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## THE BATTLE OF BRITAIN.

*The following despatch was submitted to the Secretary of State for Air on August 20th, 1941, by Air Chief Marshal Sir Hugh C. T. Dowding, G.C.B., G.C.V.O., C.M.G., A.D.C., Air Officer Commanding-in-Chief, Fighter Command, Royal Air Force.*

### PREAMBLE.

1. I have been instructed by the Air Council to write a Despatch on the Air Fighting of last Autumn, which has become known as the "Battle of Britain." The conditions are a little unusual because, firstly, the Battle ended many months ago, secondly, a popular account of the fighting has already been written and published, and, thirdly, recommendations for Mention in Despatches have already been submitted.

2. I have endeavoured, therefore, to write a report which will, I hope, be of Historical interest, and which will, in any case, contain the results of more than four years' experience of the Fighter Command in peace and war.

August 20, 1941.

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### THE BATTLE OF BRITAIN.

#### PART I.—PRELIMINARY.

3. In giving an account of the Battle of Britain it is perhaps advisable to begin by a definition of my conception of the meaning of the phrase. The Battle may be said to have started when the Germans had disposed of the French resistance in the Summer of 1940, and turned their attention to this country.

4. The essence of their Strategy was so to weaken our Fighter Defences that their Air Arm should be able to give adequate support to an attempted invasion of the British Isles. Experiences in Holland and Belgium had shown what they could do with armoured forces operating in conjunction with an Air Arm which had substantially achieved the command of the Air.

5. This air supremacy was doubly necessary to them in attacking England because the bulk of their troops and war material must necessarily be conveyed by sea, and, in order to achieve success, they must be capable of giving air protection to the passage and the landing of troops and material.

6. The destruction or paralysis of the Fighter Command was therefore an essential prerequisite to the invasion of these Islands.

7. Their immediate objectives might be Convoys, Radio-Location Stations, Fighter Aerodromes, Seaports, Aircraft Factories, or London itself. Always the underlying object was to bring the Fighter Command continuously to battle, and to weaken its material resources and Intelligence facilities.

8. Long after the policy of "crashing through" with heavy bomber formations had been abandoned owing to the shattering losses incurred, the battle went on. Large fighter formations were sent over, a proportion of the fighters being adapted to carry bombs, in order that the attacks might not be ignorable.

9. This last phase was perhaps the most difficult to deal with tactically. It will be discussed in greater detail later on.

10. Night attacks by Heavy Bombers were continuous throughout the operations, and, although they persisted and increased in intensity as Day Bombing became more and more expensive, they had an essentially different purpose, and the "Battle of Britain" may be said to have ended when the Fighter and Fighter-Bomber raids died down.

11. It is difficult to fix the exact date on which the "Battle of Britain" can be said to have begun. Operations of various kinds merged into one another almost insensibly, and there are grounds for choosing the date of the 8th August, on which was made the first attack in force against laid objectives in this country, as the beginning of the Battle.

12. On the other hand, the heavy attacks made against our Channel convoys probably constituted, in fact, the beginning of the German offensive; because the weight and scale of the attack indicates that the primary object was rather to bring our Fighters to battle than to destroy the hulls and cargoes of the small ships engaged in the coastal trade. While we were fighting in Belgium and France, we suffered the disadvantage that even the temporary stoppage of an engine involved the loss of pilot and aircraft, whereas, in similar circumstances, the German pilot might be fighting again the same day, and his aircraft be airborne again in a matter of hours.

13. In fighting over England these considerations were reversed, and the moral and material disadvantages of fighting over enemy country may well have determined the Germans to open the attack with a phase of fighting in which the advantages were more evenly balanced. I have therefore, somewhat arbitrarily, chosen the events of the 10th July as the opening of the Battle. Although many attacks had previously been made on convoys, and even on land objectives such as Portland, the 10th July saw the employment by the Germans of the first really big formation (70 aircraft) intended primarily to bring our Fighter Defence to battle on a large scale.

14. I had 59 squadrons in various stages of efficiency. A list of these units, with supplementary information, is given in Appendix A. Many of them were still suffering from the effects of the fighting in Holland and Flanders, at Dunkerque, and during the subsequent operations in France. Others were in process of formation and training. But, if the lessons of the Battle are to be correctly appreciated, due consideration must be given to the factors leading up to the situation existing when it began. Leaving out of account peace-time preparations and training, the Battle of Britain began for me in the Autumn of 1939.

15. The first major problem arose during the discussion of the question of sending Fighter Squadrons to France. The decisive factor was that of Supply. Our output at the beginning of the war was about 2 Hurricanes and 2 Spitfires per diem; and, although there were hopes of increasing Hurricane production, there was then no hope that Spitfire production would be materially increased for about a year. It is true that certain optimistic estimates had been made, but there were reasons to believe that these could not be implemented. At that time, we in England were out of range of German Fighters, and I had good hopes that unescorted bomb raids on this country could be met and defeated with a very small loss in Fighters; but there could be no illusions concerning the wastage which would occur if we came up against the German Fighters in France.

16. I therefore regarded with some apprehension the general policy of sending Home Defence Fighter Units to France; but, as it was clear that such an attitude was politically untenable, I wrote on the 16th September, 1939, a letter to the Air Ministry. In this letter I pointed out that the Air Staff Estimate of the number of Fighter Squadrons necessary for the defence of this country was 52, and that on the outbreak of war I had the equivalent of 34 (allowing for the fact that some Auxiliary Squadrons were only partially trained and equipped).

17. I wanted 12 new squadrons, but asked that 8 should be raised immediately, and made proposals for their location and employment. In a letter dated the 21st September the Air Ministry regretted that the most they could do towards meeting my requirements was to form 2 new squadrons and 2 operational training units. I was invited to a meeting of the Air Council on the 26th September,

18. On the 25th September I wrote expressing my disappointment and asking for a reconsideration. As a result of this letter, the Air Council Meeting, and a further meeting under the Chairmanship of the Deputy Chief of Air Staff, the Air Ministry wrote on the 9th October sanctioning the immediate formation of 8 new squadrons, though 6 of these could be formed initially only as half-squadrons owing to shortage of resources. This correspondence is too lengthy to reproduce here, but it deals also with my apprehensions concerning Hurricane wastage in France, which were realised in the Spring of 1940. It also dealt with an estimate worked out by the Air Ministry Organisation Staff that after 3 months of fighting we might expect the Fighter strength to have been reduced to 26 squadrons.

19. In October, 1939, the Air Ministry further reconsidered their policy, and ordered the formation of 10 additional Fighter Squadrons, 4 of which were destined for the Coastal Command.

20. In January, 1940, the Northern flank of our continuous Defence organisation was on the Forth, and the South-Western flank was at Tangmere in Sussex (with the exception of an isolated station at Filton for the local defence of Bristol and the mouth of the Severn). On the 2nd and 4th February I wrote two letters pointing out these limitations, and asking for an extension of Aerodrome facilities, Intelligence cover and communications.

21. On the 9th February I was told that a paper was in preparation, and that I would be given an opportunity to remark on the proposals at a later stage.

22. On the 16th March I received the paper referred to and forwarded my comments on the 23rd March.

23. On the 8th May I received a letter saying that a reply had been delayed. The proposals were now approved, and decisions would shortly be taken.

24. This delay was presumably unavoidable, but the result was that the organisation and development of the defences of the South and West of England were very incomplete when they were called upon to withstand the attacks which the German occupation of French aerodromes made possible.

25. The fighting in Norway has only an indirect bearing on this paper. Certain useful tactical lessons were gained, particularly with regard to deflection shooting, and I trust

that the story of the epic fight of No. 263 Squadron under Squadron-Leader J. W. Donaldson, D.S.O., near Andalsnes, may not be lost to History.

26. The outcome, as it affects this account, was the virtual loss of 2 squadrons in the sinking of the Aircraft Carrier *Glorious* after the evacuation of Narvik.

27. Next came the invasion of Holland, and the call to send Fighters to the assistance of the Dutch. The distance to Rotterdam was about the extreme range of the single-seater Fighter, which therefore operated under the disadvantage of having a very brief potential combat-time, followed by the necessity of a long sea crossing on the homeward way. The Blenheims, of course, had the necessary endurance, but they had not been designed as fighters, and their use against day fighters proved costly in comparison with the limited success which they attained.

28. The Defiants were used here for the first time, and, although they proved very effective against unescorted bombers, they, too, suffered heavy casualties when they encountered fighters in strength. As the result of this experience I formed the opinion that the Blenheims should be kept exclusively for night fighting, if possible, while I retained an open mind about the Defiants pending some experience of short-range fighting.

29. Then began the fighting in Belgium and Northern France, and at once my fears about the incidence of wastage in this type of fighting began to be realised.

30. At the beginning of April, 1940, there were 6 Fighter Squadrons in France.

31. Then 4 more complete squadrons were sent when the fighting began.

32. Then on the 13th May 32 pilots and aircraft were sent—say the equivalent of 2 squadrons.

33. Almost immediately afterwards 8 Half-Squadrons were sent. This was done under the impression that the loss of 8 Half-Squadrons would affect me less than that of 4 entire Squadrons, because it was supposed that I should be able to rebuild on the nuclei left behind. But this assumption was incorrect because I had neither the time nor the personnel available for purposes of reconstruction, and the remaining half-squadrons had to be amalgamated into Composite Units with a resulting disorganisation and loss of efficiency. At this time, too, I was ordered to withdraw trained pilots from squadrons and to send them overseas as reinforcements.

34. I had now lost the equivalent of 16 Squadrons, and in addition 4 Squadrons were sent to fight in France during the day and to return to English bases in the evening.

35. Other pilots were withdrawn from the Command through the system by which the Air Ministry dealt direct with Groups on questions of Personnel.

36. It must be remembered that during this period the Home Defence Squadrons were not idle, but that Hurricane Squadrons were participating in the fighting to a considerable extent, 4 Squadrons daily left S.E. England with orders to carry out an offensive patrol, to land and refuel in France or Belgium, and to carry out a second sortie before returning to England.

37. Hitherto I had succeeded generally in keeping the Spitfire Squadrons out of the Continental fighting. The reason for this, as stated above, was that the supply situation was so bad that they could not have maintained their existence in face of the Aircraft Casualty Rate experienced in France: between the 8th May and the 18th May 250 Hurricanes were lost.

38. When the Dunkerque fighting began, however, I could no longer maintain this policy, and the Spitfires had to take their share in the fighting.

39. When the Dunkerque evacuation was complete I had only 3 Day-Fighting Squadrons which had not been engaged in Continental fighting, and 12 Squadrons were in the line for the second time after having been withdrawn to rest and re-form.

40. All this time, it must be remembered, the attack on this Country had not begun; with a few accidental exceptions no bomb had been dropped on our soil. I was responsible for the Air Defence of Great Britain, and I saw my resources slipping away like sand in an hour-glass. The pressure for more and more assistance to France was relentless and inexorable. In the latter part of May, 1940, I sought and obtained permission to appear in person before the War Cabinet and to state my case. I was accorded a courteous and sympathetic hearing, and to my inexpressible relief my arguments prevailed and it was decided to send no more Fighter Reinforcements to France except to cover the final evacuation.

41. I know what it must have cost the Cabinet to reach this decision, but I am profoundly convinced that this was one of the great turning points of the war.

42. Another decision, of perhaps equal importance, was taken at about this time. I refer to the appointment of Lord Beaverbrook to the post of Minister of Aircraft Production. The effect of this appointment can only be described as magical, and thereafter the Supply situation improved to such a degree that the heavy aircraft wastage which was later incurred during the "Battle of Britain" ceased to be the primary danger, its place being taken by the difficulty of producing trained fighter pilots in adequate numbers.

43. After the Evacuation from Dunkerque the pressure on the Fighter Command became less intense, but it by no means disappeared. Hard fighting took place along the coast from Calais to Le Havre to cover the successive evacuations from that coast. Then the centre of gravity shifted to Cherbourg and its neighbourhood, and the "Battle of Britain" followed on without any appreciable opportunity to rest and re-form the units which had borne the brunt of the fighting.

44. The above considerations should be kept in mind when Appendix A (Order of Battle on the 8th July, 1940) is being studied.

45. The Guns and Searchlights available for the Air Defence of Great Britain were arranged as shown on the map which constitutes Appendix B.

46. The fall of Belgium and France had increased the danger to the South and West of England, and had necessitated a considerable modification of the original arrangements when bombing attacks could start only from German soil.

47. The distribution of Army Units was, as a matter of fact, in a condition of perpetual change to meet new situations as they arose, and I must pay a very sincere tribute to the flexibility of the Army organisation, and to the tact, patience and loyalty of the Commander-in-Chief of the Anti-Aircraft Command, Lt.-Gen. Sir Frederick A. Pile, Bart., K.C.B., D.S.O., M.C., which enabled these constant changes to be made without disorganisation.

48. In theory the Commander-in-Chief, Fighter Command, was the authority responsible for settling the dispositions of all guns allotted to the Air Defence of Great Britain; but this was little more than a convenient fiction. The number of guns available was so inadequate for the defence of all the vulnerable targets in the country, and the interests concerned were so diverse and powerful, that it was not to be supposed that an individual member of any one Service would be left to exercise such a prerogative uninterruptedly. A disproportionate amount of my time was taken up in discussions on gun distribution, and each decision was at once greeted with a fresh agitation, until finally I had to ask that all proposals should be discussed by a small Committee on which all interests were represented, and I normally accepted the recommendations of this Committee during quiet periods. During active operations I consulted General Pile, and we acted according to our judgment.

One rather important lesson emerged from our experience, viz., that the general fire-control of all guns in the Air Defence System should be vested in the Air Defence authorities. I do not, of course, mean that, if an invasion had taken place, the guns co-operating with the troops in the Field should have been subordinated to any A.A. Defence Commander, but the existence of "free-lance" guns*), the positions and even the existence of which were unknown to me, was an appreciable handicap, especially at night. It was impossible to acquaint them with the approach of enemy raiders, or of the fact that our own aircraft were working in the vicinity.

49. When the night attacks on London began to be really serious, General Pile, in consultation with myself, decided to send heavy reinforcements. Within 24 hours the defences to the South and South-East of London were approximately doubled, and the great increase in the volume of fire was immediately noticed and had a very good effect on public morale. The physical effect in the shape of raiders destroyed was by no means negligible, but the main effect was never generally known. The track of every raid was, of course, shown on various operations tables, and on some nights as many as 60 per cent. of the raiders approaching London from the South turned back after dropping their bombs in the open country or on the fringe of the Barrage.

50. The A.A. Guns at Dover enjoyed unusual opportunities for practice, with the result that their crews became acknowledged experts in the art of Anti-Aircraft Gunnery. Their skill, however, was attained through the circumstance that they and the Dover Balloon Barrage were continuously the objectives of German attack; they manned their guns continuously night and day, and I must pay a high tribute to their morale, enthusiasm and efficiency.

A report from the 6th A.A. Division, which was busily and typically employed, is included at Appendices C, C.A, C.B. and C.C.

51. A short Appendix (C.D) is added showing the number of rounds fired per aircraft destroyed, for the whole Anti-Aircraft Command.

52. On the map which constitutes Appendix A.A. are shown the boundaries of Groups and Sectors, and also the positions of the Balloon Barrages, together with an indication of the front covered by Radio Location Stations and the area covered by the Observer Corps.

53. The Balloon Barrages had, at this stage, had little opportunity of justifying their existence, except perhaps at Rosyth and Scapa Flow, since bombing attacks against land objectives in Britain had not yet begun. It was thought, however, (and later experience confirmed this opinion), that the heavy cost of their installation and maintenance, and their drain on man-power, were on the whole justified. It is true that their material results, in terms of enemy aircraft destroyed, were not impressive, they suffered staggering casualties in electric storms, and had brought down a number of our own aircraft; on the other hand, they exercise a very salutary moral effect upon the Germans and to a great extent protected the vital objectives, which they surrounded, against low-altitude attacks and dive-bombing.

54. This is not the place to give an account of the romantic discovery and development of Radio Location. It may be explained, however, that the backbone of the system consisted of a series of large "chain" stations at intervals averaging about 30 miles. These gave warning, by means of reflected electrical echoes, of the presence of aircraft within the radius of their effective action, which attained to nearly 200 miles in the most favourable circumstances. The average effective radius was about 80 miles, but they had the serious limitation that they failed altogether to give indications of aircraft flying below 1,000 feet.

