SECRET

BALLOON DEFENCES

1914 - 1945

APPENDICES

DM 12471/1(3)

SECRET

APPENDIX "A"

SCHEDULE OF GUN OPERATIONAL CONTROLS

BARRAGE	BARRAGE CONTROL	TELEPHONE NO.	CONTROLLING AUTHORITY	REMARKS - SITES CONTROLLED ETC.
NO. 30 GROUP				
London	30 Group	Museum 6405	Local A.A. Commander	All sites
Thames	952 Sqdn.	Sheerness 2670	"	"
Harwich	928 Sqdn.	Felixstowe 984	"	"
NO. 31 GROUP				
Birmingham N.	5 B.C.	Sutton Coldfield 2238-9	"	"
Birmingham S.	6 B.C.	Highbury 2233-4	"	"
Coventry	916 Sqdn.	Coventry 61525	"	"
Derby	7 B.C.	Derby 59271	"	"
Cardiff	14 B.C.	Llandaff 1060	"	"
Barry	14 B.C.	Llandaff 1060	"	"
Swansea	958 Sqdn.	Swansea 88412	"	"
Port Talbot	14 B.C.	Llandaff 1060	"	"
Newport	966 Sqdn.	Newport 3452	"	"
NO. 32 GROUP				
Avonmouth	951 Sqdn.	Bristol 37094	"	"
Filton	"	"	"	"
Bristol	"	"	"	"
Portsmouth	932 Sqdn.	Portsmouth 6000	"	"
Southampton	930 Sqdn.	Bassett 68766	"	"
Plymouth	934 Sqdn.	Devenport 880	"	"
NO. 33 GROUP				
Liverpool	8 B.C.	Aintree 1711	"	"
Runcorn	923 Sqdn.	Runcorn 2163	"	"
Manchester	10 B.C.	Middleton 2441	"	"
Sheffield	16 B.C.	Sheffield 37284	"	"
Hull	17 B.C.	Hull 31633	"	"
NO. 34 GROUP				
Newcastle	15 B.C.	Benton 61038	"	"
Blyth	15 B.C.	Benton 61038	"	"
Billingham	938 Sqdn.	Stockton 53853	"	"
Glasgow	18 B.C.	Bishopbriggs 451	"	"
Clyde	18 B.C.	Bishopbriggs 451	"	"
Forth	948 Sqdn.	Inverkeithing 291	"	"
Scapa	20 B.C.	Lyness 49	"	"
Methil	948 Sqdn.	Inverkeithing 291	"	"
Belfast	968 Sqdn.	Belfast 57408	"	"

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"M" BALLOON UNIT

APPENDIX "B"

NUMBER OF BALLOONS RELEASED, 1939 - 1945

Month	1939	1940	1941	1942	1943	1944	1945
January	-	120	547	2130	1709	557	-
February	-	429	1408	745	2478	404	735
March	-	403	855	1563	1240	587	500
April	-	75	977	1281	1111	672	172
May	-	-	743	1930	1000	505	-
June	-	-	1302	1275	1262	1327	-
July	-	266	1876	400	1200	850	-
August	-	219	2835	1804	-	651	-
September	-	-	1012	1401	290	421	-
October	60	70	2570	1400	140	-	-
November	547	364	1488	598	462	-	-
December	381	594	4495	1000	427	-	-
	988	2540	20108	15527	11319	5974	1407

TOTAL = 57,863

NUMBER OF OPERATIONS CARRIED OUT, 1939 - 1945

Month	1939	1940	1941	1942	1943	1944	1945
January	-	2	6	9	9	18	-
February	-	9	12	4	13	16	8
March	-	5	7	5	7	22	4
April	-	1	9	4	6	16	3
May	-	1	7	6	5	10	-
June	-	-	9	5	7	17	-
July	-	3	10	2	6	9	-
August	-	2	17	9	-	5	-
September	-	-	9	7	6	6	-
October	1	1	17	7	4	-	-
November	10	10	7	3	15	-	-
December	4	11	20	5	10	-	-
	15	45	130	66	88	119	15

TOTAL = 478

APPENDIX "C"

METEOROLOGY FOR THE BALLOON BARRAGE

General

The work of the Meteorological Office, Air Ministry for the balloon barrage may be considered under the three following headings:-

(a) Investigation of the meteorological factors affecting kite balloons.

(b) Provision of weather forecasts and warnings for the operations of balloon barrages.

(c) Instruction of balloon barrage officers in the meteorological factors affecting balloons, the use of the weather forecasts and warnings, and the recognition of weather conditions dangerous to balloons.

Investigation of meteorological factors affecting kite balloons

(i) Historical

When arrangements were being made in 1936/37, by Air Ministry for the deployment of balloon barrages it was realised that one of the chief dangers to the balloons would be that of their destruction by electrical discharge. A committee with Sir G.C. Simpson, F.R.S. (then DMO) (1) as chairman was accordingly set up to investigate the matter.

In April 1939, following discussion between the Meteorological Office and Balloon Command a meteorological officer was appointed to H.Q. Balloon Command for duties connected with the items of the above Section (General).

In the autumn of 1939, a special questionnaire (R.A.F. Form 1631) was compiled which had to be completed by barrages whenever a balloon was destroyed or damaged. The questionnaire included details of the type of balloon and rigging, height at which flying, weather conditions and any special phenomena observed such as electric shocks and lightning flashes. One copy of the completed questionnaire was sent immediately to H.Q. Balloon Command where it was examined first by the Meteorological Officer. The information derived from these questionnaires was of the highest value in ascertaining the effects of weather conditions on balloons.

Information on the work into individual weather factors e.g. Wind, Atmospheric Electricity is given in the following sections each devoted to one such factor.

(ii) Wind

The Meteorological Officer, Balloon Command, witnessed as much balloon flying as possible in winds of varying strength.

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(1) Director of Meteorological Office.

Later, following the deployment of the barrages just before the outbreak of war, much more information on the effects of wind was quickly obtained, as, in contrast to peace-time training, when balloon safety was a prime consideration, every effort was made to keep the balloons flying for as long as possible.

While the normal barrage balloon and cable are designed to withstand a steady wind of 60 m.p.h. experience soon showed that only quite new balloons could be expected to withstand successfully a wind approaching such a speed at operational height (5,000 feet).

The effects of ground turbulence were specially considered and the conclusion reached, that in the town exposure in which most barrages were sited, the balloons became unmanageable near the ground in a mean wind of force 6 or more on the Beaufort scale.

(iii) Atmospheric Electricity

Reference has already been made to the Air Ministry Committee, of 1938, on the effects of atmospheric electricity upon balloons. The Committee included representatives of the Meteorological Office, Directorate of Scientific Research, No. 30 Group of Fighter Command, and the National Physical Laboratory.

In broad outline, the Committee's conclusions were that no action could be taken to protect balloons from destruction by direct lightning stroke but that possible destruction due to burning of the fabric by brush discharge, which it was thought would occur on balloons in an intense electric field, could be avoided by using insulating rigging and non-metallic protective paint for the fabric. On the safety of the crew, the committee advised that the balloon winch should always be kept well earthed, that on the approach of a thunderstorm all the crew except the winch driver should remove themselves from the winch but that the winch driver was quite safe in his cab even if the cable were struck by lightning. This last opinion based on the Faraday cage nature of the cab was confirmed by trial using a high voltage impulse generator at the National Physical Laboratory and, later, in service in the field.

A fresh Air Ministry committee on atmospheric electrical effects on balloons was formed in May, 1939 and met at intervals during the rest of that year and in 1940 and 1941 to review experience.

The Meteorological Officer, Balloon Command, investigated all cases of destruction of balloons by electrical means including cases which had occurred before his appointment.

Summaries of details of electrical losses of balloons with comments on weather conditions were compiled monthly and distributed to D.M.O., Superintendent, Kew Observatory; Directorate of Scientific Research Air Ministry, and the National Physical Laboratory. Special reports were issued immediately after events of particular interest had occurred.

When balloon operations began on a large scale there was little evidence of the relative importance of destruction by brush discharge and direct lightning stroke. It soon became evident, however, that balloons fitted with insulating rigging and non-aluminised fabric were little, if at all, less liable to destruction than balloons made of aluminised fabric and rigged with steel wire. The question was one of much practical importance since aluminised fabric was found to withstand the weather better than insulating rigging. The brush discharge theory was then further tested at the suggestion of the National Physical Laboratory by measuring with magnetic indicators the peak currents which flow in the cables of destroyed balloons. Magnetic indicators are strips of specially prepared steels fixed at a known distance from the cable. Whenever a balloon so fitted was destroyed electrically the indicators were sent at once to the National Physical Laboratory for measurement of the induced magnetisation whence the peak current in the cable was deduced. The indicators are not sensitive to currents of less than 500 amperes, which is too heavy a current to be due to brush discharge. Their use proved that 90% of balloon casualties due to electrical means were due to direct lightning stroke. The results are summarised in the following table:-

Magnitude of current (amperes)	Number of cases	Percentage of total
No definite result	15	11
500 - 1,000	19	14
1,000 - 2,000	37	27
2,000 - 10,000	39	29
10,000 - 20,000	11	8
greater than 20,000	14	11
Total	135	100

The 11 per cent of cases listed under no definite result may contain some when there was a direct stroke carrying less than 500 amperes and others in which the magnetic indicator was incorrectly fitted.

The question of the degree of thundery activity needed for electrical danger to balloons was clarified by experience in the summer and autumn of 1939. Examination of 400 individual cases of balloons destroyed electrically showed that in 32 of these the only lightning strokes which took place were those which destroyed balloons while on a further 52 occasions, so far as could be ascertained, lightning occurred only in the barrage area. On the other hand, precipitating cumulo-nimbus clouds were present above the barrage on every occasion but one when balloons were destroyed electrically. The one occasion occurred at Cardington on 17th April, 1939, when a balloon was destroyed by a flash from a cumulus cloud which was not giving precipitation and in that case there was evidence that the cloud was near the point of precipitation. It was concluded that precipitating cumulo-nimbus clouds were definitely likely to give strikes to balloons whether these clouds had been previously giving flashes or not. Support was lent to this view by the magnetic indicator statistics already referred to which showed that out of 135 balloons destroyed electrically when fitted with magnetic links the peak current in 52% was 2,000 amperes or less. A peak current of 2,000 amperes is much less than that which occurs in most "natural" lightning flashes. Acting on this information the Meteorological Office was able in 1940 to devise a scheme for forecasting lightning risks to balloons under which one of nine categories of risk was included in every forecast issued to balloon barrages. These categories were as follows:-

Term	when used
XX	Thunderstorm actually in progress over the barrage
(a) Lightning expected	Used when, either - (1) there is practical certainty that there will be cumulo-nimbus clouds over the actual area of the barrage, and (2) lightning is known to have been observed in the existing meteorological regime in which the barrage is or will be situated, or (3) a definite line squall is approaching the barrage
(b) Lightning probable	used when - (1) it is expected that there will be cumulo-nimbus clouds over the actual area of the barrage, but (2) there have been no actual reports of lightning in the existing meteorological regime in which the barrage is or will be situated.
(c) Risk of Lightning	Used when it is expected that over the actual region of the barrage there will be cumulus which may develop into cumulo-nimbus
(d) Local lightning expected	used when - (1) there is practical certainty that there will be cumulo-nimbus cloud in the district in which the barrage is situated (but not necessarily over the barrage itself) and (2) lightning is known to have been observed in the existing meteorological regime in which the barrage is or will be situated
(e) Local Lightning probable	Used when cumulo-nimbus clouds are expected over the district in which the barrage is situated but there have been no actual reports of lightning in the existing meteorological regime in which the barrage is or will be situated

APPENDIX "C"

(f) Risk of local Lightning	Used when it is expected that there will be large cumulus which may develop into cumulo-nimbus over the district in which the barrage is situated
(g) Little likelihood of lightning	Used when none of the previous terms apply but it is not certain that there is no risk of lightning
(h) No lightning	Used when it is certain there will be no lightning. This is the case when the air is stable and it is certain that any clouds which form will not grow into cumulo-nimbus. The term is not used if there are fronts or occlusions in the region of the barrage approaching it.

