicated procedure to watch the phasing of all three slave stations on the Eastern chain, and that this and careless operating could cause large errors. It was suggested that each slave station should be monitored independently and a simplified form of operating drill was devised. Small errors were already known to exist, and it was stated that work was being carried out both by T.R.E. and the O.R.S. to reduce these. Various other administrative points were investigated, and it was suggested that the chain should operate with a degree of monitoring accuracy dependent on the circumstances. Three grades were recommended:-

(a) Grade I giving the highest degree of accuracy for operations and training of aircrews

(b) Grade II giving no guaranteed accuracy but providing training facilities for the operators, etc.

(c) Grade III main stations closed down with reserve stations switched on to provide for the maintenance of the main stations.

Whenever reserve stations were called upon to operate instead of the main stations, systematic errors were introduced into the Gee system since the transmitters could not be sited in exactly the same place. The O.R.S. carried out investigations into the magnitude of the errors introduced by the substitution of a reserve master station for the main station at Daventry on the

/Eastern

(1) A.H.B./II/69/210.
(2)

Eastern chain (Bomber Command O.R.S. Report No. S.34 (1) refers), and a phasing procedure was devised whereby the lattice co-ordinates of the target were unchanged when the reserve station was in use. It was also shown how corrections could be applied to ensure accurate fixing at any point on the route to the target. Bomber Command O.R.S. Report No. S.67 (2) on the same subject was written when a new aerial was erected on the reserve site of the master station at Daventry.

It was then discovered by the O.R.S. that certain discrepancies which had been known to exist between the slave and monitor readings were due to the fact that the slave station receiver aerials were not coincident with the transmitting aerials. The reading to be set on the cathode ray tube at the slave station differed from the nominal 'phasing' value, and the readings at all slave stations for the Eastern and Southern chains for all possible combinations of main and reserve aerials were calculated (Bomber Command O.R.S. Report No. S.68).(3) The O.R.S. work on the phasing of ground stations was completed in May 1943 by the publication of Bomber Command O.R.S. Report No. S.88 (4) which dealt with the corrections to be applied to readings at the Master and Slave stations to give correct values at any given target for any combination of main and reserve stations.

Errors in reading the Gee indicator

Apparent Alignment of Pulses

The homing technique which had been developed for use in operations was liable to two kinds of error, errors in setting up the required co-ordinates on the indicator and errors in judging when the pulses were aligned. An investigation into the second of these kinds of error, based on a series of trial flights carried out by No. 1418 Flight over Doncaster and Andover, using the Eastern Gee chain, was recorded in Bomber Command O.R.S. Report No. S.50.(5) It was concluded that the period of apparent alignment of the pulses was a function of the lattice spacing although there were insufficient results to determine the exact relationship, and that there was

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(1)
(2) A.H.B./IIH/241/22/7
(3)
(4) A.H.B./IIH/241/22/7
(5) A.H.B./IIH/258/3/12A.

a great deal of difference between the results of different navigators. It was also shown that by increasing the resolving power of the Gee indicator by using an expanded time base, it was possible to reduce the period of apparent alignment which, over the Ruhr, was estimated at between one and two minutes.

Observational Errors

Experience with Gee as a blind bombing device had shown that the accuracy obtained was not of a very high order, and that the bombs dropped had a scatter of several miles. The observational errors which could be made when using Gee due to errors in setting up the required co-ordinates when homing to a point and errors in reading the alignment of the pulses, were discussed in Bomber Command O.R.S. Report No. S.55.(1) To minimise these errors it was suggested that the ground stations should be phased in such a way that the second decimal place of the target co-ordinates would be zero. It was recommended that trials should be carried out to determine the increased accuracy to be obtained with this procedure. It was also suggested that the use of an expanded time base would facilitate determining the positions of the pulses, as was done at the ground stations. This new time base would also reduce the period of apparent alighment of the pulses. It was stated that operational navigators obtained results of much lower accuracy compared with the navigators of No. 1418 Flight, and it was anticipated that the suggested improvements would bring about an increase in the operational accuracy of Gee.

Effect of Pulse Shape

Reports were received from many crews that fixes taken over the Ruhr placed the aircraft well to the westward of their correct position. Further evidence of the existence of systematic errors was found in test flights carried out by No. 1418 Flight, and various operational squadrons over this

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(1) A.H.B./IIH/241/10/89.

country. No. 60 Group pointed out that the pulses emitted by the Gee stations were by no means of constant shape and that the slope of the leading edge was subject to considerable variation. In Bomber Command O.R.S. Report No. S.58,(1) it was shown that the shape of the Gee pulses was very important and that much better results could be expected from triangular pulses, using the tips to estimate alignment. Measurements were made at a ground site on the effect of receiver gain on the indicator reading, and it was shown that a variation of about 0.02 Gee units could be obtained as the gain was varied from maximum to a value which made the pulse just visible. The error introduced was of such a sign and magnitude that it completely accounted for the reports made by operational crews over the Ruhr.

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(1) A.H.B./IIH/241/10/89.