55. To overcome this disability, which was particularly hampering to operations against low-flying minelayers, smaller units called "C.H.L. Stations" were included in the protective line.

56. These had a restricted range (about 30 miles), and were incapable of giving heights with any degree of accuracy; they were, however, extremely accurate in azimuth, and constituted an essential feature of the Defensive and Warning Systems.

57. The Radio Location system was growing so fast and had to meet so many calls from overseas that the training of the technical personnel and the maintenance of the elaborate scientific apparatus presented great difficulties. In spite of these handicaps, however, the system operated effectively, and it is not too much to say that the warnings which it gave could have been obtained by no other means and constituted a vital factor in the Air Defence of Great Britain.

* These guns belonged to Field Force Units. As such units were, of necessity, highly mobile, their exact location was not always known to Fighter Command. Nor, after a recent move, were they always included in the telephone system.

58. The functions of the Observer Corps (since granted the "Royal" prefix) are too well known to require description here. Suffice it to say that this loyal and public-spirited body of men had maintained their watch with admirable efficiency since the beginning of the war and throughout a winter of exceptional severity. It is important to note that, at this time, they constituted the sole means of tracking enemy raids once they had crossed the coast line. Later experience was to show that "sound plots," which were all that could be given for night raiders, and aircraft flying above clouds or at extreme altitudes, were not adequate for purposes of accurate interception; but their work throughout was quite invaluable. Without it the Air Raid Warning systems could not have been operated, and Inland Interceptions would rarely have been made.

59. The credit for building up and developing the Observer Corps in recent years is due largely to its Commandant, Air Commodore A. D. Warrington Morris, C.M.G., O.B.E.

60. The Air Raid Warning System was operated centrally from Fighter Command Headquarters (with a small exception in the Orkneys and Shetlands).

61. The country was divided into about 130 "Warning Districts," the boundaries of which were determined by the lay-out of the public telephone system. These districts were shown on a map in my Operations Room, and the tracks of all enemy raids, whether over the land or sea, were plotted by means of counters deposited and removed as necessary by a number of "Plotters."

62. The counters were of three colours, according to the 5-minute period in which they were placed on the table. This was necessary to facilitate their removal at the end of 15 minutes, and so to obviate the confusion caused by "stale plots."

63. Three telephone operators were in continuous communication with the Trunk Exchanges in London, Liverpool and Glasgow, and when a raid was within 20 minutes' flying distance of a warning district the Air Raid Warning officer would send a message, as, for instance: "10. Norwich. Yellow." The London operator would transmit this to the London Trunk Exchange, and the London operator would immediately retransmit it to Norwich, where other operators would pass it on to approved recipients in the Warning District. This was a preliminary caution for the information of Police, Fire Stations, &c., and involved no public warning.

64. About 5 minutes later, if the said District were still threatened, a "Red Warning" would be given. This was the signal for the Sirens to sound. A "Green" signal indicated "Raiders Passed," and the Sirens sounded the "All Clear."

65. At night, when it became essential to maintain exposed lights in Dockyards, Railway Sidings and Factories up to the last minute, so as to obviate unnecessary loss of working time, a "Purple" warning was introduced. This was a signal for the extinction of exposed lights, but it did not connote a public warning.

66. There were also subsidiary warnings, transmitted by a fourth operator, to close down Radio Stations which might assist the enemy's navigation by enabling him to use wireless Direction Finding.

67. The credit for working out this system in conjunction with the Home Office is due largely to Air Vice-Marshal A. D. Cunningham, C.B.E.

68. The Fighter Command was divided into Groups and Sectors in accordance with the arrangement shown in Appendix A A. Only Nos. 11, 12 and 13 Groups were fully organised at the beginning of the Battle. Each Group and Sector Headquarters had an Operations Table generally similar to that already described at Command Headquarters, but covering an appropriately smaller area. The British Isles and neighbouring seas were covered by an imaginary "grid" which was used by all concerned for plotting purposes. An expression consisting of one letter and four digits gave the position of a point with an accuracy of 1 square kilometre.

69. Plots from which tracks could be built up were received first from the Radio Location Station, and later from the Observer Corps (and to a small extent from Searchlight Detachments) after a raid had crossed the coast.

70. All Radio Location plots came to a "Filter Room" table at Command Headquarters (next door to the room in which the Operations Table was situated), and, after surplus information had been eliminated, tracks were passed by direct telephone line simultaneously to my Operations Table and to those of Groups and Sectors concerned.

71. Observer Corps plots, on the other hand, went first to Observer Group Centres (where plotting tables were also installed) and thence to Sector and Fighter Group Operations tables. The tracks were then "told" to my Operations Room from the Group Tables.

72. In order to avoid waste of flying effort and false Air Raid Warnings it was obviously very necessary to differentiate between friendly and enemy formations, and this was the most difficult as well as the most important task of my Filter Room. Liaison Officers from Bomber and Coastal Commands were permanently on duty, and they were in possession of all available information concerning the operations of our own Bombers and Coastal patrols. During 1940 an electrical device became generally available which modified the echo received by the Radio Location System from our own aircraft in a characteristic manner. This was of the greatest value.

73. The credit for working out the complicated details of the Filter Room belongs largely to Wing Commander (now Group Captain) R. G. Hart, C.B.E.

74. It appeared to me quite impossible to centralise Tactical control at Command Headquarters, and even Group Commanders would be too busy during heavy fighting to concern themselves with details of Interception.

75. The system was that the Command should be responsible for the identification of approaching formations and for the allotment of enemy raids to Groups where any doubt existed. Group Commanders decided which Sector should meet any specified raid and the

strength of the Fighter force which should be employed. Sector Commanders detailed the Fighter Units to be employed, and operated the machinery of Interception.

76. Various states of preparedness were laid down, *e.g.*, Released, Available (20 minutes), Readiness (5 minutes), and stand-by (2 minutes), and Sectors reported all changes to Group Headquarters, where an up-to-date picture of the state of affairs was recorded by lights on the walls of the Operations Room. Various liaison officers from the Observer Corps, guns and searchlights were maintained in Group and Sector Operations Rooms.

77. It will be seen that the Sector Commander had on his table the best available information as to the position and track of an enemy formation; but, in order to effect an accurate interception, it was necessary that he should also know the position and track of his own Fighters.

78. This was recorded by means of R/T D/F (Radio Telephony Direction Finding). R/T signals were transmitted automatically for 15 seconds out of each minute by selected Fighter aircraft and were picked up by two or three D/F stations installed in Sectors for the purpose. The readings were passed by direct telephone lines to Sector Headquarters, and a mechanical plotting device gave an almost instantaneous plot of the Fighter's position.

79. In the more recently organised Sectors these D/F stations had not been installed, and it was necessary to keep track of the Fighters by giving them precise orders as to speed and direction, and plotting their tracks by Dead Reckoning. This method was adequate only if the force and direction of the wind at various altitudes could be correctly estimated.

80. The Sector Commander could thus see on his operations tables the positions and courses of enemy formations and of his own Fighters, and was enabled so to direct the latter as to make interceptions with the former in a good percentage of occasions by day. Interception depended, of course, on the Fighters being able to see the enemy, and, although the system worked adequately against enemy formations in daylight, the degree of accuracy obtainable was insufficient to effect interception against night raiders not illuminated by Searchlights, or against individual aircraft using cloud cover by day.

81. Orders were given to pilots in their aircraft by means of a very simple code which could be easily memorised. For instance "Scramble" meant Take off. "Orbit" meant Circle. "Vector 230" meant Fly on a course of 230 Degrees.

82. I realised that the enemy might pick up the signals and interpret them, but any elaborate code was out of the question if it included reference to some written list in the air.

83. As a matter of fact the enemy did pick up and interpret the signals in some cases, but not much harm was done, except when they were able to discover the height at which a formation was ordered to operate, and the time when it was ordered to leave its patrol line and land.

84. "Pancake" was the signal for the latter operation, and I therefore introduced several synonyms, the significance of which was not obvious to the enemy.

85. The code word for height was "Angels," followed by the number of thousands of feet; when it appeared probable that the enemy were taking advantage of this information I introduced a false quantity into the code signal. Thus "Angels 18" really meant Fly at 21,000 and not 18,000. On more than one occasion German Fighter formations arriving to dive on one of our patrols were themselves attacked from above.

86. The system as a whole had been built up by successive steps over a period of about four years, and I was not dissatisfied with the way in which it stood the test of war.

87. The steps taken to devise a system of night Interception are described later in this Despatch.

88. I must now give a brief account of the characteristics of the aircraft commonly employed on both sides. As regards the Fighter types available in the Command, the bulk of the force consisted of Hurricanes and Spitfires; the former were beginning to be outmoded by their German counterparts. They were comparatively slow and their performance and manœuvrability were somewhat inadequate at altitudes above 20,000 ft. The Spitfires were equal or superior to anything which the Germans possessed at the beginning of the Battle.

89. The Hurricanes and Spitfires had bullet-proof windscreens and front armour between the top of the engine and the windscreen. They also had rear armour directly behind the pilot, which was previously prepared and fitted as soon as we began to meet the German Fighters. The early adoption of armour gave us an initial advantage over the Germans, but they were quick to imitate our methods. While German aircraft remained unarmoured, I think it is now generally agreed that the single-seater multi-gun fighter with fixed guns was the most efficient type which could have been produced for day fighting. With the advent of armour some change in armament and/or tactics became necessary, and the subject is discussed in more detail in Appendix F.

90. The Defiant, after some striking initial successes, proved to be too expensive in use against Fighters and was relegated to night work and to the attack of unescorted Bombers.

91. The Blenheim was also unsuitable for day-time combat with Fighters, owing to its low speed and lack of manœuvrability. It had been relegated to night duties for these reasons, and because adequate space was available in its fuselage for an extra operator and the scientific apparatus which was necessary for the development of a new night-interception technique. The cockpit had not been designed for night flying and the night view was extremely bad. Its already low performance had been further reduced by certain external fittings which were essential for the operation of the Radio Detecting apparatus.

92. The Beaufighter was looked on as a Blenheim replacement in which most of the above disadvantages would be overcome. Its speed promised to be adequate and its armament consisted of 4 20-mm. Cannons instead

of the 5 .303-inch Brownings of the Blenheim. There was thus hope that decisive fire could be brought to bear in the short period during which visual contact could be expected to be maintained at night.

93. Like the Blenheim, it had not been designed as a Night Fighter (it was an adaptation of the Beaufort Torpedo Bomber), and the night view from the cockpit was bad; but Air Vice-Marshal Sir Q. Brand, K.B.E., D.S.O., M.C., D.F.C., a veteran night fighter of the previous war, had designed a new cockpit lay-out, which did not, unfortunately, materialise during my tenure of the Fighter Command. The output of Beaufighters was also very low.

94. Another type which was pressed into service as a Night Fighter was the Douglas D.B.7 (now the Havoc). It had low fire power and comparatively poor performance with its original engines. Its chief advantage lay in its tricycle undercarriage, which proved very popular for landings in bad visibility. Only one Squadron of these was in being when I left the Command.

95. One Squadron of Gladiators was still in use in the Command. As explained above, the organisation of No. 10 Group was not complete, and there was no large aerodrome close enough to Plymouth to allow of direct protection being given to that town and to the Dockyard at Devonport. A squadron of Gladiators was therefore located at a small aerodrome called Roborough in the immediate vicinity. The Gladiators, though slow by modern standards, were very manœuvrable, and had given good results in Norway by deflection shooting in the defence of fixed objectives, where the Bombers could not avoid the Gladiators if they were to reach their targets.

96. Some American single-seater aircraft were in Great Britain, but the types then available were deficient in performance and fire power and were not employed to any material extent.

97. The Whirlwind raised high hopes in some quarters. It claimed a very high top speed and carried 4 Cannon Guns. It had, however, a totally inadequate service ceiling (about 25,000 ft.) and a poor performance at that altitude. It also suffered from a continuous series of teething troubles, and the single Squadron equipped with this type was never fit for operations in my time.

98. It is very difficult to give any kind of concise description of the types of Enemy Aircraft used during the Battle. The Germans, while adhering to broad standard types, were continually modifying and improving them by fitting more powerful engines and altering the armament. The original Messerschmitt 109, for instance, had a performance comparable with that of the Hurricane, but the latest type could compete with the Spitfire, and had a better ceiling. Some of them had 4 machine guns and others had 2 machine guns and 2 cannons. Some of them were fitted to carry bombs and some were not.

99. The Messerschmitt 110 was a twin-engined fighter designed primarily for escorting Bombers and used also as a Fighter-Bomber. It was somewhat faster than the Hurricane, but naturally much less manœuvrable than the single-engined types. Its usual armament was 2 fixed cannons and 4 machine guns firing forward, and one free machine gun firing to the rear. Our pilots regarded it as a less formidable opponent than the later types of M.E. 109.

100. The Heinkel 113 Fighter made its appearance in limited numbers during the Battle. It was a single seater, generally resembling the M.E. 109. Its main attributes were high performance and ceiling, so that it was generally used in the highest of the several layers in which attacking formations were usually built up.

101. The Junkers 87 was a single-engined Dive-Bomber. It had a low performance (top speed well under 250 m.p.h.). It had 2 fixed machine guns firing forward and one free gun firing to the rear. When it was able to operate undisturbed by Fighters it was the Germans' most efficient Bomber against land or sea targets owing to the great accuracy with which it dropped its bombs; but when it was caught by fighters it was nothing short of a death-trap, and formations of J.U. 87's were practically annihilated on several occasions.

102. The Heinkel 111 and the various types of Dornier (17, 17Z and 215) constituted the main element of the German striking force. They were twin-engined aircraft and were generally similar, although the former was slightly the larger. Their speed was something over 250 m.p.h., and their armament consisted normally (but not always) of 4 free machine guns firing backwards and one firing forwards. Their radius of action varied with tankage and bomb load, but, if necessary, all objectives in England and Northern Ireland could be reached from aerodromes in France.

103. The Junkers 88 was the most modern of the German Bombers. It also was a twin-engined type with a performance of about 290 m.p.h. Its armament was generally similar to that of the H.E. 111 and the Dorniers and it had a slightly longer range. It could be used on occasions as a Dive-Bomber and, though probably somewhat less accurate than the J.U. 87, was much less vulnerable owing to its superior performance and armament.

104. Before beginning an account of the Battle, I must refer briefly to the publication entitled *The Battle of Britain*, issued by the Air Ministry. This, if I may say so, is an admirable account of the Battle for public consumption, and I am indebted to it, as well as to the book *Fighter Command*, by Wing Commander A. B. Austin, for help in the compilation of this Despatch. There is very little which I should have wished to alter, even if circumstances had permitted my seeing it before publication (I was absent in America at the time), but there are two points to which I should like to draw attention:—

105. In the diagram on page 7 the speed of the Hurricane is seriously over-rated at 335 m.p.h. I carried out a series of trials to obtain the absolute and comparative speeds of Hurricanes and Spitfires at optimum heights. Naturally the speeds of individual aircraft varied slightly, but the average speed of six Hurricanes came out at about 305 m.p.h.

106. The second point is of greater importance. I quote from page 33: "What the Luftwaffe failed to do was to destroy the Fighter Squadrons of the Royal Air Force,

*which were, indeed, stronger at the end of the battle than at the beginning.*" (The italics are mine.)

107. This statement, even if intended only for popular consumption, tends to lead to an attitude of complacency which may be very dangerous in the future. Whatever the study of paper returns may have shown, the fact is that the situation was critical in the extreme. Pilots had to be withdrawn from the Bomber and Coastal Commands and from the Fleet Air Arm and flung into the Battle after hasty preparation. The majority of the squadrons had been reduced to the status of training units, and were fit only for operations against unescorted bombers. The remainder were battling daily against heavy odds.

108. The indomitable courage of the Fighter Pilots and the skill of their Leaders brought us through the crises, and the morale of the Germans eventually cracked because of the stupendous losses which they sustained.