Headquarters Balloon Command issued an Air Staff instruction detailing the proportion of the barrage which should be flown according to the degree of lightning and other weather risks and the state of enemy activity.

For giving instrumental warning of the approach of dangerous electrical conditions, an apparatus, which relied on the increase of the electric current flowing between balloon and cable as dangerous conditions approach was suggested by the National Physical Laboratory and developed by that department and the Meteorological Office. The current between the balloon and the cable consists of a very small relatively steady current, due mainly to brush discharge from the cable, which was found to reach a value of about $\frac{1}{2}$ milliampere in the presence of dangerous conditions, superimposed on which are sudden transient currents which occur when the induced charge on the cable is changed by the sudden changes in the atmospheric electric field which occur when lightning flashes take place. The apparatus was arranged to cause a neon tube to flash or a bell to ring when the steady current reached $\frac{1}{2}$ milliampere or a transient of $\frac{1}{2}$ ampere occurred.

A remarkable occurrence which took place on a few occasions was the complete volatilization by the lightning current of the steel part of the balloon cable leaving the hemp core undamaged. Considering that for this to take place the steel must have been heated to some 3,000°C the occurrence is an impressive testimony to the short duration of the lightning stroke. Normally the cable transmitted the lightning current without being damaged.

A minor matter which was investigated was that of the explosions which on a few occasions occurred during balloon deflation, once with fatal consequences. It was found that these took place only during very dry weather and were ascribed to the explosion of a mixture of hydrogen and air by a spark caused by frictional electrification. The introduction of the use of damp groundsheets and similar measures during deflation cured the trouble.

(iv) Ice Accretion

The possibility of ice accretion affecting balloons was realised before any instance of it had occurred and the severe winter of 1939/40 provided many cases of balloons being forced down to the ground by the weight of ice on them, or of the valve being opened by the freezing of rainwater in the valve aperture. One remarkable occurrence was the formation on the ripcord of a balloon of ice sufficient in weight to pull the cord and rip the balloon.

(v) Strato-Cumulus Cloud

It is important that barrage balloons should not project above the top of a stratiform sheet of cloud thereby possibly betraying the location of an objective to any enemy force.

Besides supplying forecasts and reports of the height of the top of such clouds the Meteorological Office collaborated in the development of apparatus known as the "Cloud Indicator" to indicate to the balloon crew whether the balloon was in cloud or not. Much difficulty was experienced but a satisfactory device was finally evolved.

The apparatus was also used for measuring the height of the base and top of cloud sheets which were reported to the Central Forecast Office. These reports were received from a few balloons specially established for the purpose as well as from the normal barrages.

(vi) Use of balloons to carry Meteorological instruments Baro-thermo-hydrograph

An apparatus recording simultaneously pressure, temperature and humidity on a rotating drum, known as the baro-thermo-hydrograph was brought into use in 1939 initially as a cloud indicator. It was found that the swinging of the balloon did not jerk the pens. A rate of ascent of 200 feet per minute or less, with a stop at every 500 ft. of paid out cable, was found desirable to reduce lag to small dimensions. Readings obtained from these instruments have been found useful in investigations into the temperature and humidity structure of the lower atmosphere and balloons have been flown specially at places away from barrages to carry them for such investigations.

(vii) Gust Measurement

In 1940 and 1941 measurements of wind speed and gustiness were made at Cardington by meteorological staff using Robinson and Richard anemometers and gust records devised by Dr. Field and the National Physical Laboratory. The results were incorporated in a report to the Aeronautical Research Committee.

Provision of weather forecasts and warnings

(i) Balloon Barrages

Arrangements were made during the Czech crisis in September, 1938 for the supply of weather forecasts and the attachment of a meteorological officer to Headquarters No. 30 Group, the headquarters of the London balloon barrage (then the only one in existence) should the barrage be deployed. The barrage was not in fact deployed at that time.

Forecasts and warnings then began to be issued to the London balloon centres for training purposes.

In 1939 the supply of forecasts and warnings for the training of provincial balloon barrages began and arrangements were made for a continuous service in the event of war. The forecasts and warnings were supplied from the nearest Type 1 Meteorological Office.

The London barrage began a scheme of continuous flying of one quarter of the barrage in July, 1939 for which the full service was put into operation. The Meteorological Officer, Balloon Command, was present in the Operations Room of the London Barrage during this embodiment.

With the outbreak of war the supply of forecasts and warnings to all barrages became continuous. Forecasts were issued four times daily including a general inference; forecast of wind at surface, 1,000 ft., 3,000 ft. and 5,000 ft. with special reference to squalls or strong gusts; general weather with special reference to thunder, hail, ice accretion and severe frost; cloud type, height of base and top with special reference to likelihood of large cumulus or cumulo-nimbus; visibility. Warnings of increase of wind and the development of thundery conditions were issued when required at any time.

Shortly after this, Headquarters Balloon Command asked for a meteorologist to be attached to each barrage to advise the barrage commander on the use of the forecasts and warnings and warn him when dangerous weather conditions were imminent. Following this request a Meteorological Assistant grade II was posted to these barrages, then 7 in number (London, Warrington, Coventry, Derby, Hull, Birmingham, Sheffield), which were not adjacent to a meteorological observing station in sight of the barrage whence advice could be given. As occasion arose, Meteorologists were attached to barrages opened later which fulfilled the same conditions. (Sheerness, Crewe, Scapa Flow, Yeovil, Brockworth, Kyle of Lochalsh, Ardrossan, Swansea, Cardiff, Manchester, Falmouth, Portsmouth, Southampton). The Assistants in question received the forecasts and warnings issued to the barrage and sufficient meteorological data for the construction of skeleton charts.

In the case of other barrages it was arranged that the barrage controller should consult the responsible meteorological office whenever he thought necessary and that the forecaster at the Meteorological Office should give personal advice to the barrage whenever needed. Also all reports of thunderstorms, squalls and height of the top of stratiform cloud sheets were broadcast on the meteorological teleprinter circuit as soon as received at the Central Forecast Office. These reports were passed automatically by the responsible meteorological office if relating to occurrences within 100 miles of the barrage.

Detailed instructions regarding the forecasts and warnings required by balloon barrages were given to the Meteorological Offices concerned, the final instructions issued in November, 1940, forming Meteorological Office Synoptic Divisions Instruction No. 26.

In the middle of 1941 it was decided by Headquarters, Balloon Command that with the increase in experience of balloon barrage controllers the meteorological assistants at barrages could be dispensed with provided good telephonic communications were set up with the responsible forecast office and a meteorological course given to the control officers. Early in 1942 these conditions were fulfilled and the meteorological staff withdrawn.

In June, 1944, a very large balloon barrage was set up to south-east of London as part of the defences against the flying bombs. For the safeguarding of this barrage a meteorological office was set up at its headquarters, with a meteorological teleprinter and a telephone tie line to the Meteorological Office, Headquarters, 11 Group.

(ii) Value of Forecasts

While it cannot be said that warning was given of every risk of lightning or squall when balloons were struck or blown away yet the arrangements were generally effective, and apart from one heavy loss in London soon after the outbreak of war, few balloons were lost because of failure to provide the necessary warning. Heavy casualties from lightning occurred at waterborne barrages since balloons flying from barges cannot be close hauled, also many balloons were burnt while flying during air raids or air raid warnings periods, e.g. in July, 1940, 174 balloons were struck by lightning, 101 of them during air raid warning periods, but only 8 of them during periods when no meteorological warning of thunder was in force.

(iii) Albino

In the winter 1940/41 a scheme for releasing small spherical balloons carrying bombs and flying at a constant height into the stream of enemy bombers was put into action first in the London area and later at Liverpool. Forecasts for this work were provided by Meteorological Office Headquarters, Fighter Command which was strengthened by the posting of a highly experienced forecaster. When the scheme moved to Liverpool a radio wind finding station was set up near that city to provide wind data for the operation.

(iv) "M" Balloons

Another operation for which special forecasts were supplied was the carrying of propaganda leaflets to enemy occupied territory by small balloons. The material to be carried by the balloons had to be selected according to the areas to which the wind would carry them.

Instruction in Meteorology

After the Meteorological Officer, Balloon Command had had time to gain experience of the problems involved, the Meteorological Office issued in June, 1939, to all balloon squadrons, a typescript on weather and balloons. Lectures based on this were given by the Meteorological Officer, Balloon Command, at all balloon centres but there was not time before the outbreak of war for really thorough instruction to be given to all balloon barrage officers.

APPENDIX "C"

A further typescript on "Meteorological aspects of Balloon Barrage Operations" was issued to barrages in the autumn of 1939. In it attention was drawn to such points as the fact that the wind near the ground may become too turbulent for the balloons to be hauled down safely before the wind at operational height becomes dangerously strong, so that, with increasing winds, consideration of hauling down must be given well before the wind at flying height approaches the danger level. A similar problem exists in showery conditions, when the wind near the ground may be too turbulent for safe lowering of the balloons, when a cumulo-nimbus cloud comes along.

In the early part of 1941 a comprehensive publication entitled "Meteorology for the Balloon Barrage" (Meteorological Office Memorandum M.O.M.407) was drawn up and supplied to all balloon barrages and all meteorological offices at home and overseas. This publication may be regarded as the current authority on the effects of weather and atmospheric electricity on kite balloons.

Lectures on Meteorology were given as necessary at Balloon Command to courses for balloon barrage control officers following the inception of that type of officer in the winter 1939/40. In 1941 all control officers received in classes of 20 or less, a fortnight's course in meteorology, during which a visit was paid to the National Physical Laboratory High Voltage Department for demonstrations of electrical effects and the Air Ministry Meteorological films were shown.

APPENDIX "D"

HYDROGEN

KBC/S.50657/H2
14 October, 1939

Ibid, 24.5.40
S/B.6/DDBP/109,
Feb. 1941

It was realised at the beginning of the War that hydrogen was literally the life blood of the barrage and at all costs a working scheme was necessary to ensure that the gas was always available to meet violently fluctuating demands, sometimes at difficult and inaccessible places. Moreover, the barrage was expanding at a rate with which the supplies of cylinders, prime movers and gas could not keep pace.

Commencing with large scale improvisation, a distribution and control system was gradually evolved, whereby the limited number of cylinders available were turned over as economically and as quickly as possible, both by road and by rail.

KBC/S.50657/H2
Enc. 118A

KBC/S.51515/42
Enc. 3A and B

Factories and production eventually became the province of the Directorate of Hydrogen Production, Air Ministry, (1) which, by 1941, successfully coped with the position and provided sufficient hydrogen, with a reserve to meet enemy action. A control scheme was necessary to meet the requirements of production, since a normal steam on iron plant being set to produce at a pre-determined rate, was not flexible. Moreover, storage for hydrogen at most factories was negligible. In fact, a hydrogen factory may be considered as analogous to a "running tap", for which a succession of receptacles (the cylinders) must be always available, or waste and stoppages will occur. It was the constant aim of the organisation to maintain a steady flow of empties to meet the capacity of the factory at all times.

Inevitably, factories broke down, mainly due to compressor trouble, and immediate diversions had to be made to meet the new conditions. Also, when heavy casualties occurred in a particular area, help had sometimes to be rendered by one Group to another. Sudden and varied demands were constantly being made, a state of affairs only to be met by a system having the utmost flexibility.