109. Any attempt to describe the events of the Battle day by day would make this Despatch unduly long and would prevent the reader from obtaining a comprehensive picture of the events. I have therefore decided to show the main features of each day's fighting in an Appendix on which our own and the Germans' aircraft casualties will be shown graphically. I shall then be able to deal with the progress of the Battle by phases, thus avoiding the tedious and confusing method of day-to-day description. The information is given in Appendix D.

110. As regards our casualties, we generally issued statements to the effect that we lost "x" aircraft from which "y" pilots were saved. This did not of course mean that "y" pilots were ready immediately to continue the Battle. Many of them were suffering from wounds, burns or other injuries which precluded their return to active flying temporarily or permanently.

111. It might also be assumed that all German crews who were in aircraft brought down during the Battle, were permanently lost to the Luftwaffe because the fighting took place on our side of the Channel. Such an assumption would not be literally true, because the Germans succeeded in rescuing a proportion of their crews from the sea by means of rescue boats, floats and aircraft which will be later described.

112. The decisive features of the Battle were the Ratio of Casualties incurred by ourselves and the Germans, and the Ratio of Casualties to the numbers actively employed on both sides. Appendix D has been drawn up with these points in mind.

113. I must disclaim any exact accuracy in the estimates of Enemy losses. All that I can say is that the utmost care was taken to arrive at the closest possible approximation. Special intelligence officers examined pilots individually after their combats, and the figures claimed are only those recorded as "Certain." If we allow for a percentage of over-statement, and the fact that two or more Fighters were sometimes firing at the same enemy aircraft without being aware of the fact, this can fairly be balanced by the certainty that a proportion of aircraft reported as "Probably Destroyed" or "Damaged" failed to return to their bases. The figures, then, are put forward as an honest approximation. Judging by results, they are perhaps not far out.

114. The German claims were, of course, ludicrous; they may have been deceived about our casualties, but they know they were lying about their own.

115. I remember being cross-examined in August by the Secretary of State for Air about the discrepancy. He was anxious about the effect on the American people of the wide divergence between the claims of the two sides. I replied that the Americans would soon find out the truth; if the Germans' figures were accurate they would be in London in a week, otherwise they would not.

116. Our estimate of German casualties, then, may be taken as reasonably accurate for practical purposes; but our estimates of the strength in which attacks were made is based on much less reliable evidence. The Radio-Location system could give only a very approximate estimate of numbers and was sometimes in error by three or four hundred per cent. This is no reflection on the System, which was not designed or intended to be accurate in the estimation of considerable numbers; moreover, several stations were suffering from the effects of severe bombing attacks. As the average height of operations increased, the Observer Corps became less and less able to make accurate estimates of numbers, and, in fact, formations were often quite invisible from the ground.

117. Even the numerical estimates made by pilots who encountered large formations in the air are likely to be guesswork in many instances. Opportunities for deliberate counting of enemy aircraft were the exception rather than the rule.

118. Although Secret Intelligence sources supplemented the information available, it is possible that on days of heavy fighting complete formations may have escaped recorded observation altogether.

119. This is unfortunate, because it is obviously of the greatest importance to determine the relative strengths of the Attack and the Defence, and to know the ratio of losses to aircraft employed which may be expected to bring an attack to a standstill in a given time. History will doubtless elucidate the uncertainty, but perhaps not in time for the information to be of use in the present war.

120. My personal opinion is that, on days of slight activity, our estimates are reasonably accurate, but that they probably err on the low side on days of heavy fighting when many and large formations were employed.

121. As has been explained above, few squadrons were fresh and intact when the Battle began. No sufficient respite has been granted since the conclusion of the Dunkerque fighting to rest the Squadrons which had not left the Fighter Command, and to rebuild those which had undergone the ordeal of fighting from aerodromes in Northern France. These last had been driven from aerodrome to aerodrome, able only to aim at self-preservation from almost continuous attack by Bombers and Fighters; they were desperately weary and had lost the greater part of their equipment, since aircraft which were unserviceable only from slight defects had to be abandoned.

PART II.—THE BATTLE.

122. The Battle may be said to have divided itself broadly into 4 Phases: First, the attack on convoys and Coastal objectives, such as Ports, Coastal Aerodromes and Radio Location Stations. Second, the attack of Inland Fighter Aerodromes. Third, the attack on London. And fourth, the Fighter-Bomber stage, where the target was of importance quite subsidiary to the main object of drawing our Fighters into the air and engaging them in circumstances as disadvantageous to us as possible. These phases indicated only general tendencies; they overlapped and were not mutually exclusive.

123. It has been estimated that the Germans sent over, on an average throughout the Battle, four Fighters to each Bomber or Fighter-Bomber, but any such estimate must be very rough.

124. I must emphasise, throughout, the extreme versatility of the German methods both in the timing and direction of their attacks, and in the tactical formations and methods employed.

125. They enjoyed the great advantage of having a wide front from which attacks could be delivered. First a blow would be delivered from Calais, perhaps against London; then after a carefully-timed interval, when 11 Group Fighters might be expected to be at the end of their petrol endurance, a heavy attack would be made on Southampton and Portland. Other attacks, after being built up to formidable dimensions, would prove to be only feints, and the Bombers would turn away before reaching coast of England, only to return again in half an hour, when the Fighters, sent up to intercept them, were landing.

126. Time-honoured methods of escort were at first employed. A strong Fighter formation would fly a mile or so behind and above the Bombers. When the Germans found that our Fighters could deliver a well-timed attack on the Bombers before the Fighters could intervene, or when our Fighters attacked from ahead or below, each move was met by a counter-move on the part of the Germans, so that, in September, Fighter escorts were flying inside the Bomber formation, others were below, and a series of Fighters stretched upwards to 30,000 feet or more.

127. One Squadron Leader described his impressions of the appearance of one of these raids; he said it was like looking up the escalator at Piccadilly Circus.

128. I must pay a very sincere tribute to the Air Officer Commanding No. 11 Group, Air Vice-Marshal K. R. Park, C.B., M.C., D.F.C., for the way in which he adjusted his tactics and interception methods to meet each new development as it occurred.

129. Tactical control was, as has already been stated, devolved to the Groups; but tactical methods were normally laid down by Command Headquarters. During periods of intense fighting, however, there was no time for consultation, and Air Vice-Marshal Park acted from day to day on his own initiative. We discussed matters as opportunity offered.

130. He has reported on the tactical aspects of the Battle in two very interesting documents, which are, however, too long to reproduce here.

131. A close liaison was kept between Nos. 10 and 11 and 12 Groups. It sometimes happened that, in the heaviest attacks, practically all 11 Group Fighters would be in the air. 11 Group would then ask 12 Group to send a formation from Duxford to patrol over the aerodromes immediately East of London so that these might not be attacked when defenceless.

132. Mutual help was also arranged between Nos. 10 and 11 Groups. When Portsmouth was attacked, for instance, No. 10 would help No. 11 Group, and *vice versa* when the attack was on Portland or some Convoy to the West of the Isle of Wight.

133. The amount of physical damage done to Convoys during the first phase was not excessive. About five ships (I think) were actually sunk by bombing, others were damaged, and Convoys were scattered on occasion. It was, of course, much easier to protect the Convoys if they kept as close as possible to the English Coast, but one Convoy at least was routed so as to pass close to Cherbourg, and suffered accordingly. Later, it was arranged that Convoys should traverse the most dangerous and exposed stretches by night, and Convoys steaming in daylight either had direct protection by Fighter escorts, or else had escorts at "Readiness" prepared to leave the ground directly danger threatened.

134. Three of the Radio Location Stations in the South of England suffered rather severe damage and casualties. No Station was permanently put out of action, and the worst damage was repaired in about a month, though the Station was working at reduced efficiency in about half that time. The operating personnel, and particularly the women, behaved with great courage under threat of attack and actual bombardment.

135. As regards aerodromes, Manston was the worst sufferer at this stage. It, Hawkinge and Lympne were the three advanced grounds on which we relied for filling up tanks when a maximum range was required for operations over France. They were so heavily attacked with bombs and machine guns that they were temporarily abandoned. This is not to say that they could not have been used if the need had been urgent, but, for interception at or about our own coastline, aerodromes and satellites farther inland were quite effective.

136. Heavy damage was done to buildings, but these were mostly non-essential, because aircraft were kept dispersed in the open, and the number of men and women employed was not large in comparison with the number at a Station which was the Headquarters of a Sector.

137. Works personnel, permanent and temporary, and detachments of Royal Engineers were employed in filling up the craters on the aerodromes. Experience at this stage showed that neither the personnel nor the material provided were adequate to effect repairs with the necessary speed, and the strength and mobility of the repair parties was increased. Stocks of "hard-core" rubble had been collected at Fighter aerodromes before the war.

138. It may be convenient here to continue the subject of damage to Fighter Stations other than those attacked in the first Phase.

139. Casualties to personnel were slight, except in cases where a direct hit was made on

a shelter trench. The trenches commonly in use were lined with concrete and were roofed and covered with earth; but they gave no protection against a direct hit, and, in the nature of things, they had to be within a short distance of the hangars and offices.

140. Only non-essential personnel took cover; aircraft crews and the staff of the Operations Room remained at their posts. The morale of the men and women of ground crews and staffs was high and remained so throughout.

141. At Kenley and at Biggin Hill direct hits were sustained on shelter trenches, at the latter place by a bomb of 500 kilog. or more. The trench and its 40 occupants were annihilated.

142. Wooden hangars were generally set on fire by a bombing attack, and everything in them destroyed.

143. Steel, brick and concrete hangars, on the other hand, stood up well against attack, though, of course, acres of glass were broken. Hangars were generally empty or nearly so, and those aircraft which were destroyed in hangars were generally under repair or major inspection which made it necessary to work under cover.

144. It must, nevertheless, be definitely recorded that the damage done to Fighter aerodromes, and to their communications and ground organisation, was serious, and has been generally under-estimated. Luckily, the Germans did not realise the success of their efforts, and shifted their objectives before the cumulative effect of the damage had become apparent to them.

145. Damage to aerodrome surface was not a major difficulty. It was possible for the Germans to put one or two aerodromes like Manston and Hawkinge out of action for a time, but we had so many satellite aerodromes and landing grounds available that it was quite impossible for the Germans to damage seriously a number of aerodromes sufficient to cause more than temporary inconvenience.

146. This is an important point, because, in mobile warfare, Fighter aerodromes cannot be hastily improvised in broken country, and the number of aerodromes actually or potentially available is a primary factor in the "Appreciation of a Situation."

147. Sector Operations Rooms were protected by high earth embankments, so that they were immune from everything except a direct hit, and, as a matter of fact, no direct hit by a heavy bomb was obtained on any Operations Room. Communications were, however, considerably interrupted, and I must here pay a tribute to the foresight of Air Vice-Marshal E. L. Gossage, C.B., C.V.O., D.S.O., M.C., who commanded No. 11 Group during the first eight months of the war. At his suggestion "Stand-by" Operations Rooms were constructed at a distance of two or three miles from Sector Headquarters, and a move was made to these when serious attacks on Fighter Aerodromes began. They were somewhat inconvenient make-shifts, and some loss of efficiency in Interception resulted from their use. Work was put in hand immediately on more permanent and fully-equipped Operations Rooms conveniently remote from Sector Headquarters; these though in no way bomb-proof, were outside the radius of anything aimed at the Sector Aerodrome, and owed their immunity to inconspicuousness. Most of these were finished by October 1940.

148. Aerodrome Defence against parachute troops, or threat of more serious ground attack, was an important and a difficult problem, because Home Defence troops were few and were needed on the Beaches, and the majority of troops rescued from Dunkerque were disorganised and unarmed. The Commander-in-Chief, Home Forces, did, however, make troops available in small numbers for the more important aerodromes and armoured vehicles were extemporised. The difficulty was enhanced by a comparatively recent decision of the Air Ministry to disarm the rank and file of the Royal Air Force. The decision was reversed, but it was some time before rifles could be provided and men trained in their use.

149. The slender resources of the Anti-Aircraft Command were strained to provide guns for the defence of the most important Fighter and Bomber Aerodromes. High Altitude and Bofors guns were provided up to the limit considered practicable, and the effort was reinforced by the use of Royal Air Force detachments with Lewis guns and some hundreds of 20-mm. Cannon which were not immediately required for use in Aircraft

150. A type of small Rocket was also installed at many aerodromes. These were arranged in lines along the perimeter, and could be fired up to a height of something under 1,000 feet in the face of low-flying attack. They carried a small bomb on the end of a wire. Some limited success was claimed during a low-flying attack at Kenley, and they probably had some moral effect when their existence became known to the Enemy. They were, of course, capable of physical effect only against very low horizontal attacks.

151. The main safeguard for Aircraft against air attack was Dispersal. Some experiments on Salisbury Plain in the Summer of 1938 had shown that dispersal alone, without any form of splinter-proof protection, afforded a reasonable safeguard against the forms of attack practised by our own Bomber Command at the time. Thirty unserviceable Fighters were disposed in a rough ring of about 1,000 yards diameter, and the Bomber Command attacked them for the inside of a week with every missile between a 500-pound bomb and an incendiary bullet, and without any kind of opposition. The result was substantially:—3 destroyed, 1 damaged beyond repair, 11 seriously damaged but repairable, and the rest slightly damaged or untouched.

152. I therefore asked that small splinter-proof pens for single aircraft should be provided at all Fighter Aerodromes. This was not approved, but I was offered pens for groups of three. I had to agree to this, because it was linked up with the provision of all-weather runways which I had been insistently demanding for two years, and it was imperatively necessary that work on the runways should not be held up by further discussion about pens. I think that the 3-aircraft pens were too big. They had a large open face to the front and a concrete area, of the size of two tennis courts, which made an ideal surface for the bursting of direct-action bombs. Eventually, splinter-proof partitions were made inside the

pens, and till then some aircraft were parked in the open. Losses at dispersal points were not serious; the worst in my recollection was 5 aircraft destroyed or seriously damaged in one attack. Small portable tents were provided which could be erected over the centre portion of an aeroplane, leaving the tail and wing-tips exposed. These protected the most important parts and enabled ground crews to work in bad weather.

153. About this time an improvised Repair System was organised and worked well. With the hearty co-operation of the Ministry of Aircraft Production it was decided that Units should be relieved of all extensive repairs and overhauls, both because of their preoccupation in the Battle and because of the danger of further damage being done by enemy action to aircraft under repair. Broadly speaking, any aircraft capable of returning to its base was capable of another 15 minutes' straight flight to a Repair Depot: aircraft incapable of flight were sent by road. Small repairs, such as the patching of bullet holes, were done by the Unit. Two such Repair Depots were improvised about 30 miles to the west of London, and this undoubtedly prevented an accumulation of unserviceable aircraft at Fighter Stations.

154. It was also about this time that the final decision was made to relegate the Defiant to night operations. It had two serious disabilities; firstly, the brain flying the aeroplane was not the brain firing the guns: the guns could not fire within 16 Degrees of the line of flight of the aeroplane and the gunner was distracted from his task by having to direct the pilot through the Communication Set. Secondly, the guns could not be fired below the horizontal, and it was therefore necessary to keep below the enemy. When beset by superior numbers of Fighters the best course to pursue was to form a descending spiral, so that one or more Defiants should always be in a position to bring effective fire to bear. Such tactics were, however, essentially defensive, and the formation sometimes got broken up before they could be adopted. In practice, the Defiants suffered such heavy losses that it was necessary to relegate them to night fighting, or to the attack of unescorted Bombers.

155. The above remarks have carried me beyond the first phase of the Battle and into the second; but I find it impossible to adhere to a description of the fighting phase by phase. The Enemy's Strategical, as well as his Tactical moves had to be met from day to day as they occurred, and I give an account of my problems and the lessons to be derived from them roughly in the order of their incidence. The detailed sequence of events is sufficiently indicated in the Diagram at Appendix "D."