The channels of communication were as follows:-

Hydrogen Headquarters, Balloon Command — A.M.D.C.G. (Production)

Group Hydrogen Officer

Centre Hydrogen N.C.O. — Gas Factory N.C.O. — Self Accounting Squadron, Hydrogen N.C.O.

HTD: Instruction
No. 1

The responsibilities of the officers concerned may be briefly stated:-

KBC/51515/H2
Enc. 25A

Hydrogen, Balloon Command - Collaboration with Air Ministry, D.C.G. on -

(a) Allocation of the factories for basic and peak loads to meet anticipated demands.

(b) Control of loads on factories.

(c) Re-distribution of load in emergency.

(d) Daily adjustments of Group allocations as necessary.

(e) Inter-Group aid in emergency.

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(1) Later, Directorate of Compressed Gasses, Ministry of Aircraft Production.

Group Hydrogen Officer

(a) Control of hydrogen supplies at all Units below Group, to combine operational efficiency with economy in transport.

(b) Supervision of hydrogen distribution from factory down to Site.

Centre or Self-Accounting Squadron Hydrogen N.C.O.

(a) Control of Centre of Squadron Hydrogen L of C. vehicles in collaboration with Centre M.T. or Squadron Hydrogen Officer.

(b) Trailer movements by road and rail between Centre or Squadron and factory in accordance with Group allocations.

(c) Gantry work for -

(i) Hydrogen replenishment.
(ii) Cylinder testing.

N.C.O. i/c Factory Detachment

(a) Handling of trailers at compression point including coupling duties and discipline and fire precautions at filling point.

(b) Accommodation arrangements for visiting drivers.

(c) Liaison with factory civilian staff.

At peak, as much as 20,000,000 cu. ft. of hydrogen was collected and distributed in a week without an undue strain on the organisation. This was made possible only through the close liaison, keenness and experience of the officers and N.C.Os., forming the long chain between Air Ministry and Balloon Site.

Demands for hydrogen were often sudden and awkward, but in each instance, the necessary arrangements were laid on with the utmost speed and the demand met. Without the team work and spirit of co-operation shown by all connected with the supply of hydrogen from Group officers down to L. of C. drivers, this success would never have been achieved.

Factories

Prior to September, 1939, the only Hydrogen Factory available for regular supplies was Cardington, using a single retort method of production, and quite unable to cope with the rising demand. The country was, therefore, combed to discover other sources to augment this supply and small amounts were obtained from the British Oxygen Companies at Wembley and Wolverhampton (100,000 cubic feet per day) and from the Fuel Research Station, Greenwich (60,000 cubic feet per day).

KBC/S.50657/H2 Enc. 4A

Arrangements were also completed for hydrogen to be drawn regularly from the Imperial Chemical Industries factories at Billingham and Runcorn. Although the combined output of the factories was nominally sufficient to meet the demands from the existing Centres, unsuitable and unserviceable Motor Transport, combined with shortage of cylinders, made the collection of the hydrogen a problem of the greatest difficulty.

KBC/S50657/54/H2
24th May, 1940

Hydrogen consumption figures were not known, but by the end of October, sufficient data had been collected to gain some idea and it was found that the figure of 2 H.P. cylinders of hydrogen per L.Z. Balloon per day for all purposes, including normal replacement casualties, was a fair estimate on which to work for future planning.

Ibid.
Enc. 24A

In January, 1940, with an expanding Barrage and the possibilities of enemy action against existing factories, particularly Runcorn and Billingham, it was realised that more factories were required, dispersed as much as possible and outside vulnerable areas.

Ibid.
29th May, 1940

Ibid.
20th July, 1940

By May, 1940, the strength of the Barrage was approximately 1,400 balloons, the hydrogen being supplied by Billingham, Runcorn and Widnes, Cardington, Weston-super-Mare, Greenwich, and the British Oxygen Companies works at Wembley and Wolverhampton. With further increases in the Barrage contemplated, arrangements were made to increase the output of Weston, Cardington and Greenwich, but these did not come up to expectation and there was little or no margin at this period to cover enemy action, which was then highly probable. Accordingly, the hydrogen supply ran under a heavy risk of a complete breakdown during the period and was the cause of great concern within the Command. Fortunately, this breakdown did not occur. Greenwich, which was the main supply for the Dover barrage, kept going in spite of "D/A" bombs in the factory perimeter and some material damage, whilst I.C.I. Billingham only received minor damage, which did not affect the Hydrogen output.

Ibid.
Enc.118a,
26th Feb. 1941

The provision of new Factories at Poole, Long Eaton, Kilmarnock and Keith was accelerated and by 1941, a Directorate of Hydrogen Production was set up at Air Ministry under Lord Ridley, to deal with Hydrogen requirements for Balloon Command.

As a result, a large number of Gas Works throughout the country having the necessary surplus water gas available for hydrogen production, were surveyed, and where suitable, brought into the net-work, whilst other supplies from industrial sources were either earmarked as reserves or made available forthwith.

The list of Hydrogen Factories which in due course became available to the Command, was as follows:-

Cardington	Stirling
Billingham	Belfast
Runcorn and Widnes	Cwmbran
Weston-super-Mare	Torquay
Walkden	Greenwich
Swindon	Kilmarnock
Harpenden	Poole
Cambridge	Long Eaton
Chelmsford	Keith
High Wycombe	Wembley
Epsom	Wolverhampton
Bedford	Lyness (Silicol)
York	Pembrey (Silicol)

RESERVES

Wade
Morley
Worksop
Bishop Auckland

HYD. Instruction No.1/S51515/H2 Enc.22A

A scheme of daily allocation of trailers to Factories through Groups and Centres was inaugurated as an essential to the maintenance of even Factory outputs, economy in transport and high reserves of full trailers. This scheme, with minor modifications, continued successfully up to the time of elimination of the Command and proved capable of coping at need with a demand of over 20,000,000 cubic feet of hydrogen per week.

KBC/24527/H2

An R.A.F. detachment was located at each Factory for coupling duties and to deal with vehicles arriving for compression. This detachment carried out a routine job conscientiously and well, their relations with the civilian Managers and employees at the Factories being excellent. Where fires occurred, the airmen dealt with them with commendable promptness and efficiency, thereby reducing damage and factory stoppage to a minimum.

From 1941, the supply problem was never one of insufficient hydrogen at the Factory. Invariably, the problem in emergency, has been to devise the most rapid method of collection, essentially a problem of traffic control.

Silicol Plants

KBC/53770/HTD Parts I, II and III

In 1939, the use of Silicol Plants for the production of hydrogen to any great extent was not envisaged owing to the difficulties in supply of ferro silicon, expense of production, unsuitability of Plants and smallness of output. At that time, the only Plants available were a small number of "A" and "B" types left over from 1914-1918, together with a Jaubert experimental high pressure generator lying disused at Cardington. Later, as the Command expanded, improved Silicol Plants to meet particular conditions were brought into service for:-

(a) Emergency supplies at Scapa.
(b) South Wales barrage.
(c) Overseas units.
(d) Operation "Overlord".
(e) Operation "Anti-Diver".

(a) SCAPA

KBC/54558/HYD

Early in 1940 after a Barrage at Scapa was decided on, a "B" type Plant with 5 Reavell 1,800 lbs. per square inch compressors was erected on Hoy for use in emergency to supplement the supplies by cylinders which had to travel between Billingham and Scapa via Invergordon, with a long and uncertain turn round time. This Plant, however, was not a success, in emergency, the compressors, which were very old, failed to stand up to continuous running and eventually, it was found necessary to scrap them and replace with modern machines. With this improvement, the Plant managed on most occasions to meet the demands.

The Jaubert Plant was also transferred to Scapa. It was not very successful, however, in its new environment owing to chronic sludge valve trouble and was finally scrapped as "dangerous" when the effect of hot caustic soda on ordinary steel at high pressure became known.

(b) SOUTH WALES BARRAGE

When this barrage was deployed and No.21 Balloon Centre formed, a fixed "B" Silicol Plant was erected at Pembrey. Here again, trouble was experienced with compressors, Nurse balloons and water supply and this Plant failed signally to run regularly and satisfactorily.

(c) OVERSEAS UNITS

Previous experience with Silicol Plants in the United Kingdom during the first part of the War had not been happy and Air Ministry, D.H.P., in conjunction with the Engineer i/c Gas Plant, Cardington, went thoroughly into the design of the Plants, with the result that the new "B.2" type with mobile compressor was evolved. Initially, 3 "B.2" Plants without compressors manufactured by Messrs. Cutler, were issued to No.990 Squadron. This Squadron, after a short field training at Lochalsh, went overseas and succeeded in Flying a Mark VI barrage for a prolonged period with hydrogen manufactured in these Plants.

KBC/51211/HYD

Following close on the evolution of the "B.2" Plant and compressor was the "A.2" Plant, a refined model of the old "A" Plant used in the last War. Units of No. 260 Balloon Wing were equipped with these on a scale of one Plant per 15 Mark VI balloons and provided with crews trained at Cardington. These Units successfully maintained a Mark VI barrage in the Middle East during 1941-1942. By this time, it was realised that a well trained crew was essential to the operation of the Plants, particularly when the hydrogen produced was compressed into cylinders, and a revised establishment was evolved. Special care was taken with the training of the crew of No.1 Mobile Hydrogen Supply Unit, which operated most successfully in the production of compressed Hydrogen in Tunisia and during the invasion of Italy.

(d) OPERATION "OVERLORD"

It was decided to site a number of silicol plants in the Southern area of England to cover possible breakdowns in the normal supplies from the steam and iron factories due to enemy action, road hold-ups or other causes. Two fixed "B" plants were sited near Maidstone and Fareham respectively and two "B.2" plants with compressors at Keyhaven and Broadsand, Nr. Brixham. "A.2" plants with compressors were located at Rye, Beeding and Devoran, backed by a reserve plant at Cardington.

KBC/S.52301/HYD

The crews for these plants had a most thorough training under No.1 Balloon Training Unit, Cardington, in collaboration with Air Ministry, D.C.G., but the emergencies envisaged did not arise and apart from the normal weekly runs, these crews had no opportunity of demonstrating their undoubted capabilities.

KBC/S.53775/HYD
Part IV

(e) OPERATION "ANTI-DIVER"

For this operation, No.2 Mobile Hydrogen Supply Unit, Heyhaven, was moved to Fareham and No.3 Mobile Hydrogen Supply Unit from Broadsands to Maidstone to provide emergency factories, capable of a peak output of 32 trailers a day. Again, the load on the steam and iron factories though heavy was never in excess of output. All the vulnerable factories, with the exception of Greenwich, escaped completely.

KBC/52611/HYD

Rail Supplies

By December, 1943, hydrogen trains running a regular shuttle service between Watford and Billingham were inaugurated. Complete trailers up to five at a time were towed by tractor on to close coupled conflats and consignments of 40 to 50 trailers were loaded chocked and roped down ready for despatch within a few hours. The turn round time was four days and two trains per week were kept running for over a year, almost without a break. These trains were the backbone of the supplies to the London Barrage during the 1940 blitz and enabled the unsuitable and rapidly deteriorating Motor Transport to be husbanded for use on the shorter hauls to Greenwich and Cardington.

KBC/S.50657/HYD 14th October, 1939. Enc.6A

Difficulties with rail supplies, however, were encountered right from the start owing to the fact that cradles of cylinders were designed only for road haulage. Shifting of cylinders in transit was a recurrent feature, but this was reduced to a minimum by:-

KBC/S.51515/HYD

(a) restricting the traffic to close couple vacuum brake conflats in 40 truck consignments;

(b) careful wheel chocking and roping down of trailers by the Railway Company;

(c) inspection of balata strapping and final tightening in-situ on the conflats prior to dispatch.

During this period, both tractor drivers and loading personnel became most expert, the record for loading a 40 truck train being a bare two hours.

This rail supply led to the abandonment of the London/Runcorn road runs by Crossley vehicles towing two trailers, which had sent up the unserviceability record to astronomical proportions.

Owing to the growing shortage of petrol and rubber in 1942, the policy of using rail whenever possible was implemented and trailers, cradle assemblies and loose bottles were sent in this way according to the facilities at rail heads, etc. At the peak of this economy drive, most of the maintenance gas for the barrage was sent by rail, whilst the L. of C. vehicles were held as a stand-by at Balloon Centres as a sort of fire engine service to meet emergencies due to heavy casualties.

Ibid. Enc. 35A 18th May, 1942

It was during this period that the rail transportation of cylinders in cradle assemblies was found to be impracticable, as it caused so much damage to trucks and cradle strapping. Accordingly, this traffic was stopped by Air Ministry, Movements 4, in December, 1943, and thereafter, with the single exception of the Keith/Aberdeen

Ibid. 3rd December, 1943

loose cylinder traffic for Scapa, conveyance of Hydrogen supplies by rail was allowed only in cases where complete trailers were involved.

The marshalling of the necessary trailers and cradles in readiness for the deployment of the Anti-Diver barrage was done mainly by rail. The highest priority was given to these moves and with the help of Air Ministry, Movements 4, in providing conflats in special trains and the whole-hearted co-operation of the despatching Units, the whole of this complex movement of 2,000 cradles of cylinders (60,000), from all parts of the country, including Scapa, went almost without a hitch and with remarkable celerity.

KBC/52611/76/
HYD
27th July, 1944

Later, four special trains of conflats carrying trailers ran regularly to Poole, Weston and Long Eaton with an average turn round of four to five days. Arrivals and departures were cleverly synchronised by the London Area Movement Control.

Finally, experience has shown that a 30-40 truck special train of close coupled conflats conveying complete trailers can run almost indefinitely without incident and maintain a reliable turn round time.

Road Supplies

KBC/50657/HYD
Enc. 30A

The cradle assembly of 30 High Pressure or 36 Medium Pressure cylinders mounted initially on a Brockhouse trailer chassis and later on an Eagle chassis was intended for road traction as a single tow. The prime mover supplied in 1939 for towing was the 30-100 H.P. Crossley with auxiliary gear. From dire necessity to maintain an expanding barrage, this vehicle was made to tow two trailers weighing 5½ tons each over long lines of communication, and inevitably, a high unserviceability ratio resulted. The auxiliary gear proved to be a particular weakness, whilst an acute shortage of spares prevailed throughout the whole time this vehicle was in service.

Particularly in the initial stages, the standard of driving was high and the way in which the L. of C. drivers coaxed these overloaded, unsuitable vehicles over long distances day after day, often under bad road conditions, is worthy of the highest praise.

The convoy system for Hydrogen replenishment was not applicable since compressor output of factory was not more than one trailer per hour. Accordingly, vehicles ran between Centre and factory only indirectly supervised. Nevertheless, accidents to L. of C. traffic were remarkably low and the drivers carried out their duties to schedule, conscientiously and well.

It is particularly worthy of mention that at a later stage when the huge Hydrogen requirements to support the Anti-Diver Barrage had to be collected, the L. of C. drivers, working day and night without fuss or incident, maintained a more than adequate reserve of full trailers at all times.

Early in 1941, the Crossley was replaced by the Dodge which had a cradle mounted on the chassis and towed one trailer in addition, gantries being set up at Balloon Centres for changing cradles.

KBC/27047/9/HYD
14th February, 1942

The situation was, thereafter, greatly eased, as the vehicles in general stood up to the job and the number allotted to the Command on a scale of 13 per 120 balloons and 20% I.R., was adequate up to the time of the anti-Diver deployment.

KBC/52611/HYD

For the anti-Diver barrage, the number of L. of C. vehicles was augmented by 100 Dodges and other vehicles from outside the Command to a scale of one vehicle per three balloons. This generous scale proved more than adequate to deal with all demands and also allowed the necessary reserve for unserviceability and for servicing.

Cylinders

KBC/S.50657/HYD
Enc. 6A
14th October, 1939

From the commencement of hostilities, the position of cylinders in the Command was one of varying degrees of shortage. All supplies came from the Chesterfield Tube Company and the rate of delivery of new cylinders could not keep pace with the barrage expansion and additional commitments.

S/B.6/DDBP/109
21st February, 1941

The position was made still more acute by the diversion of a part of the output to the manufacture of oxygen cylinders with higher priority.

KBC/550657/131/42
11th August, 1941
Ibid.
20th August, 1941

The shortage of cylinders which was most serious in the early stages was, however, offset to a considerable extent by the vigilance of the Centre Hydrogen Officers in maintaining a quick turn-round to factory and the evolution of efficient systems for the collection of empties. The opening of new factories close to barrages, thereby reducing the length of Lines of Communication between factory and barrage, helped to alleviate the position during the latter stages.

KBC/S.53819/H2
Enc. 23A

The remarkable way in which the cylinders have stood up to enemy action, immersion in sea water, etc., is worthy of note. The cylinder walls are a mere 0.28" thick, but such is the quality of the steel no splintering occurred under enemy action, punctures from shrapnel being quite clean.

The effect of sea water on the cylinders was no more serious than could be overcome by periodic greasing of valve and plug and when at a later date examination by introscope at Testing Stations commenced, the inside walls of the majority of the cylinders were found to be in reasonably good condition even after 4-5 years service.

Operations

The following operations, each of which created a hydrogen problem requiring an individual solution, are taken in chronological order.

1. "ALBINO"

The supply arrangements for this operation were grafted on to the existing distribution scheme for the static barrage.

It was arranged to keep two trailers of full high-pressure cylinders on all "Albino" Sites ready for immediate use, but apart from practice inflation, the scheme remained in a state of "stand-by" throughout its existence.

2. "PETARD"

Arrangements were made for a concentration of prime movers and trailers on the North and South sides of the Thames with a reserve common to both at No.1 Balloon Centre, Kidbrooke. Arrangements were also made to meet the anticipated heavy load on factories.

3. "OUTWARD"

KBC/S.51817/HYD

For this operation carried out by R.N. Boom Defence from three points on the East Coast, inflations were performed direct from cradles mounted on trailers or Dodge prime movers. When conditions were favourable 20-30 cradles of hydrogen were emptied in one hour, rushed back to factory for priority filling and returned to launching site ready to continue the operation if necessary.

This operation was more often than not coincident with a heavy casualty period in the L.Z. barrage and the fitting in of the daily allocations to factory to meet both commitments simultaneously called for considerable ingenuity on the part of the Hydrogen officer at No.30 Group and his W.A.A.F. assistant. The latter became most experienced in making these daily allocations and proved invaluable at a later date when the complex allocations for the anti-Diver barrage had to be made.

4. "OVERLORD"

The hydrogen plan for this operation received the most careful attention, being designed to cover as far as humanly possible every contingency due to enemy action, breakdown of communications, L. of C., factories etc.

Accordingly, by denuding out-lying L.Z. commitments of the maximum number of trailers, cylinders and prime movers and distributing them at appropriate centres, reserve parks and hards between Felixstowe and S. Wales, a most impressive concentration of equipment for the functioning of high speed hydrogen distribution was made.

Southern England was divided into areas:-

East Anglia	Dorset
Kent	Devon
Sussex	Cornwall
Hants.	S.Wales

and additional hydrogen co-ordinating officers appointed to be responsible for meeting the requirements in the County areas. These officers were briefed at Headquarters, Balloon Command and sent down to their respective areas to obtain an intimate knowledge of the lay-out and to make working contacts with naval balloon officer and others. Each devised a supply scheme in detail to meet the express demands in his area.

Reserve Parks adjacent to Hards were prospected and requisitioned and the appropriate allowance of prime movers and trailers calculated for each park.

The routeing of L. of C. vehicles between factories, centres and reserve parks and hards was also carefully worked out with the Army Movement Control.

Further, as an insurance against breakdown of factories and failures in the supply lines, a number of Silicol Plants were sited as follows:-

	Type	Output in Trailers per Day
Maidstone	Fixed B	10
Rye	A. 2	1
Beeding (Shoreham)	A. 2	1
Fareham	Fixed B	10
Keyhaven	B. 2	6
Broadsands (Brixham)	B. 2	6
Devoran (Cornwall)	A. 2	1

The crews were carefully trained at Cardington by No. 1 B. T. U. in collaboration with A. M. D. C. G. who worked out the training scheme and provided from his staff at Air Ministry a technically qualified supervisor and examiner.

Dumps of low pressure cylinders were placed at Cowes Shore Servicing Station and at Tilbury to meet expected sudden and heavy demands at those points. Well before D. Day all dispositions had been made, silicol plants tested, and trailers were in position at the Initial Reserve Parks.

The series of exercises preceding D. Day proved invaluable in testing out the dispositions made, and when the anticipated day arrived the scheme came into operation smoothly and without incident. In fact, such was the ease with which the demands were met the actual arrival of D. Day came almost as an anti-climax.

Factories worked faultlessly, no enemy action was experienced and lines of communication remained open and largely unaffected. Even when the high wind caused heavy balloon casualties at certain places, replacement of balloons was made without any strain on hydrogen supplies, whilst vessels arriving at unexpected points, or in numbers in excess of the anticipated quota, were dealt with almost as a routine matter.

5. "DIVER"

The fact that the advent of the flying bomb did not coincide with operation "Overlord" simplified the supply of hydrogen for the Curtain Barrage very considerably. Initially a hydrogen distribution scheme to cater for 500 balloons was devised.

KBC/52611/HYD

84 Dodges, 464 cradles and 480 trailers were ear-marked for the operation, being collected and held as follows in readiness for the order to deploy:-

		Dodges	Cradles	Trailers
Stanmore	3 B.C.	9	93	84
Kidbrooke	1 B.C.	33	262	229
Bristol	11 B.C.	10	70	60
Lichfield	12 B.C.	7	14	7
	"Outward"	25	25	-
		84	464	380

Later when the number of balloons increased to 1,800 a total of:

260 Dodges   1,800 Cradles   and 1,603 trailers

were withdrawn from all over the Command, including No.950 Squadron, Scapa and allocated to Nos.22, 23 and 24 Balloon Centres (1) in proportion to the balloons flown.

As the deployment progressed, it was considered necessary to increase the number of hydrogen vehicles to cover expected high unserviceability and excessive hydrogen consumption, 100 dodges and 260 other vehicles, single cradle carriers or towers, being drafted into the Command. This influx eased the position during the latter part of the deployment, but in the initial stage whilst these additional vehicles were being converted to hydrogen carriers, Balloon Command Dodges helped out by two M.T. Companies of the U.S. Army with G.M.C. trucks bore the whole brunt of the heaviest hydrogen traffic.

The L. of C. drivers made a splendid response, working day and night without intermission, whilst the factories, notably Cardington and Poole, seemed incapable of overloading. In fact, the cry from the factories during the whole of this period was "send us more trailers", never a protest to ease off. On the surface, the collection of this 20,000,000 cu. ft. of hydrogen a week appeared unspectacular - "hydrogen was always there" - but it was possible only through the closest co-operation of all concerned.

To ease the strain on the L. of C. vehicles and airmen, special trains were arranged with Air Ministry, Movements 4, to collect from the distant factories - Pool, Weston and Long Eaton. London Movements Control synchronised these trains on a regular four day turn round and they ran consistently and smoothly without incident.

Miscellaneous Commitments

As the war progressed, Balloon Command, the largest user of hydrogen, inevitably became the recognised source of supply for the commodity, for all and sundry, both at home and abroad.