156. Throughout the Battle, of course, fighting continually occurred over the sea, and German aircraft, damaged over England, had to return across the Straits of Dover or the English Channel. Far more German than British crews fell into the sea. The Germans therefore developed an elaborate system of sea-rescue. Their Bombers had inflatable rubber dinghies, and various other rescue devices were adopted. Crews were provided with bags of a chemical known as fluorescine, a small quantity of which stained a large area of water a vivid green. Floating refuges with provisions and wireless sets were anchored off the French coast. "E Boats" and rescue launches were extensively employed, and white-painted float-planes, marked with the Red Cross, were used even in the midst of battle. We had to make it known to the Germans that we could not countenance the use of the Red Cross in this manner. They were engaged in rescuing combatants and taking them back to fight again, and they were also in a position, if granted immunity, to make valuable reconnaisance reports. In spite of this, surviving crews of these aircraft appeared to be surprised and aggrieved at being shot down.

157. Our own arrangements were less elaborate. Life-saving jackets were painted a conspicuous yellow, and later the fluorescine device was copied. Patrol aircraft (not under the Red Cross) looked out for immersed crews, and a chain of rescue launches with special communications was installed round the coast. Our own shipping, too, was often on the spot, and many pilots were rescued by Naval or Merchant vessels.

158. This is perhaps a convenient opportunity to say a word about the ethics of shooting at aircraft crews who have "baled out" in parachutes.

159. Germans descending over England are prospective Prisoners of War, and, as such, should be immune. On the other hand, British pilots descending over England are still potential Combatants.

160. Much indignation was caused by the fact that German pilots sometimes fired on our descending airmen (although, in my opinion, they were perfectly entitled to do so), but I am glad to say that in many cases they refrained and sometimes greeted a helpless adversary with a cheerful wave of the hand.

161. Many of the targets attacked during the first two phases of the Battle were of little military importance, and had but slight effect on our War Effort. Exceptions to this were day-attacks carried out on the Spitfire works at Southampton and the sheds at Brooklands where some of our Hurricanes were assembled and tested. Both these attacks had some effect on output, which would have been serious but for the anticipatory measures taken by Lord Beaverbrook.

162. About this time one Canadian, two Polish and one Czech squadrons became fit for Operations.

163. A squadron of Canadian pilots of the Royal Air Force (No. 242) had been in existence for some months, and was one of the squadrons which went to France in June to cover the evacuation from the West Coast. On its return it became one of the foremost fighting Squadrons in the Command, under the leadership of the very gallant Squadron Leader (now Wing Commander) D. R. S. Bader, D.S.O., D.F.C., No. 1 (Canadian) Squadron, now also came into the line and acquitted itself with great distinction.

164. I must confess that I had been a little doubtful of the effect which their experience in their own countries and in France might have had upon the Polish and Czech pilots, but my doubts were soon laid to rest, because all three Squadrons swung in the fight with a dash and enthusiasm which is beyond praise. They were inspired by a burning hatred for the

Germans which made them very deadly opponents. The first Polish Squadron (No. 303) in No. 11 Group, during the course of a month, shot down more Germans than any British unit in the same period. Other Poles and Czechs were used in small numbers in British Squadrons, and fought very gallantly, but the language was a difficulty, and they were probably most efficiently employed in their own National units. Other foreign pilots were employed in British Squadrons, but not in appreciable numbers. The American "Eagle" Squadron was in process of formation during the Battle.

165. The Auxiliary Squadrons were by this time practically indistinguishable from Regulars. It will be remembered that the Scottish Auxiliaries were responsible for the first Air success of the War in the Firth of Forth. To set off against the discontinuity of their training in peace time they had the great advantage of permanency of personnel, and the Flight Commanders at the outbreak of the War were senior and experienced. At the same time, this very permanence led to the average age of the pilots being rather high for intensive fighting, which exercises a strain which the average man of 30 cannot support indefinitely. This point has now ceased to be of importance because of fresh postings. It is mentioned only because it is a factor to be kept in mind in peace time. No praise can be too high for the Auxiliaries, both as regards their keenness and efficiency in peace time and their fighting record in war.

166. I may perhaps mention the question of the Long Range Guns which were mounted along the coast of France near Cap Grisnez. They were within range of our coastal aerodromes, which they occasionally subjected to a desultory shelling. Their main targets, however, were Dover and the Convoys passing through the Straits. So far as I am aware, neither they nor the guns which we installed as counter measures, had any great influence on the air fighting, but they did of course make it impossible for any of our warships to approach the French coast in clear weather, and might have had an important effect if it had been possible for the Germans to launch an invading army.

167. About the end of the second phase, the problems of keeping units up to strength and of relieving them when exhausted began to assume formidable proportions. It was no new experience, because the drain of units and pilots to France, coupled with the Dunkerque fighting, had created similar problems in the Spring.

168. The comparative relaxation in the intensity of the fighting in June and July had afforded a little respite, but units had only partially recovered and were neither fresh nor up to strength when the fighting again became intense.

169. When Squadrons became exhausted, obviously the most satisfactory way of reinforcement was by means of moving complete units, and this was done when time allowed. Serviceable aircraft were transferred by air, and Operational Aircraft Crews (about 35 men per Squadron) were transferred by Civil Aircraft put at my disposal for the moves. The remainder of the personnel travelled by train or motor transport according to circumstances. Some of the distances involved were considerable, as for instance when a Squadron from Wick had to be brought down in the London Area.

170. The First-line strength of a Squadron was 16 aircraft, of which not more than 12 were intended to be operationally available at any one time. The other 4 would normally be undergoing Inspection or Overhaul. In addition to this there was a small reserve of three to five aircraft per Squadron available on the station.

171. There was a limit to the number of trained pilots which could be kept on the strength of a Squadron even in times of operational passivity, because not more than about 25 could be kept in full practice in Flying Duties.

172. A fresh squadron coming into an active Sector would generally bring with them 16 aircraft and about 20 trained pilots. They would normally fight until they were no longer capable of putting more than 9 aircraft into the air, and then they had to be relieved. This process occupied different periods according to the luck and skill of the unit. The normal period was a month to six weeks, but some units had to be replaced after a week or 10 days.

173. Air Vice Marshal Park found that the heaviest casualties were often incurred by newly-arrived Squadrons owing to their non-familiarity with the latest developments of air fighting.

174. It soon became impossible to maintain the to-and-fro progress of complete unit personnel from end to end of the country, and the first limitation to efficiency which had to be accepted was the retention of the majority of personnel at Sector Stations and the transfer only of flying personnel and aircraft crews. This limitation was regrettable because it meant that officers and men were strange to one another, but worse was to come.

175. By the beginning of September the incidence of casualties became so serious that a fresh squadron would become depleted and exhausted before any of the resting and reforming squadrons was ready to take its place. Fighter pilots were no longer being produced in numbers sufficient to fill the gaps in the fighting ranks. Transfers were made from the Fleet Air Arm and from the Bomber and Coastal Commands, but these pilots naturally required a short flying course on Hurricanes or Spitfires and some instruction in Formation Flying, Fighter Tactics and Interception procedure.

176. I considered, but discarded, the advisability of combining pairs of weak units into single Squadrons at full strength, for several reasons, one of which was the difficulty of recovery when a lull should come. Another was that ground personnel would be wasted, and a third was that the rate at which the strength of the Command was decreasing would be obvious.

177. I decided to form 3 Categories of Squadron:—

(*a*) The units of 11 Group and on its immediate flanks, which were bearing the brunt of the fighting.

(*b*) A few outside units to be maintained at operational strength and to be available as Unit Reliefs in cases where this was unavoidable.

(*c*) The remaining Squadrons of the Command, which would be stripped of their operational pilots, for the benefit of the A Squadrons, down to a level of 5 or 6. These C Squadrons could devote their main energies to the training of new pilots, and, although they would not be fit to meet German Fighters, they would be quite capable of defending their Sectors against unescorted Bombers, which would be all that they would be likely to encounter.

178. The necessity for resorting to such measures as this indicates the strain which had been put on the Fighter Command and the Pilot Training organisations by the casualties which the Command had suffered in this decisive Battle.

179. In the early stages of the fight Mr. Winston Churchill spoke with affectionate raillery of me and my "Chicks." He could have said nothing to make me more proud; every Chick was needed before the end.

180. I trust that I may be permitted to record my appreciation of the help given me by the support and confidence of the Prime Minister at a difficult and critical time.

181. In the early days of the War the question of the provision of Operational Training Units (or Group Pools, as they were called at that time) was under discussion. It was referred to in the correspondence which I have mentioned in paragraph 17 of this Despatch. At that time I was so gravely in need of additional Fighter Squadrons that I was willing to do without Group Pools altogether while we were still at long range from the German Fighters.

182. The functions of these Group Pools, or O.T.Us., was to accept pilots direct from Flying Training Schools or non-fighter units of the Royal Air Force and train them in the handling of Fighter types, formation flying, fighting tactics, and R/T control and interception methods. I realised that the Fighters in France could not undertake this work and must have a Group Pool allotted primarily to meet their requirements, but I felt that, so long as we at Home were out of touch with German Fighters, I would prefer to put all available resources into new Squadrons and to undertake in Service Squadrons the final training of pilots coming from Flying Training Schools, provided that they had done some formation flying and night flying, and had fired their guns in the air.

183. Of course, when intensive fighting began, final training of pilots in Squadrons could no longer be given efficiently, and at the time of the Battle three O.T.Us. were in existence. It was found that three weeks was about the mimimum period which was of practical value, but that a longer course, up to six weeks, was desirable when circumstances permitted.

184. During the Battle the output from the O.T.Us. was quite inadequate to meet the casualty rate, and it was not even possible to supply from the Flying Training Schools the necessary intake to the O.T.Us.

185. The lack of flexibility of the Training system, therefore, proved to be the "bottleneck" and was the cause of the progressively deteriorating situation of the Fighter Command up till the end of September. This statement is in no sense a criticism of the Flying Training Command. The problem, as I state it here, can have no ideal solution and some compromise must be adopted.

186. Assuming that in periods of maximum quiescence the Fighter Squadrons of the Royal Air Force require an intake of x pilots per week, in periods of intense activity they require about ten times the number.

187. It is necessary to start the flying training of a pilot about a year before he is ready to engage Enemy Fighters, and therefore the training authorities should be warned, a year ahead, of the incidence of active periods. This is obviously impossible. If they try to be ready for all eventualities by catering for a continuous output to meet a high casualty rate, the result is that, during quiet periods, pilots are turned out at such a rate that they cannot be absorbed, or even given enough flying to prevent their forgetting what they have been taught. If, on the other hand, they cater for the normal wastage rate, Fighter Squadrons are starved of reinforcements when they are most vitally needed.

188. The fundamental principle which must be realised is that Fighter needs, when they arise, are not comparative with those of other Commands, but absolute. An adequate and efficient Fighter force ensures the Security of the Base, without which continuous operations are impossible.

189. If the Fighter defence had failed in the Autumn of 1940, England would have been invaded. The paralysis of their fighters in the Spring was an important factor in the collapse of the French resistance. Later, the unavoidable withdrawal of the Fighters from Crete rendered continued resistance impossible.

190. Day Bomber and Army Co-operation aircraft can operate when their own Fighters are predominant, but are driven out of the sky when the Enemy Fighters have a free hand.

191. I submit some suggestions by which the apparently insuperable difficulties of the problem may be reduced.

(*a*) Start by aiming at a Fighter output well above that needed in quiescent periods.

(*b*) Ensure that at Flying Training Schools, pupils earmarked for other duties may be rapidly switched over to Fighter training.

(*c*) Organise the O.T.Us. with a "Normal" and an "Emergency" Syllabus, the latter lasting for three weeks and the former twice as long.

(*d*) Fill up the Service Fighter Squadrons to a strength of 25 pilots, or whatever the C.-in-C. considers to be the maximum which can be kept in flying and operational practice.

(*e*) Form Reservoirs, either at O.T.Us. or in special units where surplus pilots may maintain the flying and operational standard which they have reached.

(*f*) When the initiative lies in our hands (as, for instance, when we are planning to deliver an offensive some time ahead), the

intake of Flying Training Schools should be adjusted to cater for the additional stress which can be foreseen.

(g) (And this applies principally to overseas theatres of war where rapid reinforcement is impossible.) Let the Day Bomber and Army Co-operation Squadrons have a number of Fighters on which they can fly and train as opportunity offers. This is a revolutionary suggestion, but it is made in all seriousness. If their Fighters are overwhelmed the Day Bomber and Army Co-operation units will not be able to operate at all. No very high standard of training should be attempted, especially in Radio-controlled Interception methods: but the intervention of these units as Fighters, working in pairs or small formations, might well prove to be the decisive factor in a critical situation.

192. It will be observed that, at the end of the second Phase of the Battle, the power of reinforcing by complete units had substantially disappeared. We still possessed an effective reserve of trained pilots, but they could be made available only by stripping the Squadrons which were not engaged in the South and South-East of England.

193. The effective strength of the Command was running down, though the fact was not known to the public, nor, I hoped, to the Germans. They for their part must certainly be feeling the effect of their heavy losses, but there was very little indication of any loss of morale, so far as could be seen from a daily scrutiny of the examinations of Prisoners of War. Our own pilots were fighting with unabated gallantry and determination.

194. The confidence of the German High Command probably received something of a shock about this time. The sustained resistance which they were meeting in South-East England probably led them to believe that Fighter Squadrons had been withdrawn, wholly or in part, from the North in order to meet the attack. On the 15th August, therefore, two large raids were sent, one to Yorkshire and one to Newcastle. They were escorted by Fighters. The distance was too great for Me. 109s, but not for Me. 110s.

195. If the assumption was that our Fighters had been withdrawn from the North, the contrary was soon apparent, and the bombers received such a drubbing that the experiment was not repeated. I think that this incident probably had a very depressing influence on the outlook of the German High Command.

196. As I have said, our own pilots were fighting with the utmost gallantry and determination, but the mass raids on London, which were the main feature of the third phase of the Battle, involved a tremendous strain on units which could no longer be relieved as such. Some Squadrons were flying 50 and 60 hours per diem.

197. Many of the pilots were getting very tired. An order was in existence that all pilots should have 24 hours' leave every week, during which they should be encouraged to leave their station and get some exercise and change of atmosphere: this was issued as an order so that the pilots should be compelled to avail themselves of the opportunity to get the necessary rest and relaxation. I think it was generally obeyed, but I fear that the instinct of duty sometimes over-rode the sense of discipline. Other measures were also taken to provide rest and relaxation at Stations, and sometimes to find billets for pilots where they could sleep away from their Aerodromes.

198. During this third phase the problem arose, in an acute form, of the strength of Fighter formations which we should employ. When time was the essence of the problem, two squadrons were generally used by A.V.M. Park in No. 11 Group. He had the responsibility of meeting attacks as far to the Eastward as possible, and the building up of a four-squadron formation involved the use of a rendezvous for aircraft from two or more aerodromes. This led to delay and lack of flexibility in leadership.

199. On the other hand, when No. 12 Group was asked to send down protective formations to guard the aerodromes on the Eastern fringe of London, it was often possible to build up big formations, and these had great success on some occasions, though by no means always.

200. Because a similar situation may well arise in future, I think that it is desirable to enter into some detail in this connection.

201. I may preface my remarks by stating that I am personally in favour of using Fighter formations in the greatest strength of which circumstances will permit, and, in the Dunkerque fighting, where we could choose our time and build up our formations on the outward journey, I habitually employed four-Squadron formations as a preferable alternative to using two-Squadron formations at more frequent intervals; but, during the attacks on London, the available strength of Fighters did not admit of this policy, nor was time available.

202. I quote from Air Vice-Marshal Park's report:—

"The general plan adopted was to engage the enemy high-fighter screen with pairs of Spitfire Squadrons from Hornchurch and Biggin Hill half-way between London and the coast, and so enable Hurricane Squadrons from London Sectors to attack bomber formations and their close escort before they reached the line of fighter aerodromes East and South of London. The remaining Squadrons from London Sectors that could not be despatched in time to intercept the first wave of the attack by climbing in pairs formed a third and inner screen by patrolling along the lines of aerodromes East and South of London. The fighter Squadrons from Debden, Tangmere, and sometimes Northolt, were employed in wings of three or in pairs to form a screen South-East of London to intercept the third wave of the attack coming inland, also to mop up retreating formations of the earlier waves. The Spitfire Squadrons were redisposed so as to concentrate three Squadrons at each of Hornchurch and Biggin Hill. The primary rôle of these Squadrons was to engage and drive back the enemy high-fighter screen, and so protect the Hurricane Squadrons, whose task was to attack close escorts and then the bomber formations, all of which flew at much lower altitude."

203. I think that, if the policy of big formations had been attempted at this time in No. 11

Group, many more Bombers would have reached their objectives without opposition.

204. Air Vice-Marshal Park also quotes the results of the ten large formations ordered from Duxford into No. 11 Group in the last half of October, when the Germans were employing Fighter-types only. Nine of these sorties made no interception, and the tenth destroyed one Me. 109.

205. The most critical stage of the Battle occurred in the third phase. On the 15th September the Germans delivered their maximum effort, when our Guns and Fighters together accounted for 185 aircraft. Heavy pressure was kept up till the 27th September, but, by the end of the month, it became apparent that the Germans could no longer face the Bomber wastage which they had sustained, and the operations entered upon their fourth phase, in which a proportion of enemy Fighters themselves acted as Bombers.

206. This plan, although the actual damage caused by bombs was comparatively trivial, was aimed primarily at a further whittling down of our Fighter strength, and, of all the methods adopted by the Germans, it was the most difficult to counter. Apart from the previous difficulty of determining which formations meant business, and which were feints, we had to discover which formations carried bombs and which did not.

207. To meet this difficulty, Air Vice-Marshal Park devised the plan of using single Spitfires, flying at maximum height, to act as Reconnaissance aircraft and to report their observations immediately by R/T.

208. A special Flight was organised for this purpose, and it was later recommended that the Spitfires should be employed in pairs, for reasons of security, and that the Flight should become a Squadron. A special R/T receiving set was erected at Group Headquarters so that reports might be obtained without any delay in transmission from the Sector receiving station. There is reason to believe that the Germans also adopted a system of using high-flying H.E. 113s as Scouts. Their information concerning our movements was transmitted to the ground and relayed to their Bombers in the air.

209. In the fourth phase, the apparent ratio of losses in our favour dropped appreciably. I say " apparent " because, in fighting at extreme altitudes, fighters often could not see their victims crash, and the percentage reported as Certainly Destroyed was unfairly depressed. Our own casualties, nevertheless, were such that the C. Category squadrons, which I was hoping to build up to operational strength again, remained in their condition of semi-effectiveness.

210. Serious as were our difficulties, however, those of the enemy were worse, and by the end of October the Germans abandoned their attempts to wear down the Fighter Command, and the country was delivered from the threat of immediate invasion.

211. The Order of Battle at the beginning of November is shown at Appendix E. Categories of Squadrons (A, B. or C, *vide* paragraph 177) are indicated.

212. Increasingly throughout the Battle had the importance of a high " ceiling " been manifested. It is by no means necessary that every Fighter shall have its best performance at stratospheric heights; any such policy would result in a loss of performance at lower altitude, and we must never lose sight of the basic principle that the Fighter exists for the purpose of shooting down Bombers, and that its encounters with other Fighters are incidental to this process.

213. There are, nevertheless, arguments for giving to a percentage of Fighters a ceiling (determinable by specific physiological tests) above which no enemy can climb without the use of Pressure Cabins. Just as the " Weather Gauge " was often the determining factor in the tactics of sailing ships, so the " Height Gauge " was often crucial in air combat. Exhaust-driver turbo-superchargers have certain advantages over gear-driven blowers at great height, and should be considered for adoption in spite of their disadvantages.

214. It must be remembered also that the initiative always rests with the Bomber, who can select at will the height at which he will make his attack. We must be prepared, therefore, for the appearance of the pressure-cabin Bomber, flying at a height unattainable by any non-pressurised Fighter. (I should perhaps explain that there is a height, about 43,000 feet, above which the administration of any quantity of oxygen at atmospheric pressure becomes ineffective because it cannot be inhaled and a pressure cabin or a pressure suit becomes essential.) Of course, a pressure-cabin Bomber is inefficient and vulnerable, because it is difficult to operate free guns from a pressure cabin, and pressure leakage from holes made in the walls of the cabin will prostrate the crew. The threat from pressurised Bombers is therefore serious only if we have no Fighters to meet them, and for this reason we should always possess a limited number of pressurised Fighters.

215. Various other lessons were learned from the experience of fighting at extreme altitudes. One very tiresome feature was that a considerable proportion of ultra-high-flying raids was missed by the Intelligence systems, or reported so late that time was not available to climb and intercept. This made it necessary to employ standing patrols just below oxygen height (about 16,000 feet). These patrols climbed to intercept at extreme height when ordered to do so. This cut at the roots of the Fighter Command system, which was designed to ensure economy of effort by keeping aircraft on the ground except when required to make an interception.

216. Another lesson was that the system of using an " Above Guard " should be retained even when an attack was initiated from extreme altitude.

217. Flying and fighting-fatigue increases with altitude, and the comfort of the pilot requires unremitting attention. Cockpit heating and the meticulous pursuit and elimination of air leaks are of great importance. Attention should also be paid to the elimination of icing on cockpit hoods (which are apt to freeze immovably) and on the inside and outside of windscreens.

218. A serious handicap, which I have not hitherto mentioned, was the fact that the change over from " High Frequency " to " Very High

Frequency " Radio Telephony was still in progress. The V.H.F. was an immense improvement on the H.F., both in range and clarity of speech; but the change over, which had started nearly a year before, was held up by the slow output of equipment. This meant that much work had to be done on aircraft Radio equipment during the Battle, and Squadrons equipped with V.H.F. could not communicate with H.F. Ground Stations, and *vice versa*.

219. Some of our worst losses occurred through defective leadership on the part of a unit commander, who might lead his pilots into a trap or be caught while climbing by an enemy formation approaching " out of the sun." During periods of intense activity promotions to the command of Fighter squadrons should be made on the recommendation of Group Commanders from amongst Flight Commanders experienced in the methods of the moment. If and when it is necessary to post a Squadron Leader (however gallant and experienced) from outside the Command, he should humbly start as an ordinary member of the formation until he has gained experience. Only exceptionally should officers over 26 years of age be posted to command Fighter Squadrons.

220. The experience of the Battle made me a little doubtful if the organisation of a squadron into 2 Flights, each of 2 Sections of 3 aircraft, was ideal. It was, of course, undesirable to make any sweeping change during the Battle, and I relinquished my Command shortly after its termination; but the weakness lay in the Section of 3 when it became necessary to break up a formation in a " Dog Fight." The organisation should allow for a break up into pairs, in which one pilot looks after the tail of his companion. A Squadron might be divided into 3 Flights of 4 (which would limit the employment of half-Squadrons), or it might consist of 2 Flights of 8, each comprising 2 Sections of 4. This latter suggestion would upset standard arrangements for accommodation.

221. The matter is not one which can be settled without consultation with various authorities and Branches of the Air Ministry. I therefore merely raise the point without making any definite recommendation.

222. A great deal of discussion took place before and in the early stages of the war as to the best method of " harmonisation " of the guns of an 8-gun Fighter: that is to say the direction, in relation to the longitudinal axis of the aircraft, in which each gun should be pointed in order to get the best results.

223. There were three schools of thought:—

One maintained that the lines of fire should be dispersed so that the largest possible " beaten zone " might be formed and one gun (but not more than one) would always be on the target.

The second held that the guns should be left parallel and so would always cover an elongated zone corresponding with the vulnerable parts of a Bomber (Engines, Tanks and Fuselage).

The third demanded concentration of the fire of all guns at a point.

224. Arguments were produced in favour of all three methods of harmonisation, but in practice it was found that concentration of fire gave the best results. Guns were harmonised so that their lines of fire converged on a point 250 yards distant: fire was therefore effective up to about 500 yards, where the lines of fire had opened out again to their original intervals after crossing at the point of concentration.

225. It was very desirable to get data as to the actual ranges at which fire effect had been obtained. The Reflector Sight contained a rough range-finder which the range of an aircraft of known span could be determined if it was approached from astern, but, in spite of this, pilots, in the heat of action, generally underestimated the ranges at which they fired.

226. Cinema guns, invaluable for training purposes, were used in combat also; and many striking pictures were obtained, from which valuable lessons were learned.

227. The types of ammunition used in the guns varied during the course of the Battle. It was necessary to include some incendiary ammunition, but the type originally available gave a distinct smoke-tracer effect. Now tracer ammunition in fixed guns at any but very short range gives very misleading indications, and I wished pilots to use their sights properly and not to rely on tracer indications. (The above remarks do not apply at night, nor to free guns, where tracer is essential for one of the methods taught for aiming.)

228. During the Battle " de Wilde " ammunition became available in increasing quantities. This was an incendiary ammunition without any flame or smoke trace, and it was extremely popular with pilots, who attributed to it almost magical properties. 8-gun Fighters, of course, were always liable to be sent up at night, and it was therefore desirable to retain some of the older types of incendiary bullets. These were preferred to the " tracer " proper, which gave too bright a flame at night.

229. A typical arrangement, therefore, was:—

Old-type incendiary in the 2 outer guns,
de Wilde in one gun while supplies were limited,
Armour piercing in 2 guns, and ball in the other 3.

230. A discussion on the offensive and defensive equipment of aircraft will be found in Appendix F. It will be of interest to all concerned with the Design of Technical Equipment of Aircraft.

## PART III.—NIGHT INTERCEPTION.

231. No story of the Battle would be complete without some account of the Night operations. It is true that they constituted only a subsidiary activity in comparison with the main German objective of fighting us to a standstill by day so that Air Superiority might be attained as a preliminary to Invasion. The night attacks did little directly to affect the efficiency of the Day Fighting Squadrons, though they had certain indirect effects. Although actual casualties were insignificant, disturbance and loss of sleep were caused; damage was done to factories where aircraft engines and accessories were produced; and the stress of continuous operations, day and night, imposed a very heavy strain on Formation Commanders and Staff officers, and upon the personnel of all Operations Rooms.

232. I had long been apprehensive of the effect of Night attacks, when they should begin, and of the efficacy of our defensive measures.

233. We relied on daytime interception methods, and on the Searchlights to illuminate and hold the Bombers. If they were capable of doing this, all would be well, since the distance at which an illuminated Bomber can be seen by night is comparable with the range of visibility by daylight.

234. The first night attack worthy of the name was made early in June and the results were encouraging. Aircraft were well picked up and held by the Searchlights and 6 were shot down. The attack was, however, made at comparatively low altitudes (8,000-12,000 ft.) and the Germans, profiting by this lesson, resorted thereafter to greater heights at which the Searchlights were practically ineffective. In close consultation with myself, General Pile tried every conceivable method of operation, but without material success.

235. About this time Radio Location instruments were fitted in Blenheims and it became necessary to develop at high pressure a system of operation which should enable Night Fighters to make interceptions even against unilluminated targets.

236. The difficulty of this task will be realised when it is considered that it became necessary to put the Fighter within one or two hundred yards of the Enemy, and on the same course, instead of the four or five miles which were adequate against an illuminated target.

237. It may be asked why the Searchlights were so comparatively impotent when they had afforded an accessory to successful defence at the end of the last war. The answer lies partly in the height factor already discussed, and partly in the greatly increased speed of the Bomber, which was about three times that obtaining in 1914. The sound locator, on which Searchlights mainly relied at this time, naturally registered the apparent position of the source of sound and lagged behind the target to the extent of the time taken by sound to travel from the target to the Sound Locator. When the speed of the target is low it is comparatively easy to allow for this lag, but at the speeds of modern bombers the angular distance which must be allowed for in searching is so great that the Searchlights were generally defeated.

238. The first thing which appeared obvious to me was that a " sound Plot " track transmitted from the Observer Corps with a variable and unpredictable " lag " was good enough only for Air Raid Warning purposes and was much too inaccurate to be of use for controlled interception at night: height indications also were little better than guesswork. The Radio Location apparatus (known as A.I.) fitted in twin-engined fighters had a maximum range of 2 or 3 miles, but it was limited by the height at which the Fighter was flying. If, for instance, the Fighter was flying at 10,000 feet, ground echoes were reflected from all ranges greater than this, and an aircraft echo from 10,500 feet would be indistinguishable among the ground echoes.

239. The minimum range of the A.I. was also restricted at this time to about 1,000 feet. Below this distance the aircraft echo was swamped by instrumental disturbance. Continuous and intensive development work was in progress to minimise these limitations.

240. No Radio Location apparatus was available at this time for inland tracking, and I turned for help to the Army, which had developed for use with guns a Radio Location apparatus known as the G.L. Set. Within a limited range (about 40,000 feet) this set could give very accurate position plots, and, moreover, could read height to within plus or minus 1,000 feet at average ranges.

241. Although these sets were few in number and were urgently required for their original purpose of gun control, General Pile realised the urgency of our need and made available about 10 sets for an experiment in the Kenley Sector on the usual line of approach of London Raiders, which commonly made their landfall near Beachy Head.

242. The G.L. sets were installed at Searchlight Posts, and direct telephone communication was arranged with the Kenley Sector Operations Room. Here a large blackboard was installed, and the G.L. plots were shown at intervals of about 30 seconds and with a greater accuracy in height than had before been possible by any means.

243. The track of the pursuing fighter was determined by means of the R/T Direction Finding Stations.

244. Major A. B. Russell, O.B.E., T.A.R.O., co-operated in the development of this system in the Kenley Sector. His practical knowledge and tireless enthusiasm were of the greatest value.

245. Promising results were obtained almost from the first and numerous instances occurred where echoes were obtained on the A.I. sets in the aircraft. Practical results were, however, disappointing, partly because the A.I. apparatus proved to be unexpectedly capricious in azimuth, and partly because the Blenheim was slower than many of the German Bombers and was deficient in fire-power. Many Germans escaped after an initial A.I. " pick-up " and even after visual contact had been effected.

246. The A.I. apparatus was then fitted into the Beaufighters, which were just beginning to appear in Service. The machines and their engines suffered from " teething trouble " to an unusual degree, and the adaption of A.I. to a new type was accompanied by certain difficulties. In addition, they were operating from a wet aerodrome at Redhill, and the development of delicate electrical apparatus, combined with a new type of aircraft and engine, with rudimentary maintenance facilities, was a matter of the greatest difficulty. In nine cases out of ten something would go wrong with the aeroplane or with the A.I. set or with the R/T Direction Finding apparatus or with the Communication system before an interception could be made. No. 219 Squadron, under Squadron Leader J. H. Little, were engaged in this work and operated with great energy and enthusiasm under extremely adverse and difficult conditions.

247. It would, of course, have been desirable to carry out all this development work by day when faults would have been much more easily detected and remedied, but the low rate of Aircraft Serviceability precluded Day-and-Night work, and London was being bombed almost every night, so that I could not afford to neglect the chance of getting practical results.

These, though disappointing, were not entirely negligible; several Bombers were shot down in this area during the experimental period, and many discovered that they were pursued and turned back before reaching their objectives. Night Fighting Development work was also going on at the same time at the Fighter Interception Unit at Tangmere in Sussex.

248. A supplementary use was found for the A.I. by the installation of A.I. "Beacons" in the vicinity of Night Flying Aerodromes. These afforded a valuable Navigational aid for "Homing" in cases where any defect occurred in the R/T D/F system.

249. Shortly before I left the Command a new piece of Radio-Location apparatus became available in the shape of the "G.C.I." set with the Plan Position Indicator. This was an Inland-Reading Set which showed the position of all aircraft within its range on a fluorescent screen as the aerial was rotated.

250. The main advantages of this set were that it had a longer range than the G.L. set and it was possible to track the Bomber and the Fighter by the same apparatus instead of following one with the G.L. and the other by R/T D/F. Moreover it was found that in some circumstances the accuracy of the R/T D/F method was inadequate for night interceptions.

251. On the other hand, the accuracy of height readings by the G.C.I. apparatus was less than that obtainable with the G.L. I understand that this has now been improved.

252. Whatever the exact technical method of plotting positions and tracks of aircraft, the object was to place the Fighter behind the Bomber, and in such a position that the echo of the latter would show in the Fighter's A.I. set. The Fighter then tried to overtake the Bomber until it became visible to the naked eye.

253. At that time only multi-seaters could be fitted with A.I., and therefore, concurrently with the Night Interception experiments, methods were tried of using the Searchlights as pointers for Night Fighters, even if the target were out of range of the Searchlight Beam. Experiments were made with the Searchlights in "clumps" to increase their illuminating power and the visibility of their beams to Fighters at a distance.