At one time or another, the following activities were supplied by the Command:-

(1) L.Z. and Mark VI Balloon Barrages.
(2) Mark VI Balloons for ship protection.
(3) Calibration of Anti-Aircraft guns.
(4) "Outward" operations from three points on the East Coast.
(5) "Albino" and "Petard" operations.
(6) Balloons carrying propaganda leaflets.
(7) Electrolytic Hydrogen for the drawing of Tungsten filaments, manufacture of Anti-Tank bullets and hard metal tools (initiated by Balloon Command and taken over by Ministry of Aircraft Production).
(8) Man lifting balloons for paratroop training.
(9) Hydrogen for under water cutting.

(1) No.22 B.C., Biggin Hill,
No.23 B.C., Gravesend,
No.24 B.C., Redhill.

(10) Flame Throwers.
(11) United States Army requirements.
(12) Meteorological Balloons.
(13) Balloon experiments conducted by Balloon Development Establishment, Royal Navy, etc.

In addition to the above, a scheme for the supply of coal gas in hydrogen trailers for the aid of blitzed factories was organised by E.S.O., Ministry of Aircraft Production, with the aid of Balloon Command resources which came into action effectively after enemy action on Exeter and Cowes.

Use of Coal Gas

In April, 1940, it was realised that Hydrogen supplies were failing to keep pace with barrage demands, due to increased consumption, shortage of Motor Transport and failure of plants to reach promised gas output.

Further, all existing factories were under grave risk of stoppage due to enemy action, making the grounding of the whole barrage, due to lack of hydrogen, a distinct possibility.

KBC/S.50985/HYD

Experiments were, therefore, performed on a Gas Works Site in No.907 Squadron to ascertain the results of inflating a L.Z. balloon with varying percentages of coal gas. These experiments showed that whilst operational efficiency was impaired, it was possible to fly at 4,500 feet with a 25% admixture of coal gas with hydrogen and that on 100% coal gas, a height of 1,000-1,500 feet was attainable. Pending the erection of the new hydrogen factories, authority was given for the installation of coal gas on 900 Sites, this figure being increased later to 1,100.

KBC/S.61582/F.5
12th July, 1940

The measurement of the coal gas, owing to a general unavailability of normal meters, was on a flow/time basis as contracted with the respective Gas Companies. It was necessary to use unkinkable hose in place of the normal canvas topping up hose between balloon and gas point owing to the low pressure of the supply. Further, it was realised that the use of coal gas necessitated the immediate introduction of some form of percentage oxygen meter to determine the point at which the hydrogen coal gas mixture with air became dangerous, therefore, the modified orsat apparatus, which gave the percentage of oxygen by absorption in chromous chloride, was introduced.

In practice, however, this apparatus, though accurate, proved too fragile and difficult to service and was replaced almost immediately by the metro meter (devised by the Works Chemists of the South Metropolitan Gas Company), which followed the usual "teething" troubles, eventually became the standard purity meter for the Barrage.

The use of coal gas, owing to its effect on performance, was naturally viewed with disfavour and in certain instances, in mis-directed efforts to restore lost lift, an excessive use of hydrogen was indulged in, resulting in an increase of hydrogen consumption instead of a saving. A technique in the use of coal gas was, however, evolved, whereby only balloons required to fly below 4,500 feet were flown with hydrogen-coal gas mixtures, which improved the position considerably.

KBC/50985/HYD
30th March, 1941

KCB/21850/ENG
7th July, 1941

Meanwhile, with heavier balloons and cables and a Ruling Operational Height of 6,500 feet, the normal use of coal gas became more and more restricted in its application, but it was still considered advisable in March, 1941, in the interests of economy, to make as much use as possible of the gas. By July, 1941, however, with new Hydrogen factories in production, requirements were well covered and thereafter, coal gas was only to be used in emergency when hydrogen supplies were not available, or when it was desired to keep a balloon inflated for a few more days.

Consumption Figures

The appended consumption figures in tabular form are extracted from the statistics forwarded monthly to Air Ministry, showing the Hydrogen drawn by Balloon Command.

The incidence of weather, porosity, enemy action, etc., is clearly reflected in the divergence from the standard consumption index figure of 2 H.P. Cylinders per L.Z. Balloon per day.

Year	Month	Average number of Balloons flying	Number of H.P. cylinders used per Balloon per day
1939	November	560	2.17
	December	626	1.94
1940	January	615	1.42
	February	409	2.15
	March	485	2.08
	April	619	1.79
	May	1,113	2.56*
	June	1,104	2.88*
	July	1,200	2.80*
	August	1,501	2.40*
	September	1,562	2.81*
	October	1,746	2.21
	November	1,767	2.28
	December	1,931	1.92
1941	January	2,035	1.44
	February	2,066	1.56
	March	2,105	2.08
	April	2,168	1.71
	May	2,236	1.73
	June	2,272	1.60
	July	2,332	1.63
	August	2,358	1.33
	September	2,360	1.24
	October	2,335	1.32
	November	2,336	1.11
	December	2,310	1.11
1942	January	2,328	.94
	February	2,309	1.08
	March	2,240	1.21
	April	2,170	1.7
	May	2,207	1.79
	June	2,160	1.79
	July	2,156	1.63
	August	2,167	1.61
	September	2,189	1.68
	October	2,167	1.50
	November	2,149	1.23
	December	2,166	1.27
1943	January	2,145	1.24
	February	2,047	2.02
	March	1,977	1.49
	April	1,676	2.32
	May	1,553	2.33
	June	1,587	2.12
	July	1,587	2.41
	August	1,584	2.35
	September	1,593	1.88
	October	1,533	1.88
	November	1,539	1.65
	December	1,538	1.65
1944	January	1,409	2.00
	February	1,122	2.85
	March	1,139	2.61
	April	1,192	2.20
	May	1,207	2.36
	June	1,158	2.76
	July	1,358	3.20 ø
	August	1,905	2.40 ø
	September	1,785	1.46 ø

* = Porosity and Enemy Action
ø = Anti-Diver Barrage

APPENDIX "E"

CATERING

The London Balloon barrage had been in existence for just over a year when the formation of Balloon Command took place. The personnel of the London Barrage consisted of a small number of regulars supplemented by members of the Auxiliary Air Force; they were employed as a general rule at the Centre Headquarters.

During the early days catering problems did not really arise, as it was only during occasional week-ends and Bank Holidays that crews were deployed to Balloon sites, and in these cases it was arranged that food should be sent out to them from the headquarters.

However, with the rapid expansion of Balloon Command the feeding of personnel began to present considerable difficulties. These difficulties were common only to this Command, as the majority of Royal Air Force units were all fed under one roof and apart from the normal obstacles of supplies and domestic problems, the catering could be accomplished in a straightforward manner.

Flight Cooking

From the commencement of the war the feeding of Balloon Command personnel with the hundreds of small feeding points presented major problems which had to be solved on novel lines. It was decided that the principle of Flight cooking, and the distribution of cooked food in Hay Boxes by bicycle to the sites, would be instituted. However, at the outbreak of war few provincial Balloon Centres had been completed and little or no cooking equipment had been delivered, in spite of the fact that a considerable number of the sites were operating. Various methods of feeding were in existence; some crews were given the higher rate of ration allowance and made their own arrangements for buying and cooking their food; others were supplied with rations from the Balloon Centre and the crews cooked them as best they could on Primus stoves, etc.; and in other cases, hot food was despatched from the Balloon Centres which, of course, arrived cold and had to be re-heated on any fire that could be found.

Obviously all these varying methods were most unsatisfactory, so it was decided to adhere rigidly to the policy which had been laid down, namely that all cooking should be done centrally and distributed to sites in Hay Boxes. Thus Flight cooking came into being in Balloon Command, with a few exceptions, such as waterborne sites, and sites to which, owing to their isolated position, distribution by bicycle was impracticable.

Rations were drawn in bulk from the Royal Army Service Corps and the Navy, Army and Air Force Institute by the Balloon Centre, divided up according to the daily ration strength and taken by van to the Flight Cooking Centres, where the food was prepared and cooked, and distributed in Hay Boxes to sites by means of cycles designed to carry these boxes.

The advantages claimed were that:-

(i) Food was prepared in one central cookhouse and was uniform.

(ii) Cooked rations could be equally divided amongst sites.

(iii) A limited number of cooks was required.

These were set against the disadvantages of site cooking, which was said to be uneconomical; there was also a lack of suitable equipment, and it was thought that the standard of cooking would deteriorate. The method of central feeding remained in being until 1941.

Flight Cooking Centres

These centres were generally requisitioned property, such as large houses, schools, pavilions, etc., and were situated in an area within easy reach of most balloon sites. Most properties were equipped with gas cookers, but where this was not the case "Minor Formation Petrol" cookers and ovens were installed. Approximately 100 to 120 personnel were catered for daily, each balloon site sending in one of the crew to collect the hot food which had been placed in a Hay Box.

Cooks

There was of course, as there always is, a shortage of cooks. To obviate this, a school of cookery was started at each balloon centre, where personnel were given instructions on the many problems which presented themselves, especially on the handling of a Minor Formation petrol cooker.

Catering Officers

Balloon Command was the first Command in the Royal Air Force to introduce Catering Officers. In January, 1940 authority to establish these officers was granted by the Air Ministry; it then became possible to supervise all catering and to introduce a uniform system of service, messing and distribution. However, as time went on it was realised that Flight Cooking was by no means perfect; many difficulties were experienced, chiefly that of transporting the hot food to the sites, contending with snow and ice, bad roads, fog, and, of course, the ever present shortage of experienced personnel. It was obvious that the problem would have to be tackled from an entirely different angle.

Site Cooking

Early in 1941 it was decided once again to try out the policy, which had been so frowned upon in the early days, of Site cooking. This scheme was successfully accomplished on two units in September, 1941, and so began the complete reorganisation of Balloon Command catering.

Equipping the sites was the chief worry. On each site a small kitchen had to be added, together with a variety of small cooking utensils. Large ration distributing stores had to be organised at all Balloon Centres, where bulk rations could be divided into site lots for onward transmission to the respective feeding points. In fact the Centre ration stores became more or less a grocery stores from which hundreds of feeding points were supplied.

Criticism was loud and varied; the main argument being that the balloon operators on the sites would not be able to prepare good meals due to their lack of any cooking experience. Actually the opposite was the case. Balloon operators who probably had never so much as boiled a kettle of water produced the most amazingly good meals. Site cooking was without doubt a complete success. The final improvement was the introduction to all sites except mobile squadrons of the Outpost cooker, which burned either coke or coal.

When the time came for the Women's Auxiliary Air Force to replace Royal Air Force personnel the same policy was continued with the same successful results.

Curtain Barrage

On the development of the Diver Barrage, which undoubtedly involved the largest catering commitment Balloon Command had to undertake, the same procedure of ration distribution was adopted, and the sites continued to cook their own food, the only difference being that sites were supplied with oil burner stoves instead of the Outpost cookers.

Commendation

The success of Balloon Command's catering achievements can be summed up in a D.O. letter received by the Command Catering Officer (S/Ldr. J. Roach) from the Air Ministry E.41 (G/Capt. A. Wall) who wrote:-

> ".....I always feel that I have never given Balloon Command the special attention that its special catering problems merit, but you may interpret that as a very great compliment to yourself and your predecessors. In spite of all the special difficulties which your Command come up against, in the organisation of good catering, I may say that I have never heard anything but praise for the standard of cooking in Balloon Command and that is a thing that I can say of no other Command in the Royal Air Force....."

SECRET

APPENDIX "F"

THE DEVELOPMENT OF EDUCATIONAL FACILITIES IN BALLOON COMMAND

At the outbreak of hostilities, the General Education Scheme throughout the Royal Air Force was suspended and it was not until early in 1940 that the scheme was revived, and Command Education Officers appointed.