254. A small Radio-Location set was designed to fit to the Searchlight itself, so as to get over the time-lag which was such an insuperable obstacle to the use of Sound Locators. It is probable that if Searchlights can substitute the speed of light for that of sound they may take on a new lease of useful life.

255. The disadvantage of relying entirely on Radio-controlled methods of Night Interception is that "saturation point" is quickly reached, and when mass raids are in progress only a limited number of fighters can be operated. Results obtained in the Spring of 1941 show that Day Fighters can obtain important results in conditions of good visibility, especially if attention is paid to all methods of improving the night vision of pilots.

256. During the Battle the "Intruder" system was initiated on a small scale. Night fighters without A.I. were sent across to France in an attempt to catch Bombers while taking off from, or landing at, their aerodromes; or to intercept them at points where they habitually crossed the French Coast.

257. I had to leave the Development of Night Interception at a very interesting stage; but it is perhaps not too much to say that, although much remained to be done, the back of the problem had been broken. The experiments had, of course, been carried out in a small area, and raiders which avoided the area could be intercepted only by previously existing methods; but the possibilities had been demonstrated and could be applied on a larger scale as soon as the necessary apparatus was provided.

258. The method is, of course, also applicable to the day interception of raiders making use of cloud cover, which have hitherto proved extremely elusive; and it is not too much to hope that the eventual development of very high-frequency A.I. may enable accurate fire to be opened against unseen targets, so that not even the darkest night nor the densest cloud will serve as a protection to the Raider.

259. The day may come when every Single-Seater Fighter is fitted with A.I., but this is not yet feasible. What can be done is to fit all Searchlights with Radio-Location apparatus so that every Searchlight Beam is a reliable pointer towards an enemy, even if the range is too great for direct illumination.* If then the Fighter can be informed in addition of the height of the Raider, Day Fighters will be able to join usefully and economically in night operations on dark nights.

* As a result of the experience gained during this period, all searchlight equipments have since been fitted with Radar control. This, combined with intensified training, has made them, since 1941, extremely accurate.

## APPENDIX "A."

FIGHTER COMMAND.

*Order of Battle, 8th July*, 1940.

NO. 10 GROUP.

| *Squadron.* | *War Station.* | *Type of Aircraft.* |
|---|---|---|
| 87 | Exeter | Hurricane. |
| 213 | Exeter | Hurricane. |
| 92 | Pembrey | Spitfire. |
| 234 | St. Eval | Spitfire. |

APPENDIX "A."—*cont.*

No. 11 GROUP.

| | | |
|---|---|---|
| 43 | Tangmere | Hurricane. |
| 145 | Tangmere | Hurricane. |
| 601 | Tangmere | Hurricane. |
| FIU Unit | Tangmere | Blenheim. |
| 64 | Kenley | Spitfire. |
| 615 | Kenley | Hurricane. |
| 245 | Hawkinge | Hurricane. |
| 111 | Croydon | Hurricane. |
| 501 | Croydon | Hurricane. |
| 600 | Manston | Blenheim. |
| 79 | Biggin Hill | Hurricane. |
| 610 | Gravesend | Spitfire. |
| 32 | Biggin Hill | Hurricane. |
| 54 | Rochford | Spitfire. |
| 65 | Hornchurch | Spitfire. |
| 74 | Hornchurch | Spitfire. |
| 56 | North Weald | Hurricane. |
| 25 | Martlesham | Blenheim. |
| 151 | North Weald | Hurricane. |
| 1 | Northolt | Hurricane. |
| 604 | Northolt | Blenheim. |
| 609 | Northolt | Spitfire. |
| 236 | Middle Wallop | Blenheim. |

No. 12 GROUP.

| | | |
|---|---|---|
| 19 | Duxford | Spitfire. |
| 264 | Duxford | Defiant. |
| 85 | Debden | Hurricane. |
| 17 | Debden | Hurricane. |
| 29 | Digby | Blenheim. |
| 611 | Digby | Spitfire. |
| 46 | Digby | Hurricane. |
| 23 | Wittering | Blenheim. |
| 266 | Wittering | Spitfire. |
| 229 | Wittering | Hurricane. |
| 66 | Coltishall | Spitfire. |
| 253 | Kirton-in-Lindsey | Hurricane. |
| 222 | Kirton-in-Lindsey | Spitfire. |

No. 13 GROUP.

| *Squadron.* | *War Station.* | *Type of Aircraft.* |
|---|---|---|
| 41 | Catterick | Spitfire. |
| 219 | Catterick | Blenheim. |
| 152 | Acklington | Spitfire. |
| 72 | Acklington | Spitfire. |
| 249 | Leconfield | Hurricane. |
| 616 | Leconfield | Spitfire. |
| 603 "A" | Turnhouse | Spitfire. |
| 141 | Turnhouse | Defiant. |
| 602 | Drem | Spitfire. |
| 603 "B" | Montrose | Spitfire. |
| 3 | Wick | Hurricane. |
| 504 | Wick | Hurricane. |

NON-OPERATIONAL SQUADRONS.
(Forming or reforming.)

| *Group.* | *Squadron.* | *Aerodrome.* | *Type of Aircraft.* |
|---|---|---|---|
| 10 Group | 238 | Middle Wallop | Hurricane. |
| | 1 (Canadian) | Middle Wallop | Hurricane. |
| 11 Group | 257 | Hendon | Hurricane. |
| 12 Group | 242 | Coltishall | Hurricane. |
| 13 Group | 73 | Church Fenton | Hurricane. |
| | 605 | Drem | Hurricane. |
| | 607 | Usworth | Hurricane. |
| | 263 | Grangemouth | Hurricane. |

## APPENDIX "C."

6TH A.A. DIVISION, JULY-OCTOBER 1940.

(*Note.*—This report relates only to 6th A.A. Division. It does not cover the operations of A.A. Command as a whole.)

*Glossary of Abbreviations.*

| | | |
|---|---|---|
| H.A.A. | ... | Heavy Anti-Aircraft. |
| L.A.A. | ... | Light Anti-Aircraft. |
| G.O.R. | ... | Gun Operations Room. |
| A.A.L.M.G. | ... | Anti-Aircraft Light Machine-Gun. |
| V.I.E. | ... | Visual Indicator Equipment. |
| G.P.O. | ... | Gun Position Officer. |
| G.L. | ... | Radio Location Set for Gun Laying. |
| V.P. | ... | Vulnerable Point. |
| F.A.S. | ... | Forward Area Sight. |
| S.O.R. | ... | Sector Operator's Room. |
| G.D.A. | ... | Gun Defended Area. |

### 1. *Layout of A.A. Defences.*

(*a*) The area covered by 6th A.A. Division coincided with the R.A.F. sectors Debden, North Weald, Hornchurch, Biggin Hill and Kenley (*i.e.*, the major part of No. 11 Fighter Group, R.A.F.). Thus the coastal boundary extended from Lowestoft (exclusive) in the North to Worthing (exclusive) in the South; the internal boundary marching with that of the Metropolitan area.

(*b*) Distribution of A.A. defences was briefly as follows:—

(i) *H.A.A. Guns.*

The Divisional area contained four main "gun defended areas" at Harwich, Thames and Medway North (guns emplaced along the North bank of the Thames Estuary), Thames and Medway South (guns emplaced along the South bank of the Thames Estuary and defending Chatham and Rochester) and Dover (including Folkestone). In addition, H.A.A. guns were deployed for the defence of certain aerodromes.

Each "gun defended area" was based on a Gun Operations Room: at Felixstowe, Vange, Chatham and Dover respectively. This G.O.R. was connected directly to 11 Fighter Group Operations Room at Uxbridge, from which it received plots of enemy raids, which were in turn passed down to all gun sites.

The armament of each H.A.A. site consisted of the following: 4 (sometimes 2) 4.5, 3.7 or 3-inch guns with predictor. Appendix "A" shows the H.A.A. defences as at the beginning of August 1940 and the end of October 1940.

(ii) *L.A.A. Guns.*

45 Vulnerable Points in the Divisional area were defended by L.A.A. guns. These V.Ps. consisted of Air Ministry Experimental Stations, Fighter Aerodromes, Dockyards, Oil Depots, Magazines, Industrial Undertakings and Factories.

Armament consisted of the following guns: 40-mm. Bofors (with Predictor No. 3 and Forward Area Sights), 3-inch, 20 cwt. (Case I), A.A.L.M.G. and 20-mm. Hispano. Appendix "B" shows the V.Ps. with their armament as in August and October 1940.

(iii) *Searchlights.*

Searchlights were deployed in single light stations at approximately 6,000 yards spacing throughout the area, but with a closer spacing in certain instances along the coast and in "gun defended areas" where the distance between lights was approximately 3,500 yards.

These lights were deployed on a brigade basis following R.A.F. sectors, and each light was connected by direct telephone line and/or R.T. set No. 17 to Battery Headquarters via troop H.Q. and thence to an army telephone board at the R.A.F. Sector Operations Room.

The equipment of a Searchlight site consisted of the following:—

90-cm. Projector with, in most cases, Sound Locator Mk. III. In some instances sites were equipped with Sound Locators Mk. VIII or Mk. IX. During the late Summer and Autumn the number of Mk. VIII and Mk. IX Sound Locators gradually increased, and V.I.E. equipment and 150-cm. Projectors were introduced. Each Searchlight site was equipped with one A.A.L.M.G. for use against low-flying aircraft and for ground defence.

### 2. *Enemy Tactics.*

(a) *High Level Bombing Attacks.*

These took place *generally* between heights of 16,000/20,000 feet. Bombers approached their targets in close protective formations until running up to the line of bomb release, when formation was changed to Line Astern (if there was a definite objective to the attack). Attacks frequently occurred in waves, each wave flying at approximately the same height and on the same course. On engagement by H.A.A. guns, avoiding action was taken in three stages:—

*Stage* 1.—The bombers gained height steadily and maintained course and formation.

*Stage* 2.—Formations opened out widely and maintained course.

*Stage* 3.—Under heavy fire, formations split and bombers scattered widely on different courses. It was after this stage had been reached that the best opportunity was provided for fighters to engage.

(b) *Low Level and Dive Bombing Attacks.*

In the latter stages of the enemy air offensive numerous instances of low level and dive bombing attacks occurred, in particular against fighter aerodromes (Manston, Hawkinge, Lympne, Kenley).

L.A.A. and H.A.A. employed in dealing with these forms of attack met with varying success, but in cases where no planes were brought down the effect of fire from the A.A. defence almost invariably disconcerted the dive bomber so that few bombs were dropped with accuracy.

Considerable efforts were made by Me. 109's and Ju. 87's to destroy the balloon barrage at Dover, and, though at times they partially succeeded, excellent targets were provided for the Dover H.A.A. and L.A.A. guns.

### 3. *Part played by H.A.A. Guns.*

Targets of all types presented themselves to H.A.A. sites, ranging from solid bomber formation to single cloud hopping or dive bombers, balloon strafers or hedge hoppers, all of which were successfully engaged by appropriate method of fire.

The action of the defence achieved success in the following ways:—

(*a*) The actual destruction or disablement of enemy aircraft (see Appendix "C").

(*b*) The breaking up of formations, thus enabling the R.A.F. to press home attacks on smaller groups of bombers.

(*c*) Destroying the accuracy of their bombing by forcing the enemy aircraft to take avoiding action.

(*d*) By pointing out to patrolling fighters the whereabouts of enemy formations by means of shell bursts.

The following methods of fire were in operation at this period:—

(a) *Seen Targets.*

(i) Each gun site was allotted a zone of priority and responsibility for opening fire on a target rested with the G.P.O.

(ii) Targets could be engaged by day if identified as hostile beyond reasonable doubt or if a hostile act was committed. By night, failure to give recognition signals was an additional proviso.

(iii) It was the responsibility of the G.P.O. to cease fire when fighters closed to the attack.

(b) *Unseen Targets.*

Unseen firing at this time was in its infancy and considerable initiative was displayed in evolving methods for engaging targets unseen by day or by night.

The following methods were employed:—

(i) *Geographic Barrages.*

Many forms of barrage were used by different G.D.As. but all were based on obtaining concentrations at a point, on a line, or over an area, through which the enemy aircraft must fly.

Suitable barrages for lines of approach and heights were worked out beforehand. Approach of enemy aircraft was observed by G.L. and, by co-ordination at G.O.Rs., the fire from each site could be controlled to bring a maximum concentration of shell bursts at the required point.

(ii) *Precision Engagements.*

*Method A.*—Due to poor visibility or wrong speed settings searchlight intersections were often made without actual illumination of the aircraft. By obtaining slant range from G.L. and following the intersection on the Predictor, sufficient data were available to enable shells to burst at or near the intersection.

*Method B.*—This provided for engagement without searchlight intersections. Continuous bearings and slant ranges from the G.L. were fed into the Predictor and engagement of target undertaken on the data thus provided. For sites which were not equipped with G.L. the appropriate information was passed down from G.O.R.

It will be appreciated that procedure varied with different Gun Zones, according to circumstances and the equipment available. It should be remembered that all engagements of unseen targets were subject to the express permission of the Group Controller at Uxbridge, so that danger of engaging friendly aircraft was obviated.

(c) *Anti-Dive-Bombing Barrage.*

Special barrages against dive bombers were organised round the following V.Ps.: Harwich Harbour, Thameshaven Oil Installations, Tilbury Docks, Chatham Dockyard, Sheerness Dockyard, Dover Harbour, Purfleet Oil and Ammunition Depots.

This barrage could be employed at any time at the discretion of the G.P.O. when he considered that other and more accurate methods were unlikely to be effective. The barrage was designed for a height of 3,000 feet and assumed a dive angle of 60°. It was based on a barrage circle round each gun site which was divided into 4 quadrants in which the barrages were placed.

The maximum effort from H.A.A. guns was required from the 19th August to the 5th October, during which time the crews had little rest, continuous 24 hours manning being required at Dover, a "duty gun station" system being worked in all areas.

Evidence is available to show how time and time again enemy bombers would not face up to the heavy and accurate fire put up by gun stations. Particularly worthy of mention are two attacks on Hornchurch aerodrome when on both occasions fighters were on the ground for refuelling. A.A. fire broke up the formation and prevented *any damage to the station* buildings and aircraft on the ground.

4. *Part played by L.A.A. Guns.*

The targets which offered themselves to L.A.A. guns were in the main small numbers engaged in dive bombing or low level attacks on V.Ps. Opportunity usually only offered fleeting targets, and quickness of thought and action was essential to make fullest use of the targets which presented themselves.

Success against targets by L.A.A. guns was achieved in the following ways:—

(*a*) The destruction or disablement of enemy aircraft (See Appendix "C").

(*b*) The prevention of accurate bombing causing the bombers to pull out of their dive earlier than they intended.

Methods of firing employed by L.A.A. guns as follows:—

(i) *Bofors.*

Fire was directed either by No. 3 Predictor or by Forward area Sights; some Bofors were not equipped with the Predictor when the latter method only could be used.

The Predictor equipped guns require a 130 Volt A.C. electric supply which was provided either from engine-driven generators or from the mains. Shooting with the Predictor achieved very great accuracy and the results and destruction of aircraft and the average ammunition expenditure proved the efficiency of this equipment (see Appendix "C"). The F.A.S. method permitted quick engagements of targets although without the accuracy afforded by the Predictor.

(ii) *3-inch 20-cwt. Guns (Case I).*

Some V.Ps. were equipped with the 3-inch 20-cwt. gun without Predictor which was fired from deflection sights; shrapnel was normally used. H.E., however, was used for targets at greater height.

(iii) *A.A.L.M.G.*

Lewis Guns on A.A. mountings proved extremely effective in attacking low-flying enemy aircraft. These guns were mounted in single, double or quadruple mountings and were fired by the Hosepipe method using tracer ammunition.

(iv) *Hispano 20-mm. Equipment.*

A few of these weapons only were deployed and, owing to shortage of ammunition and lack of tracer, were not found very effective.

5. *Part Played by Searchlights.*

(a) *Day.*

Owing to the close spacing of Searchlight sites they formed a valuable source of intelligence and rapid reports were able to be made upwards of casualties to friendly and enemy aircraft, pilots descending by parachute and other incidents of importance. In addition, they have been able to provide valuable reports of isolated enemy aircraft, trace of which had been lost by the Observer Corps.

The value of the A.A.L.M.G. with which each site was equipped cannot be too highly stressed, and during the 4 months under review no less than 23 enemy aircraft were destroyed, confirmed, by A.A.L.M.G. at Searchlight sites (this includes a few in which A.A.L.M.G. at H.A.A. sites also shared). Prisoner of War reports showed that it was not generally known by the German Air Force pilots that Searchlight sites were equipped with A.A. defence.

(b) *Night.*

Tactical employment of Searchlights at night was by either—

(i) 3-beam rule, in which 3 sites only engaged the target; or

(ii) by the Master-beam system, in which one Master beam per three sites exposed and was followed by the remaining two beams acting under the orders of the Master beam.

The decision to engage was the responsibility of the Detachment Commander, and no direct tactical control was exercised from Battery Headquarters.

In the early stages of the Battle of Britain night activity was on a small scale and Searchlights had few raids to engage. Some illuminations were effected, but throughout it was difficult, by ground observations, to assess the actual numbers. Frequently illuminations were reported by sites not engaging the targets. The difficulty of illumination was increased as the number of night raids increased, owing to the difficulty of sites selecting the same target.

There is evidence to show that Searchlight activity, whilst being difficult to measure, forced enemy aircraft to fly at a greater height than they would otherwise have done. Bombs were frequently dropped when enemy aircraft were illuminated, which were possibly intended to discourage Searchlights from exposing. Evasive tactics by the enemy consisted of changing height and speed continuously to avoid being illuminated rather than a violent evasive action upon illumination.

6. *G.L. Equipment.*

At the beginning of August experiments had just been completed to determine whether G.L. equipment could satisfactorily be used as a Ships detector. Apart from the results of this experiment three other facts emerged:—

(*a*) The G.L. principle was of considerable value when used in conjunction with Searchlights.

(*b*) That G.L. sets sited in an anti-ship rôle, *i.e.*, on the top of a cliff, were of considerable value in detecting low-flying aircraft.

(*c*) It showed the value of small R.D.F. detectors within the main R.A.F. chain, in plotting enemy aircraft direct to sectors.

At the beginning of the Battle of Britain, 21 G.L. sets were in use by 6th A.A. Division, and by October this number had been increased by another 14.

(i) *G.L. at Gun Stations.*

The main function of these equipments was to provide data for Unseen target engagements as described above. One other function of these sets is worth special mention.

Two sets were specially sited on the cliffs at Dover to pick up targets at low level. These sets were able to register aircraft taking off from the aerodromes immediately behind Calais, thereby obtaining information considerably earlier than could be provided by the main R.D.F. station on the coast. This information was reported back to Uxbridge Operations Room by a priority code message which indicated the approximate number of aircraft which had taken off and their position. This report was received some 5/6 minutes before it could be received through the usual R.D.F. channels, and therefore enabled the Controller to order his Fighters off the ground correspondingly earlier than would otherwise have been the case.

This system, which was also adopted somewhat further along the coast in the neighbourhood of Beachy Head, was of all the more value as the enemy were heavily bombing the R.D.F. stations, which were consequently sometimes out of action.

(ii) *G.L. Stations with Searchlights.*

During the latter stages of the offensive, when the night raids on London commenced, it was realised that the G.L. would be of considerable assistance to Night Fighters. An " elevation " attachment to the equipment was produced and this enabled height to be obtained, which in conjunction with a plotting scheme at S.O.R., enabled Searchlight beams to be directed more accurately on a target to assist night fighters. The results obtained from this were not completely satisfactory, but they showed the way to the development of the present system.

(iii) *Mine-Laying Aircraft.*

It was found that the experiments conducted in the ship-detector rôle could be very satisfactorily applied to detecting mine-laying aircraft which flew in at a height too low to be picked up by the C.H. Stations. It enabled accurate tracks of these aircraft to be kept which were afterwards passed to the Naval Authorities, who were then able to sweep up the mines which had been laid by these aircraft.

7. *Statistics.*

Careful records have been kept of ammunition expenditure and enemy aircraft shot down, and details are shown in Appendix " C."

The following points are worthy of note:—

(*a*) The total enemy aircraft Destroyed, Confirmed Category I by 6th A.A. Division during the months July-October 1940, inclusive, was

221; of this total 104 were destroyed on seven days, thus:—

| | |
|---|---|
| 15 August, 1940 ... ... | 15 |
| 18 ,, ,, ... ... | 22 |
| 24 ,, ,, ... ... | 10 |
| 31 ,, ,, ... ... | 20 |
| 2 September, 1940 ... | 13 |
| 7 ,, ,, ... | 14 |
| 15 ,, ,, ... | 10 |
| | 104 |

(*b*) A considerable number of enemy aircraft were claimed as Probably Destroyed and Damaged.

(*c*) The total amount of H.A.A. expended was 75,000 rounds.

(*d*) The total amount of Bofors ammunition expended was 9,417 rounds.

### 8. *Ground Defence*

Preparations were made by all A.A. defences to assume a secondary ground defence rôle; Bofors were provided with A/T ammunition, and sited to cover approaches to aerodromes, V.Ps., &c. Certain 3.7 inch guns suitably sited were given an anti-ship rôle, and preparations were made for barrages to be put on certain beaches. Under the immediate threat of invasion in May 1940, mobile columns of A.A. troops were formed, but these troops reverted to their A.A. rôle before the Battle of Britain began.

### 9. *Lessons Learnt.*

(*a*) The outstanding lesson learnt from this intensive air attack was undoubtedly the soundness and suitability of the organisation and arrangements of the control and direction of the anti-aircraft defences. These measures devised in peace time and perfected during the earlier and quieter period of hostilities, stood the severe test with amazing resilience and adaptability. No major alterations in the system were indicated or, indeed, were made subsequent to these operations.* The way in which the activities of the anti-aircraft linked in and were capable of co-ordination with the major partners in the venture—R.A.F. Fighter Command, No. 11 Fighter Group, and sector commands—is perhaps worthy of special note.

* This statement applies only to the higher organisation, and must not be taken to mean that no improvements were made in the control and direction of A.A. gunnery.

(*b*) Other lessons learnt are by comparison of minor import. Chief among them was the great vulnerability of aircraft if caught by accurate H.A.A. fire when in close formation. A good instance of this occurred in an action on the 8th September, when a geschwader of 15 Do. 17s, flying in formation at 15,000 feet, approached a gun site South of River Thames. The opening salvo from the four 3.7-inch guns brought down the three leading aircraft, the remaining machines turning back in disorder, scattering their bombs on the countryside in their flight to the coast.

The value of H.A.A. fire as a means of breaking up bomber squadrons to enable them to be more easily dealt with by our fighters was demonstrated on numerous occasions in the Thames Estuary.

The importance of A.A. shell bursts as a "pointer" to fighters, even though the guns cannot themselves effectively engage the enemy, was also frequently demonstrated.

(*c*) A somewhat negative lesson was the inability of A.A. guns, however well served, to completely deny an area to penetration by determined air attack. Evidence, however, was overwhelming that accurate fire, apart from causing casualties, did impair the enemy's aim, and thus avoid, or at least mitigate, the damage to precise targets.

(*d*) A rather unexpected result was the high proportion (about 10 per cent.) of planes brought down by A.A.L.M.G. fire. It is doubtful, however, whether with the increased armour now carried by enemy aircraft this lesson still obtains.

(*e*) The value of training in recognition was repeatedly emphasised throughout these operations. Fortunately, very few instances of friendly aircraft being engaged occurred. Apart from the accuracy of the information as to movement of aircraft furnished to gun sites, this was no doubt due to a reasonable standard in recognition having been attained.

It was, and still is, continually brought home to the A.A. gunner that, before all else, he must not engage a friendly aircraft. With this thought firmly impressed on the G.P.O., some instances of late engagement or failure to engage perforce occurred. In some cases, had the standard of training been higher, to enable the earlier recognition of a machine as "hostile beyond reasonable doubt," the number of machines destroyed would have been increased.

Chelmsford, August 2, 1941.

## APPENDIX "C.A."

### H.A.A. GUN DEFENDED AREAS AND ARMAMENT.

| G.D.A. | August 1940. | | | October 1940. | | |
|---|---|---|---|---|---|---|
| | 4·5-in. | 3·7-in. | 3-in. | 4·5-in. | 3·7-in. | 3-in. |
| Harwich ... ... ... ... ... | — | 15 | 8 | — | 8 | 7 |
| T. and M. North ... ... ... ... | 32 | 8 | 12[a] | 24 | 4 | 12 |
| T. and M. South ... ... ... ... | 32 | 32 | 14 | 28 | 20 | 10 |
| Dover and Manston ... ... ... | — | 12 | 16 | — | 12 | 16 |
| Wattisham ... ... ... ... | — | — | 4 | — | — | 4 |
| Biggin Hill ... ... ... ... | — | — | 4 | — | — | 4 |
| Kenley ... ... ... ... ... | — | — | — | — | — | 2 |
| North Weald ... ... ... ... | — | + 4 | 4 + 2 | — | — | 4 |

## APPENDIX "C.B."

### L.A.A., V.P.'s AND ARMAMENT.

| V.P. | August 1940. | | | | | October 1940. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 40-mm. | A.A.L.M.G. (No. of Barrels). | His-pano. | 3-in., Case I. | Misc. | 40-mm. | A.A.L.M.G. | His-pano. | 3-in., Case I. | Misc. |
| *Aerodromes.* | | | | | | | | | | |
| Debden ... ... | 4 | 3 | — | — | — | 4 | 17 | — | — | — |
| Wattisham ... | — | 12 | — | — | — | 4 | 8 | — | — | — |
| Biggin Hill ... | 3 | 2 | — | — | — | 6 | 3 | — | — | — |
| Manston ... | 4 | 4 | — | — | — | 4 | 4 | — | — | — |
| West Malling ... | 2 | 10 | — | — | — | 4 | 10 | — | — | — |
| Croydon ... | — | 12 | — | — | — | 4 | 8 | — | — | — |
| Kenley ... ... | 4 | 8 | — | 2 | — | 4 | 10 | — | 3 | — |
| Redhill ... ... | — | — | — | — | — | 3 | — | — | — | — |
| Gravesend ... | 4 | 4 | — | — | — | 4 | — | — | — | — |
| Shorts (Rochester) | — | — | — | — | — | 4 | 8 | 3 | — | — |
| Detling ... ... | — | — | — | — | — | 2 | 12 | 2 | — | — |
| Eastchurch ... | — | — | — | — | — | 2 | 10 | — | — | — |
| Hawkinge ... | 4 | 4 | — | — | — | 4 | 4 | — | — | — |
| Lympne... ... | — | — | — | — | — | — | 2 | — | — | — |
| North Weald ... | 3 | 12 | — | — | — | 5 | 8 | — | — | — |
| Martlesham ... | 4 | 10 | — | — | — | 4 | 11 | — | — | — |
| Rochford ... | 2 | 8 | — | — | — | 4 | 12 | — | — | — |
| Hornchurch ... | 3 | 7 | — | — | — | 5 | 7 | — | — | — |
| Stapleford Abbotts | — | — | — | — | — | 2 | — | — | — | — |
| *A.M.E. Stations.* | | | | | | | | | | |
| Darsham ... | 2 | 7 | — | — | — | 2 | 8 | — | — | — |
| Dunkirk ... | 3 | 6 | — | — | — | 3 | 7 | — | — | — |
| Rye ... ... | 3 | 6 | — | — | — | 3 | 11 | — | — | — |
| Pevensey ... | 3 | 6 | — | — | — | 3 | 21 | — | — | — |
| Bawdsey ... | — | — | — | — | — | 3 | 3 | — | — | — |
| Great Bromley ... | — | — | — | — | — | 3 | 11 | — | — | — |
| Canewdon ... | 3 | 4 | — | — | — | 3 | 12 | — | — | — |
| *Industrial and Oil.* | | | | | | | | | | |
| Crayford ... | — | 8 | — | — | — | 3 | 30 | 3 | 1 | — |
| Dartford ... | — | — | — | — | — | 1 | 20 | 4 | — | — |
| Northfleet ... | — | — | — | — | — | — | 16 | — | — | — |
| Grain (Barges) ... | 2 | 4 | — | — | — | 2 | 34 | 2 | 1 | — |
| Chelmsford ... | — | 8 | — | — | — | 2 | 21 | — | — | — |
| Murex (Rainham) | — | 20 | — | — | — | — | 20 | — | — | — |
| Purfleet ... | — | 14 | — | 2 | — | — | 16 | — | 2 | — |
| Canvey ... ... | — | 12 | — | 2 | — | — | 12 | — | 1 | — |
| Thameshaven ... | — | 4 | — | 4 | — | — | — | — | 3 | — |
| Shellhaven ... | — | 8 | — | 3 | — | — | 8 | — | 1 | — |
| *Naval.* | | | | | | | | | | |
| Chatham ... | — | — | — | — | — | — | 24 | 4 | 3 | — |
| Chattenden ... | — | — | — | — | — | — | 28 | — | — | — |
| Sheerness ... | — | — | — | — | — | 4 | 22 | 5 | — | — |
| Landguard ... | — | — | — | — | — | — | 15 | — | 1 | — |
| Wrabness ... | — | — | — | — | — | — | 23 | — | — | — |
| Parkeston Quay | — | — | — | — | — | — | 10 | — | — | — |
| Dover ... ... | 5 | 9 | — | 4 | — | 9 | 16 | 4 | — | 4 A/T |
| Tilbury ... ... | — | 14 | — | — | — | — | 18 | — | — | — |
| Southend Pier ... | — | — | — | — | 1—2-pdr. | — | — | — | — | 1—2-pdr. |

## APPENDIX "C.C."

### I.—AMMUNITION EXPENDITURE AND CLAIMS, CATEGORY I.

| ——— | Total Ammunition Expended. | Enemy Aircraft Destroyed. | Average Rounds per E/A. |
|---|---|---|---|
| H.A.A. (seen targets) ... ... ... ... | 48,155 | 161 | 298 |
| H.A.A. (barrage and unseen fire) ... ... | 26,869 | 11 | 2,444 |
| L.A.A. Bofors only ... ... ... ... | 9,417 | 47 | 200 |
| A.A.L.M.G. (at S.L. and H.A.F. sites) ... ... | Not recorded | 23 | — |

NOTES :—

(i) The above table gives records from September 3, 1939 to November 3, 1940.

(ii) The total enemy aircraft destroyed during the months inclusive July–October was 221.

(iii) The following ammunition was expended from September 3, 1939 to June 30, 1940—

H.A.A. ... ... ... ... ... 2,995

L.A.A. (Bofors) ... ... ... ... 1,919

(iv) All the enemy aircraft destroyed by L.A.A. (47) have been credited to Bofors for the purpose of the average ; in practice, Lewis guns had a considerable share in several of these as well as in two cases Hispano (2,941 rounds) and 3-in. Case I (194 rounds).

(v) Bofors average may be still further sub-divided thus :—

With Predictor ... ... ... ... 179 (3,187 rounds)

With F.A.S. ... ... ... ... ... 232 (6,230 rounds)

APPENDIX "C.C."—*cont.*

II.—TABLE SHOWING TYPES OF AIRCRAFT DESTROYED JULY–OCTOBER 1940.

| *Type.* | *No.* |
|---|---|
| HE. III ... ... ... ... ... ... | 30 |
| Do. 17 ... ... ... ... ... ... | 39 |
| Do. 215 ... ... ... ... ... ... | 14 |
| Ju. 87 ... ... ... ... ... ... | 15 |
| Ju. 88 ... ... ... ... ... ... | 19 |
| Me. 109 ... ... ... ... ... ... | 80 |
| ME. 110 ... ... ... ... ... ... | 15 |
| Unidentified ... ... ... ... ... | 9 |
| | 221 |

III.

| | |
|---|---|
| Destroyed by day ... ... ... ... | 203 |
| Destroyed by night ... ... ... ... | 18 |
| | 221 |

APPENDIX "C.D."