Squadron Leader H.R. Davies was posted as Education Officer to Balloon Command on 4th April, 1940.

At this time, the Command presented a most difficult problem from the educational point of view. It spread over most of England and Scotland, with a very large percentage of its personnel distributed among thousands of balloon sites. The Balloon Centres and Royal Air Force Station, Cardington were the only places where personnel were sufficiently centralised to enable educational facilities to be arranged on a scale comparable to those on a normal station.

Collections of books were found at most balloon sites, but in general they offered unappetising reading, and were useless both from an educational and a recreational point of view. At the Balloon Centres, the accommodation previously used for educational purposes had been put to other uses on the suspension of the General Education Scheme. Thus, there were no educational facilities in the Command, and the position invited experiment.

Conversations and discussions with both officers and other ranks revealed that there was urgent need for providing education. The personnel stationed on sites had just endured a hard winter, with no operational activity; time had hung heavy on their hands, and there had been considerable scope for mental recreation, but no arrangements had been made to provide it.

The Air Ministry were undecided as to the scale on which Education Officers were to be established, but in October, 1940, an order was published providing for their establishment on stations to a limited scale. In Balloon Command, one Education Officer was established at each Centre of two squadrons.

Meanwhile, the Command Education Officer had visited Regional Committees likely to play a part in the operation of the scheme, in order to ensure that there would be no delay once the education staff was provided. Provision had also been made of small, but well-selected reference libraries for all Balloon Centres and recreational libraries at sites through the Services Central Book Depot; arrangements had been made for part-time teachers, both Service and civilian, for visiting lecturers, and for attendance at classes available under local education authorities. By February, 1941, there were Education Officers at all Balloon Centres and at Cardington, enabling a relatively energetic scheme to be put into operation.

Instructional facilities were primarily directed to Service needs and priority of claims on educational services was:-

(a) training of potential aircrew;

(b) training in basic educational requirements of Royal Air Force trades to encourage remustering;

(c) training in shorthand and typewriting to improve clerical efficiency.

Training of Potential Aircrew

Many of the personnel in Balloon Command were members of the Auxiliary Air Force, and represented a varied cross-section of professions, trades, educational background and outlook. It was obvious that among the personnel of the Command there was a large body of men qualified mentally and physically to play a more active part in the war than balloon operating.

The Centre Aircrew Training Scheme represented a big advance in the development of the Balloon Command Educational Scheme. It was originated by a request from the Air Officer Commanding No. 32 Group (1) for the establishment of some central school for the general educational training of potential aircrew.

The scheme was launched experimentally in balloon centres of No. 32 Group in April, 1941, and was an immediate success. The Air Officer Commanding Balloon Command (2), saw it in operation at No. 13 Balloon Centre and was more than satisfied regarding its possibilities; on returning to his headquarters, he instructed the Education Officer to extend its application to the rest of Balloon Command and to increase the duration of the course from two to three weeks.

The training of potential aircrew candidates was continued in strength until 1943, when the demand for volunteers for aircrew grew less; nevertheless, Balloon Command continued to provide an appreciable number of volunteers, especially for Air Gunner duties.

Owing to the time lag in calling up cadets for training, a scheme was then introduced into Balloon Command whereby volunteers who had been through a Centre and a Refresher course were required to attend for three hours' instruction in aircrew subjects each week, the attendance being during working hours. This had the dual effect of sustaining the cadets' interest in their work and ensuring that they did not become mentally stale.

Education for Deployed Personnel

The problem of airmen and airwomen on the balloon site was always uppermost in the minds of the Command Educational Staff, and Education Officers at Balloon Centres were constantly being reminded of the necessity for maintaining constant touch with these dispersed personnel.

At this time, the Air Ministry agreed to the employment of Airmen Schoolmasters at the home stations of Education Officers in Balloon Command, thus giving the latter more time and scope for visiting their "flocks" and bringing educational facilities to squadrons, flights and sites.

(1) Air Commodore A.A. Walser, M.C., D.F.C.

(2) AVM Sir E.L. Gossage, KCB, CVO, DSO, MC.

In early 1942, Headquarters Balloon Command suggested the development of recreational handwork within the Command, which would give valuable leisure-time occupation to a high proportion of operating personnel who were not attracted by class-room instruction.

The aim was to find something of interest for everyone to do; that the aim was achieved is very apparent from the large number of successful handicraft exhibitions staged by different centres, no less than thirty-eight exhibitions being held during 1943, at centres, stations and squadrons. The handicrafts tackled included leatherwork, plastic work, carpentry, embroidery, weaving, pottery and toy-making; in connection with this last craft, it is interesting to note that more than 1,000 toys made by the airmen of No. 1 Balloon Centre were presented to the Lord Mayor of London at Christmas, 1942.

The development of handicrafts during the winters 1941/42 and 1942/43 made a most valuable contribution to the maintenance of good morale. During 1944, in spite of the major movements involved in the re-organisation of the Command in preparation for the invasion of the Continent and the formation of the anti-"Diver" barrage, interest in handicrafts was sustained, and when squadrons returned to their winter quarters on the passing of the flying bomb menace, there was a remarkable increase of activity in all types of handicraft work.

Development of Discussion Groups

During 1941, an Air Ministry Order was published, laying down the need for making regular arrangements for talks by visiting lecturers on matters of current interest. This order set the seed for the development of the Discussion Group in the Royal Air Force.

Education Officers at Balloon Centres contacted the teaching staffs of local schools, Regional Committees and Local Government Authorities in order that lectures and talks might be given to personnel on centres, squadrons and sites. While the lectures were mainly concerned with current affairs and citizenship, they did include diverse subjects among the arts and sciences. Some units also organised courses in "Practical Citizenship" and visits were arranged by Local Government Authorities to their respective departments.

Progress in the Discussion Group Scheme was such that by April, 1944, the position had been reached in which there was a discussion group to every twenty-five persons in the Command, an indication that almost all personnel had participated. The importance of lectures and site talks on current affairs and other matters had been fully realised.

Some idea of the magnitude of the task of providing suitable lecturers for the vast number of small units in Balloon Command may be gathered from the fact that for the year ending April, 1945, over 5,500 lectures and talks were arranged by the Regional Committees, with whom the Education Officers worked in the closest liaison. The success of the Lecture and Discussion Group Scheme in Balloon Command could not have been achieved without the co-operation of these Committees.

APPENDIX "G"

POLISH BALLOON FLIGHT SERVING WITH THE ROYAL AIR FORCE IN GREAT BRITAIN

In September, 1939, when the German forces overwhelmed Poland and all organised resistance was compelled to cease, many officers, NCO's and men of the former Polish Balloon Battalions, the 1st Balloon Battalion of Torun and the 2nd Balloon Battalion of Legionowo, crossed the Rumanian and Hungarian frontiers. In certain cases, they made the crossing as whole units, consisting of Observer Balloon and Barrage Balloon Companies, but in many instances, officers and men who were unable to rejoin their parent units, made their own crossings individually. From Hungary and Rumania, these officers and men, in groups or singly, escaped from the concentration camps in which they were interned and eventually arrived in France.

Here the Polish Balloon Units were not yet organised and therefore these men were detached for various other duties in the Polish Air Force or were transferred to other branches of the service. After the collapse of France and following an order given by the Commander-in-Chief of the Polish forces, these men once again successfully made their escape, this time to Great Britain. Thirty-seven officers and about three hundred and fifty NCO's and men of the former Polish Balloon units landed in this country and were directed to an assembly point in Blackpool.

In 1940, when the defences of Great Britain against enemy air attacks were extended and many additional Balloon Squadrons were formed, it was thought that these men, all of whom had had experience in balloons, could be engaged in this particular branch of the service, where they could play their part in the defence of Great Britain, at the same time continuing their fight against Germany.

The former chief of the Balloon Department in the Headquarters of the Polish Air Force in Poland, (1) who had been appointed Polish Liaison Officer to Headquarters, Balloon Command, and who was the senior Staff Officer of the Polish Balloon Units, submitted a project to the Headquarters of the Polish Air Force in London, that the British authorities be approached with a view to forming a Polish Balloon Unit which could be used in the defence of Great Britain. This proposal was favourably considered by the British authorities and in October, 1940, the first group of Polish balloon airmen was sent for special training to Cardington.

On 20th December, 1940, after they had completed their training, these operators were posted to Glasgow and there, as a part of No. 945 Squadron, they commenced to fulfil operational duties on the balloon sites allotted to them. In the early part of 1941, these Polish airmen were fully employed on four balloon sites and as more and more of them completed their training at Cardington, it was possible to increase the number of sites operated by them until a complete flight was eventually formed, manned entirely by Polish personnel.

Service with No. 945 Squadron continued until 20th July, 1942, when the Polish Balloon Flight moved to Donibristle House, Aberdour, Fife; there its new flight headquarters was established and they became part of No. 929 Squadron. The balloons of this squadron were

(1) Wing Commander Hilary Grabowski.

deployed to protect Rosyth Dockyard and the Royal Naval aerodrome at Donibristle from bombing or torpedo attacks, and to prevent the laying of mines by enemy aircraft in the Firth of Forth. This latter commitment was fulfilled by the Polish flight, who manned mobile waterborne sites, carrying out night patrols in the swept channels.

At about this time, facilities were offered by Headquarters Balloon Command to enable Polish NCO's to increase their knowledge of balloon operating, by attending advanced balloon handling courses at Pucklechurch and Cardington. Also many Polish balloon operators received special training on waterborne sites, and for this purpose were attached to another flight of No. 929 Squadron, for a period of twelve months. Others were given the opportunity of becoming acquainted with the work which was carried out at the Admiralty Shore Servicing Stations, where Mark VI balloons which were used for convoy work, were serviced. This attachment was prior to their being transferred to vessels proceeding up and down the coast.

Polish airmen of this flight also formed a crew for a Mark XI balloon, which was to be used for parachute training and for this purpose, they were sent to No. 10 Balloon Centre at Manchester, where they received a special course of instruction. On completion of their training, this crew was then attached to a camp in Scotland, where they manned the balloon for training Allied paratroopers.

All this training gave the Polish balloon operators great experience and a wide knowledge of many types of balloon used in Great Britain, a very important fact, as these men are considered to be the nucleus of future balloon units in Poland.

On 15th June, 1944, Germany started a new type of warfare against England, when they commenced launching flying bombs against London and the Southern Counties. As the danger from these missiles became greater, Balloon Command gave an order that all units at their disposal should proceed to the South of England to form a "Curtain Barrage". On 3rd July, 1944, the Polish balloon flight received orders to proceed to Cardington where all the necessary equipment was issued. They were then deployed at Otwood in Surrey, as part of No. 950 Squadron, where they flew their twenty-two balloons as part of the "Curtain Barrage".

Owing to the rapid advance of the Allied armies in France and the capture of the launching sites there, the Germans began to launch their flying bombs from bases in Belgium and Holland. As part of the scheme to prevent the missiles from penetrating into the London area, No. 950 Squadron was ordered, on 26th August, 1944, to occupy new positions in North Kent, and with them went the Polish flight. Later, the launching of these flying bombs became sporadic and it was therefore decided to dissolve the "Curtain Barrage". On 23rd September, 1944, the Polish flight received an order to deflate all balloons and be prepared to move north, there to await further instructions. At Newcastle, No. 950 Squadron was disbanded, and the members of the Polish flight were sent to the permanent balloon unit at Cardington.