AMMUNITION EXPENDITURE AND ENEMY AIRCRAFT DESTROYED THROUGHOUT ANTI-AIRCRAFT COMMAND FOR JULY, AUGUST AND SEPTEMBER 1940.

| | |
|---|---|
| July 1940— | |
| Day* ... ... ... ... | 344 rds. per aircraft. |
| Night ... ... ... ... | (26 a/c = 8,935 rds.) |
| August 1940— | |
| Day* ... ... ... ... | 232 rds. per aircraft. |
| Night ... ... ... ... | (167 a/c = 38,764 rds.) |
| September 1940— | |
| Day† ... ... ... ... | 1,798 rds. per aircraft. |
| Night ... ... ... ... | (144 a/c = 258,808 rds.) |

* Mainly by day, little night activity.
† Including considerable night activity and large expenditure of ammunition by night.

APPENDIX "E."

FIGHTER COMMAND.

*Order of Battle, November 3, 1940.*

No. 9 GROUP.

| *Squadron.* | *War Station.* | *Type of Aircraft.* | *Category.* |
|---|---|---|---|
| 312 (Czech) | Speke | Hurricane | C |
| 611 | Ternhill | Spitfire | C |
| 29 (½) | Ternhill | Blenheim | Night-Flying |

No. 10 GROUP.

| | | | |
|---|---|---|---|
| 79 | Pembrey | Hurricane | C |
| 87 (½) | Bibury | Hurricane | B |
| 504 | Filton | Hurricane | C |
| 609 | Middle Wallop | Spitfire | A |
| 604 | Middle Wallop | Blenheim | Night-Flying |
| 238 | Middle Wallop | Hurricane | A |
| 56 | Boscombe Down | Hurricane | A |
| 152 | Warmwell | Spitfire | A |
| 601 | Exeter | Hurricane | C |
| 87 (½) | Exeter | Hurricane | B |
| 234 | St. Eval | Spitfire | C |
| 247 (½) | Roborough | Gladiator | C |

APPENDIX "E."—*cont*

No. 11 Group.

| | | | |
|---|---|---|---|
| 25 | Debden | Blenheim and Beaufighter | Night-Flying |
| 73 | Castle Camp | Hurricane | Night-Flying |
| 17 | Martlesham | Hurricane | A |
| 229 | Northolt | Hurricane | A |
| 615 | Northolt | Hurricane | A |
| 302 (Polish) | Northolt | Hurricane | A |
| 257 | North Weald | Hurricane | A |
| 249 | North Weald | Hurricane | A |
| 46 | Stapleford | Hurricane | A |
| 264 | Hornchurch | Defiant | Night-Flying |
| 41 | Hornchurch | Spitfire | A |
| 603 | Hornchurch | Spitfire | A |
| 222 | Rochford | Spitfire | A |
| 141 | Gravesend | Defiant | Night-Flying |
| 74 | Biggin Hill | Spitfire | A |
| 92 | Biggin Hill | Spitfire | A |
| 66 | West Malling | Spitfire | A |
| 421 (½) | West Malling | Hurricane | Reconnaissance |
| 605 | Croydon | Hurricane | A |
| 253 | Kenley | Hurricane | A |
| 501 | Kenley | Hurricane | A |
| 219 | Redhill | Blenheim and Beaufighter | Night-Flying |
| 145 | Tangmere | Hurricane | A |
| 213 | Tangmere | Hurricane | Night-Flying |
| 422 (½) | Tangmere | Hurricane | Night-Flying |
| 602 | West Hampnett | Spitfire | A |
| 23 | Ford | Blenheim | Night-Flying |

No. 12 Group.

| *Squadron.* | *War Station.* | *Type of Aircraft.* | *Category.* |
|---|---|---|---|
| 303 (Polish) | Leconfield | Hurricane | C |
| 616 | Kirton-in-Lindsey | Spitfire | C |
| 85 | Kirton-in-Lindsey | Hurricane | C |
| 151 | Digby | Hurricane | C |
| 1 | Wittering | Hurricane | C |
| 266 | Wittering | Spitfire | C |
| 29 (½) | Wittering | Blenheim | Night-Flying |
| 72 | Coltishall | Spitfire | C |
| 64 | Coltishall | Spitfire | C |
| 242 | Duxford | Hurricane | A |
| 310 (Czech) | Duxford | Hurricane | A |
| 19 | Duxford | Spitfire | A |

No. 13 Group.

| | | | |
|---|---|---|---|
| 607 | Turnhouse | Hurricane | C |
| 65 | Turnhouse | Spitfire | B |
| 232 (½) | Drem | Hurricane | C |
| 263 (½) | Drem | Hurricane | C |
| 1 (Canadian) | Prestwick | Hurricane | C |
| 32 | Acklington | Hurricane | C |
| 610 | Acklington | Spitfire | C |
| 600 (½) | Acklington | Blenheim | Night-Flying |
| 43 | Usworth | Hurricane | C |
| 54 | Catterick | Spitfire | C |
| 600 (½) | Catterick | Blenheim | Night-Flying |
| 245 | Aldergrove | Hurricane | C |

No. 14 Group.

| | | | |
|---|---|---|---|
| 3 | Castletown | Hurricane | C |
| 111 (½) | Dyce | Hurricane | C |
| 111 (½) | Montrose | Hurricane | C |

APPENDIX "E."—*cont.*

NON-OPERATIONAL SQUADRONS.

| *Group.* | *Squadron.* | *Station.* | *Type of Aircraft.* |
|---|---|---|---|
| 9 Group | 308 (Polish) | Baginton | Hurricane |
| 12 Group | 306 (Polish) | Church Fenton | Hurricane |
| | 307 (Polish) | Kirton-in-Lindsey | Defiant |
| | 71 (Eagle) | Church Fenton | Buffalo |
| 13 Group | 263 (½) | Drem | Whirlwind |

NOTE.—Two "B" Squadrons, Nos. 74 and 145, had already been thrown into the battle, leaving only two available at the end.

## APPENDIX "F."

### NOTE ON THE OFFENSIVE AND DEFENSIVE EQUIPMENT OF AIRCRAFT.

1. The general principle of developing the maximum possible fire power, which is accepted in all Armies and Navies, must presumably be applicable to Fighter Aircraft, provided that this can be done without unduly sacrificing Performance and Endurance.

2. The 8-gun fighter may be said to exemplify this principle, and at the beginning of the war its results were decisive against German Bombers, which were unarmoured at that time.

3. Our Fighter pilots were protected against the return fire of Bombers by their engines, and by bullet-proof glass and armour, for their heads and chests respectively.

4. Furthermore, at this time the return fire from German Bombers was negligible. They had concentrated on Performance as the principle means of evasion (a false lesson drawn from the low speed of the Fighters used in the Spanish War) and the few guns which they carried were manually controlled, and so badly mounted that they were practically useless. These facts, in combination with the fire power and armour protection of our own Fighters, made the latter virtually immune to the fire of unescorted Bombers, and their casualties in Home Defence fighting up to the Spring of 1940 were quite negligible.

5. The German Bombers had good self-sealing tanks, and this was perhaps the only important particular in which they were ahead of us. In our development work we had demanded that tanks should be "Crash Proof" as well as self-sealing, and the drastic conditions, which our experimental tanks had to meet had made them unduly heavy and cumbrous.

6. So far as our Fighters were concerned, the wing tanks in the Hurricane were removed and covered with a fabric known as "Linatex" which had fairly good self-sealing characteristics. The reserve tank in the fuselage was left uncovered, as it was difficult of access and it was thought that it would be substantially protected by the armour which had been fitted. During the Battle, however, a great number of Hurricanes were set on fire by incendiary bullets or cannon shells, and their pilots were badly burned by a sheet of flame which filled the cockpit before they could escape by parachute.

7. The reserve tanks were therefore covered with Linatex as a matter of the highest priority, and a metal bulkhead was fitted in front of the pilot to exclude the rush of flame from the cockpit.

8. The Germans soon began to fit fuselage armour to protect their pilots and crews, but for some unexplained reason neither side had fitted armour behind the engines of their Bombers. The back of the engine is much more vulnerable to rifle-calibre bullets than the front, owing to the mass of ancillary equipment which is there installed. While the back of the engine lies open to attack, the rifle-calibre machine gun remains a useful weapon, and the fact is a fortunate one for us.

9. The application of armour to Bombers did not, of course, come as a surprise to us, and its implications had long been discussed.

10. Excluding devices such as hanging wires, exploding pilotless aircraft, etc., I have always thought that the courses open to the Fighter, when rifle-calibre machine-gun fire from astern becomes ineffective, may be summarised as follows:—

(A) Deliver fire from ahead or from a flank.
(B) Pierce the armour.
(C) Attack the fuel tanks with incendiary ammunition.
(D) Destroy the structure of the aircraft by means of direct hits from explosive shells.
(E) Use large shells with Time and Percussion fuzes.

Discussing these in order:—

11.—(A) Fire from ahead or from a flank is effective but difficult to deliver accurately at modern speeds. Fire from ahead proved very effective on occasions during the Battle, but relative speeds are so high that the time available for shooting is very short, and Fighters generally find themselves in a position to deliver such an attack more by accident than by design.

12. Beam attack is very difficult to deliver accurately, owing to the amount of deflection which had to be allowed. The deflection ring on a Fighter's sight allows for an enemy speed of 100 m.p.h., and therefore a full diameter outside the ring must sometimes be allowed.

13. The method is effective against formations, when the aircraft hit is not always the one aimed at, and certainly the Gladiators in Norway developed this technique with great success. On the whole, however, Fighters which were constrained to this method of attack would have a very limited usefulness.

14.—(B) The simplest reaction for the Fighter is to pierce the armour, but it entails the use of bigger calibres. It must be remembered also that it is not sufficient merely to pierce the armour, but the bullet must have sufficient remaining velocity to do lethal damage thereafter. High velocities, in addition to bigger calibres, are therefore necessary.

15. The .5-inch gun appeared, at first sight, to be the natural successor to the .303 inch, but experiments showed that the type available to us in the Autumn of 1940 was practically defeated by the 8-mm. armour carried in the M.E. 109. It was true that the bullet would pierce 20-mm. or more of armour in the open, but it was found that the minute deceleration and deflection of the axis of the bullet, caused by its passage through the structure of the fuselage, exercised a very important diminution on its subsequent penetrative powers.

16. Experiments carried out with .5-inch guns of higher velocity in America have given encouraging results, and it is not at present possible to dogmatise on the subject. It would, however, be foolish to adopt a gun which could be defeated by a slight thickening of the armour carried by the Bomber and the aim should be to defeat the thickest armour which it is practically possible for the enemy to carry.

17. We have at present no gun of a calibre between .5-inch and 20-mm. (.8 inch). The latter was originally adopted by the French because it was of about the right size to fire an explosive shell through an airscrew of a Hispano Suiza engine, and was adopted by us from them. If, therefore, it proves to be of the best weight and calibre for an armour piercing, that is due to accident rather than design.

18. A study of available data might lead one to suppose that a calibre of about 15-mm. would be the ideal, and I understand that this size has recently been adopted by the Germans; but we cannot now start designing a new gun for this war, and we must choose between the .5-inch and the 20-mm. We shall soon get reliable data from American Fighter types in action. They have faith in the .5-inch gun.

19. The Armament of the Royal Air Force is not its strongest point, and in my opinion we should do our own Design and Experimental work, and satisfy our requirements without being dependent on Woolwich and Shoeburyness.

20.—(C) Incendiary ammunition may be fired from guns of any calibre and Bomber tanks have been set on fire by .303 inch ammunition. The bigger the bullet, however, the bigger the hole, and a small bullet stands a good chance of being quenched before it can take effect. In any case, the fuel tanks of a Bomber constitute so small a proportion of the whole target that they cannot be made the sole objective of attack; and it seems that the adoption of a large-calibre gun and the use of a proportion of incendiary ammunition therein will afford a satisfactory compromise.

21.—(D) It was assumed by the French that the 20-mm. shell would be effective against the structure of modern aircraft. I do not know what trials they carried out, but the tests done by us at Shoeburyness and Orfordness indicate that the effect of a 20-mm. shell exploding instantaneously on the surface of an aircraft is almost negligible, except in a small percentage of lucky strikes. The normal effect is that a hole of about 6-inch diameter is blown in the surface, and that the effect at any distance is nil, since the shell is blown almost into dust. Occasionally the fuze penetrates and does some damage, but this is slight in comparison with the total weight of the shell. Even the big 37-mm. shell, though it may be spectacular damage, will not often bring a Bomber down with a single hit. Greater damage is done if the fuze is given a slight delay action, so that it bursts inside the covering of the aircraft, but small delay action fuzes are unreliable in operation and difficult to manufacture, and, on the whole, it seems doubtful if explosive shells are as efficient as armour-piercing and incendiary projectiles, especially as they will not penetrate armour. Another point must be remembered, viz., that a drum of explosive shells is a very dangerous item of cargo: if one is struck and detonated by a bullet it is not unlikely that they will all go off and blow the aeroplane to pieces.

22.—(E) The use of large shells (comparable to Anti-Aircraft types) from Fighter aircraft is practically prohibited by considerations of weight if a gun is used. The gun itself must be heavy and the structure must be strengthened to withstand the shock of recoil. The walls and base of the shell also have to be made uneconomically heavy to withstand the discharge. All these difficulties, however, can be overcome if the Rocket principle is used. It is true that a Rocket can be discharged only in the direct line of flight, but that is no particular handicap to a Fighter. It can have a light firing tube, there is no recoil, and the shell can be designed for optimum fragmentation effect. (I have been told that a 3-inch Rocket shell develops the same explosive and fragmentation effect as a 4.5-inch Anti-Aircraft gun shell). It also starts with an advantage over the terrestrial rocket in that it has an initial velocity of about 300 m.p.h. through the air, which gives it enhanced accuracy. For this weapon a " Proximity Fuze " would be ideal, but, pending the development of this, there is no reason why the Rocket should not be used with a Time and Percussion Fuze used in conjunction with a range-finder in the Aircraft.

23. This item was put on the programme about 7 years ago, and I think it a great pity that it was allowed to drop. True, unexpected difficulties may be encountered, and nothing may come of the project, but it is an important experiment, and our knowledge of what is and is not possible will not be complete until it has been tried.

24. I think that our decision to adopt the 20-mm. gun is probably the wisest which we could have taken, but to carry increased load efficiently something bigger than the Hurricane or Spitfire is needed. The Typhoon with 2,000 h.p. should be ideal when it has been given an adequate ceiling.

25. In the meantime the Hurricane must be somewhat overloaded with 4 Cannons, and mixed armament (2 Cannons and 4 Brownings) in the Spitfire is merely a compromise necessitated by loading conditions. Might not the high-velocity American .5-inch gun prove a suitable armament for the small fighter?

26. As regards ammunition for the 20-mm. gun, the so-called " solid " bullet was merely a cheap steel bullet produced by the French for practice purposes. Its mass and velocity have enabled it hitherto to smash through armour to which it has been opposed, but an improved design will probably be needed before long; doubtless the matter is receiving attention. I understand that the incendiary bullet—the equivalent of the de Wilde .303-inch—has been giving good results.

27. One other attribute of a naked steel bullet must not be overlooked, viz., its incendiary effect when it strikes a ferrous structure. During ground trials a Blenheim was set on fire by the second hit from a " solid " bullet. Unfortunately, German aircraft do not normally contain much iron or steel.

28. If we look into the not too distant future, I think we shall find that an additional and quite different reason may arise for the adoption of the high-velocity gun with a comparatively heavy projectile. I refer to the increasing intensity and effect of return fire from Bombers.

29. Our Fighters are protected to a very large degree from the return fire of Bombers which they attack from astern, so long as they have to sustain the impact only of rifle-calibre bullets.

30. The situation will be quite different, however, if turrets with .5-inch guns are commonly used in Bombers. The Bomber has the comparative advantage over the pursuing Fighter of firing " down-wind " (one may get a clear idea of the situation by imagining both aircraft to be anchored in space, with a 300-m.p.h. wind blowing from the Bomber to the Fighter). The result is likely to be that effective armouring of Fighters against return fire will be impossible, and fighting ranges in good visibility may be considerably lengthened. In such circumstances high velocity, flat trajectory and a heavy projectile will attain increasing importance; attention will also have to be paid to accurate methods of sighting, and allowance for gravity drop.

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