Headquarters Balloon Command, at the request of the Polish Liaison Officer, had from time to time granted to Polish officers opportunities to be employed in various offices under Balloon Command, in order that they might widen their knowledge of the operations and aims of the Command. Two Polish officers were employed in the Balloon Development Establishment at Cardington, where they were engaged on the construction of all types of balloons, one of them carrying into execution the prototype of Kite Balloon "P". A senior Polish officer was posted for duties in the Operations Rooms of Nos. 23 and 24 Balloon Centres at the time of the forming of the "Curtain Barrage". A special task was assigned to him and in particular he was given the opportunity to become acquainted with the exigencies of the co-operation between Balloon Command and Fighter Command and other units designed for the aerial defence of Great Britain. Another Polish officer was given the opportunity of making himself familiar with waterborne balloon sites in the United Kingdom, where he gained valuable knowledge and experience in this branch of balloon operations.

During the period of their operation as a Polish balloon flight, the Commander-in-Chief of the Polish Forces, at the request of the Air Officer Commanding-in-Chief of the Polish Air Force, awarded to several Polish officers and men, the Cross of Merit, as a reward for their devotion to duty and for their excellent work whilst serving in Great Britain, and in addition for their services in France and during the German-Polish campaign.

APPENDIX "H"

BALLOON MOORINGS

The Problem facing the Command on Deployment

It is safe to say that although when the Auxiliary Air Force (Balloon Branch) took over the job of providing Barrage Protection in accordance with the pre-arranged plan, the problem of maintaining balloons on war sites had received some consideration, it was by no means solved.

The embodiment of the Auxiliary Air Force on 24th August, 1939, and the operational necessity of maintaining inflated balloons in the various barrage areas, only served to emphasise what had been learned in this respect by those London squadrons which had carried out trial deployments during June, July and August, 1939, on war sites in the London area. This was, that the methods both of flying and mooring balloons which had been developed at Cardington were by no means the complete answer to the problem.

The L.Z. balloon has a volume of 19,150 cubic feet, with an overall length of 63 feet and a maximum diameter of about 25 feet. Winches, securely moored with brakes on, have been dragged considerable distances along the ground by their attached balloons. Wire mooring strops and substantial shackles of cast steel have been broken and twisted. Concrete anchorage blocks weighing some tons and sunk in the ground have been uprooted and thrown about the place. These examples serve to illustrate the force exercised by a balloon in high winds.

Unless everything is kept under complete control during high winds, not only is the balloon and its equipment endangered, but also the safety and lives of the balloon crew.

Before proceeding to describe the development of methods for mooring balloons, it is desirable that the actual problem which faced Auxiliary Balloon Squadrons on their embodiment should be clearly stated.

The L.Z. balloon had been designed primarily to fly. The balloon was a development of the observer type balloons used in the previous war. Although a form of balloon barrage had actually existed in London for a period during the Great War, the lessons learned were not of great use. A small scale deployment during the Munich crisis in 1938 had taught little. The problem in 1939 was, in any case, very different, on account of the vastly increased scope of air attack and air traffic. This required an enormous extension of anything which had previously existed and - by reason of the fact that an air obstacle presented at least the same hazard to friendly aircraft as to hostile aircraft - needed to be regulated in such a manner that it could be brought into existence when required as protection, and removed at other times to allow freedom of manoeuvre to friendly aircraft.

The personnel who had been recruited to man the barrage, had in the main received no worthwhile training prior to embodiment, largely due to lack of equipment and training facilities.

A certain number of officers had attended short courses at Cardington and a small nucleus of Cardington-trained regular airmen were posted into each unit. The majority of the personnel engaged had never seen a balloon.

In view of the lack of experience gained in the previous War, it is not surprising that the scheme evolved by Cardington for both flying and mooring balloons broke down in practice. In fairness to those who were responsible for the pre-war methods of handling balloons, it must be stated that the commitment outlined by Air Ministry was envisaged as being one requiring complete mobility. It was largely due to the underlying essential principle of mobility that many of the items of equipment, and methods developed by Cardington, proved unsuitable in actual practice.

As the function of the barrage crystallised, it became at once apparent that in practice (at any rate as far as the barrage protection of towns was concerned) there was no need to keep to mobility as an essential part of the operational requirement. It could be taken as an accepted principle that those barrages initially deployed could remain on a static basis.

Initially the mobile policy tended to handicap the functioning of the barrage, and as the main operational function of the barrage in the earlier stages tended to be a static one rather than mobile, it was natural and in fact essential that the initial policy should be remoulded to conform to the conditions which existed. The main problem in the early days was therefore to evolve a satisfactory technique for flying and mooring balloons under all weather conditions on a static basis on all kinds of sites. It should be mentioned, however, that the Air Ministry's initial idea that the barrage should be essentially mobile did in fact materialise later.

It should be remembered also that it was not anticipated that balloons should be grounded except for inspection, but should fly at all times. Consequently the mooring problems later appreciated in the field were not given full consideration at that time.

The design of the L.Z. balloon has never been fundamentally altered, although improvements to the fabric and fittings have been continuous. The balloon used for the flying bomb ("Diver") barrage was fundamentally the same as the balloon in use when deployment in 1939 took place. It is streamlined and of the ballonet type, depending upon air pressure inside the ballonet compartment to maintain its streamlined shape. This has an important bearing on the problem of mooring. A balloon of the ballonet type presents a more difficult mooring problem than a pressure balloon. The former depends upon the amount of air entering the ballonet to maintain its internal pressure, whilst the latter is filled to a determined pressure, and is constructed in an elastic form so that its shape and rigidity is maintained within fairly wide limits of the amount of gas contained.

The ballonet type balloon must, at all times, whether flying or moored, present its nose to the direction of wind, so that air can freely enter the ballonet scoop, and so maintain inside the balloon a pressure equal to the external wind force.

When flying, the balloon automatically rides nose to wind on the end of its mooring cable, by reason of the design of the rudder and fins. If this balloon is moored at ground level, it must either swing into wind automatically like a wind vane, or alternatively it must be manually turned head to wind on each change of wind direction. It will readily be understood that a balloon of the ballonet type moored to the ground broadside to the direction of wind, will have no air entering the ballonet, and consequently the gas inside will be at a lower pressure than the external wind force. This will result in the wind "saucering" the fabric and destroying the streamlined shape. As a concave shape has a much greater wind resistance than a convex one, the stresses and strains set upon the fabric of the balloon and its mooring rigging will be excessive. In high winds this will certainly result in tearing of fabric and uprooting of moorings.

A pressure type balloon, always offering a convex section to the wind by reason of its fixed internal pressure, will stand much greater beam wind pressure than the ballonet type balloon.

Again on account of its non-rigid nature, any attempt to hold a balloon down to the ground by means of fastenings attached to externally applied patches on the surface of the balloon must be arranged to give a degree of elasticity at each securing point, and also ensure that the direction of pull of each securing rope or ballast bag is always in accordance with the angle at which the patch is applied. Operationally also the method of mooring must be such as to permit the balloon to be moored, or released from its mooring within an acceptable time, and by an acceptable number of men.

From the foregoing it will be seen that the initial problem confronting Auxiliary Squadrons on their initial deployment was to produce some method of mooring balloons which provided:-

(a) that the balloon was moored nose to wind;

(b) that in the event of a change of wind direction the balloon either moved into wind automatically or was capable of being manually moved into wind with the minimum of effort and in the minimum space of time;

(c) that the bed was capable of holding the balloon for short periods of wind in order to allow for variable wind directions on enclosed sites where no true wind existed;

(d) that the balloon could be maintained in the moored position in any degree of wind speed; (As many barrages were located in extremely exposed coastal areas, this in fact meant the maximum wind speeds experienced in the British Isles).

(e) that the form of mooring was non-rigid and conformed to the 23 available mooring patches on the balloon itself;

(f) that the operation of mooring or releasing from the mooring, could be carried out by a reasonable number of men in a time which was operationally acceptable.

(g) that the works services required for the installation of anchorages were not excessive.

It was not appreciated at this time that the flying of balloons might require to be controlled to such a degree that the barrage would remain grounded to a much greater extent than it would fly, nor that speed of operation to or from moorings would become such an important factor. Nor were all the points enumerated above fully appreciated at the outset. In fact it is safe to say that the true appreciation of these requirements constituted more than half of the actual solution to the problem. After it had been appreciated what was required, it took a comparatively short time to reach a practical solution.

It was, however, quickly realised that the initial policy of flying balloons at all times except when the daily inspection and topping up was carried out was likely to lead to severe casualties. The limiting factors to the safety of balloons when flying were:-

(a) the strength of the cable in respect of snatch loads;

(b) the point at which the balloon (or in practice the rudder fins disintegrated;

(c) lightning.

Severe casualties in the first weeks of September, 1939, resulted in an immediate reconsideration of the "fly through everything" policy.

In the case of waterborne sites, no mooring problems arose, as it was not possible to moor these balloons. In gale or lightning conditions, waterborne balloons had to take their chance. The introduction of the Mark X lightning divertor type balloon, and the use of a stronger cable (K.B.85) in some measure reduced the number of casualties suffered on waterborne sites, but in general, the ratio of casualties remained much higher on waterborne sites than on land sites.

It became clear, therefore, after a short period, that for weather reasons, if no other, balloons could not be left to fly at all times. When a balloon broke away flying, it generally meant that the cable on the winch had to be re-reeved, and so even though with the moorings initially available, the balloon may be very little safer on the ground, it was at least certain that the cable was safe, and certain balloon components would not be lost though the balloon itself may become a casualty. Consequently the development of some form of a balloon mooring which would embody the requirements outlined above became a matter of immediate urgency.

The general scheme of flying and mooring L.Z. Balloons developed by the Balloon Development Establishment had formed the basis of pre-war training of balloon personnel, and constituted the only accepted method of balloon handling when the embodiment and deployment of the barrage occurred. Briefly these methods can be described as follows:-

The balloon was flown directly from the winch lead off gear.

The balloon was ground moored on to a "bed" consisting of two wire strops secured to the ground by screw pickets. The wire served as an anchorage for the lower ends of slips (adjustable strops). The upper ends of these slips were attached to the patches on the balloon to which the flying rigging was secured. (The lower ten patches). Between each of the lower ten patches a length of line was attached known as a "bridle" or "handline". Sandbags secured to these bridles on either side of the balloon supplemented the slip anchorages.

An upper series of ten patches (five on either side of the balloon and one on the nose) carried a series of six handling and four picketting lines. These lines, as their names indicate, were used both for handling the balloon when close to the ground, and for picketting or mooring the balloon to the ground. When moored on the bed, these lines were anchored out to screw pickets or nests of sandbags to supplement the slips from the lower ten patches, and the bridle bags. The fins and rudder were furled and secured by a series of furling lines. The furling lines were attached to a number of small securing patches on either side of the fins and rudder.

The method of handling the balloon on to the bed was laborious and lengthy. First of all, the bed wire had to be placed in such a manner that the bed wire was longitudinally in the direction of the existing wind.

The winch from which the balloon was flying had to be manoeuvred so that it was at the windward end of the bed, with the leading off gear in a convenient position to allow the balloon to be hauled down on to the bed. The six handling guys had to be reeved to blocks attached to screw pickets and bent on to the six legs of a rope "spider" which in turn was attached to a block and tackle purchase gear. The tackle in turn had to be anchored to screw pickets or some other anchorage in such a position as to allow manual hauling from the stern of the balloon. The balloon was then hauled down manually on the tackle from its position over the winch lead off gear on to the bed. The winch driver had to pay out sufficient flying cable at the same time as the manual hauling party hauled the balloon down on to the bed, to allow for the movement of the balloon from winch to bed.

Having hauled the balloon down to the bed the tackle was tied off and held whilst the remainder of the crew attached slips and sandbags to moor the balloon. The raising of the balloon from bed to winch in order to fly was the reverse of this process. Compared with the requirements which constitute a satisfactory mooring, it will be seen that the original methods left very much to be desired.

The development of a form of mooring from this most unsatisfactory scheme to one which embodied all the stated requirements was the most urgent operational requirement, if the barrage was ever to operate in a satisfactory and efficient manner, and was to play its allotted part in the scheme of anti-aircraft defence. The solution of this vital question of balloon handling and mooring was in fact essential, without which all other development was useless.

It will be seen that the initial scheme offered by the Balloon Development Establishment contained the following cardinal disadvantages:-

(a) the winch had to be manoeuvred into position each time the balloon was bedded. This quickly reduced sites into a morass and resulted in innumerable winches being bogged and balloons being rendered non-operational;

(b) the whole bed and hauling points had to be moved each time the wind direction changed. This involved lifting and relaying the bed-wire strops in a different direction;

(c) when bedded down it was impossible to turn the balloon on the bed in the event of a change in wind direction, with the result that balloons either had to remain out of wind, or had to be put up again to point of attachment on the winch whilst the bed was altered, and then bedded down again in the new direction. Both leaving the balloon out of wind or altering the direction of the bed were extremely hazardous operations in bad weather;

(d) the rigid nature of the slip and picketting attachments of the bed were extremely bad for the ten patches on the balloon, causing excessive stresses on the fabric and frequently pulling them off with a portion of the envelope. The bed would not stand any beam wind. Immediately the balloon became a point out of wind, the direction of pull on the patches tended to strip them off;

(e) the manual work involved in bedding or raising the balloon was considerable even in calm weather, and became almost impossible in high winds. This required a large crew and in the initial stages, squadrons were very much under strength. Further, the time taken over these operations was such that in rough weather the balloon was out of control over a long period;

(f) reliability of screw picket anchorages was entirely dependent upon the nature of the ground on the balloon site. On many sites the ground prevented screw pickets from being put in at all; on others consisting of made-up ground, sand, etc., screw pickets would not hold. Some other method of providing reliable anchorages had to be evolved.

This problem might be solved in two ways. Either the mooring be developed on the lines of the bedded down position or on the close haul position. The latter involved mooring the balloon at some low height in the flying position. In other words, the balloon could fly on its winch rigging from point of attachment, but be so restrained that it could not break away, or dash itself to pieces on the ground. This form of mooring would rely to some considerable extent on the natural flying stability of the balloon as designed. Unfortunately, ground wind currents were always inclined to be more turbulent than upper wind currents, particularly on enclosed sites, or those in undulating terrain.

There were certain advantages to be gained by mooring the balloon in the close haul position as opposed to bedding down. Initially, however, although developments on both forms of mooring proceeded to a great extent hand in hand, the balloon itself required certain major developments in design before it could be made to withstand really high winds in the close haul position. In particular the fabric of fins and rudder which in the earlier designs consisted of single ply material tended to disintegrate when flying or at close haul in quite moderate winds. This was especially the case when the fabric had become weathered. Consequently the limitations of the original L.Z. and L.Z."C" type balloons handicapped the development of a satisfactory form of close haul mooring. Although the problem continued to receive serious attention, it was not until balloons with two ply and smaller stabiliser became in good supply that any important step forward in introducing the "close haul" as an authorised form of storm mooring could be taken.

It follows, therefore, that first steps towards a solution of the balloon mooring question should have concentrated largely on the development of a suitable form of bed-down mooring.

The T.7 Cradle Bed

In the early days of the War, all squadrons carried out a considerable amount of experimental work on balloon beds. The London squadrons who had carried out trial deployment periods during June, July and August, 1939, had quite a clear conception of the problem and the requirements of a satisfactory balloon bed by reason of their experiences gained on these deployments. The London squadrons again were not only better trained, but also better manned. In the provinces, the Balloon Centres themselves were in the main only in the course of construction when war broke out. The strength of provincial squadrons was far from establishment and opportunities for training under these circumstances were obviously very slight. It naturally followed that the first developments in the main took place in the London area, although at a later date many useful and valuable ideas originated in the provincial squadrons. The co-ordination of all the suggestions and developments towards a solution of the bedding question was placed in the hands of Flight Lieutenant H.F. Tiarks of 906 Squadron, who later became Training Technical Staff Officer at Headquarters, Balloon Command.

The need for an all-directional bed and the essential requirement to avoid the continual shifting of the position of the winch and the labour of manually hauling down the balloon were the first points to be tackled. This led to a series of experiments being carried out on sites in the London area in September, 1939. These experiments were co-ordinated by Flight Lieutenant Tiarks under the direction of Headquarters, No. 30 Group and completed in October, 1939. As soon as any promising progress was made, it was circulated in the form of drawings with a description by the co-ordinating officer, to various other provincial squadrons which were sufficiently advanced in their deployment and organisation to be able to give the new developments a proper trial on sites. Reports of progress made were also circulated to these squadrons and reports from the units concerned on the results of their own trials in the field were regularly collected and sifted. In this way, all new and promising developments were swiftly tried out, and either discarded as operationally unsuitable or improved as the result of trials and embodied into the bedding scheme.

All-Directional Bed

The position of the main bed or anchorages were largely determined by the fact that these points had to be used for the attachment of blocks through which the three handling guys on either side of the balloon were reeved in order to haul down on to the bed.

It was found that by positioning eight anchorage points at equal distances around the circumference of a circle having a radius of approximately 15 feet, the balloon could be bedded down in eight different positions, i.e. the eight points of the compass. By joining these points with a wire strop to form an octagon to which the slips could be attached, a form of bed was produced. This was a big step forward as the original "Arrow Bed" only allowed the balloon to be bedded down in two positions fore and aft. The direction of pull of the slips on the ten patches was not satisfactory when attached directly to the simple octagon wire, and various designs of laying wire strops around the basic octagon to provide suitable positions for the securing of slips to give a straight pull to patches were evolved. This led to what was known as the "Star Bed" and later to the double octagon which remained in use until the introduction of the central anchorage.

Around the circumference of a circle drawn at a radius of 37 feet from the same central point, a series of 24 equidistant anchorage points was placed. By providing 24 points on the mooring circle, suitable anchorages were available for securing the picketting lines and handling guys whichever of the eight bedding positions the balloon was in.

Further improvements followed in the form of beckets spliced at a suitable point in the handling guys and picketting lines to allow for a mooring slip to be hooked in. The outboard end of the mooring slip was in turn hooked to the appropriate point on the mooring circle. This permitted the picketting lines to be much shortened, and the handling guys to remain bent on to the spider when the balloon was bedded, thus saving time and labour in handling.

Again to eliminate the harsh pull on the upper ten patches caused in turbulent winds due to the mooring slips being secured to rigid anchorages, tensioning slips, carrying at their lower ends two or three sandbags, were designed for attachment to the beckets in the handling guys and picketting lines. When tensioned these slips broke the straight line between the upper ten patches and the mooring circle points to which they were secured. As the balloon rolled in winds, resilience was given to the upper ten patch mooring as the bags on the tensioning slips ("snubber bags", as they became known) had to be lifted before the pull came on to the rigid mooring circle anchorage.

APPENDIX "H"

Central Anchorage

Having in large measure reached a solution for the layout of the all-directional bed, the next essential step was to develop some scheme which would avoid the necessity for moving the winch each time the wind direction changed in order to bed down the balloon.

As has been described in the original scheme, the balloon flew directly from the lead-off gear of the winch at the rear of the winch tender chassis. It was seen that if the balloon, instead of flying directly from the winch could fly from a point which was at the centre of the all-directional bed, it would, when hauled down, be immediately over the centre of the bed, and whatever the direction of the wind, would be approximately over one of the eight bedding positions provided by the bed. Thus if a pulley block could be attached to a substantial anchorage in the centre of the bed, and the flying cable from the winch led around this pulley, the balloon would fly from the anchorage in the centre of bed remote from the winch. The winch could then be moved to any convenient position on the site, and remain static whatever the direction of wind. Various types of "deadman" including a millstone to which the pulley block was attached by means of a chain, were sunk on sites in the London area, and around these an eight point star bed was installed. Results were very satisfactory. Operational times were speeded up, and the site instead of becoming like a ploughed field on account of the constant movement of the winch, began to assume some degree of orderliness.

Bollard Hauling

Having arrived at a fixed winch position, it then became possible to consider the use of the winch bollard to provide the power for hauling down the balloon by means of the tackle, from its point of attachment at the central anchorage to the bedded position, so that slips, sandbags and mooring slips, could conveniently be attached, and the fins furled and secured.

It will be seen that to haul down the balloon on to the eight different bed positions, only four anchorage points were required. The balloon always flew bow to wind. Thus if the hauling points were placed west, south-west, south and south-east of the central anchorage, the balloon could be hauled down on to the bed with the wind in any of these quarters, by anchoring the tackle in the appropriate position and hauling from the bow of the balloon. If the wind was from east, north-east, north or north-west the same tackle anchorages could be used if hauling from the stern was resorted to. With four fixed points for the tackle anchorage it was only necessary to instal one further anchorage as a fairlead immediately in line with the bollard on the winch. By leading the hauling end of the tackle rope around the tackle anchorage block and then around a block on the fairlead point back to the winch bollard, it was possible by operating the winch bollard to haul down the balloon in the eight different directions provided by the bed.

Originally, the tackle consisted of a length of $2\frac{1}{2}$ inch manila rope passing around a single block at the mooring end of the purchase, and a double block at the anchored end, thus giving a three-to-one purchase. The free ("hauling") end of this tackle rope having been passed around the fairlead block was given three turns around the bollard. With the bollard in motion, an operator, putting strain on to the free end, obtained sufficient grip between the rope and the bollard drum to haul down the balloon. Paying out was done by allowing the turns around the bollard to slip. Control was obtained again by the bollard operator tensioning or easing the free end.

Later, in order to dispense with the bollard operator and to obtain "positive" control, 1" G.P. wire was substituted for the tackle rope. The hauling end of this wire was anchored to the bollard which was then used as an auxiliary winch. Additionally the tackle purchase was reduced by substituting a single block for the double block at the anchored end of the tackle, in order to reduce the length of wire to be taken on the bollard drum, and to speed up the operation of hauling the balloon down to the bed.

The solution to the most serious of the problems involved in the bedding of balloons was now within sight. It remained to develop these ideas and introduce them in an operational form. It was arranged for the installation of modified star (eight point) beds, central anchorages and bollard hauling anchorages on two sites of No. 906 Squadron (1) and after they had been in operation long enough to show that these methods offered vast advantages and appeared satisfactory, it was decided to request that Balloon Command should visit the sites. Subject to the installation of adequate electrical "earthing" arrangements for the central anchorage, Engineering Services at Headquarters, Balloon Command approved the general layout.

After an inspection in December, 1939, the Air Officer Commanding, Balloon Command directed that the arrangements for bedding on these sites should be introduced as soon as possible throughout the Command.

The main item of equipment which was immediately required and which was in short supply was the central anchorage pulley block. In the experiments a block was used which was provisioned on the scale of three per flight for use as a breakdown snatchblock. The design of this block was reasonably suited to the job of central anchorage block, and although no doubt a better type block could have been designed at the time for the purpose, it was thought that supplies would be forthcoming more rapidly if the existing type block was accepted.

In actual fact, however, there were many exasperating delays in the supply of these blocks which greatly impeded the work of installing the new anchorages. By the summer of 1940, however, most sites were operating on the new bed.

Bed Anchorages

The unsatisfactory nature of screw pickets as anchorage points for both bed points and hauling points has already been referred to, as have the "deadman" type

(1) In Regent's Park, London.

of central anchorages which were used in all the early experiments. It was clearly necessary to provide on sites some more permanent and stable form of anchorage than could be supplied by these methods.

At this point, Air Ministry Works Department were asked to design suitable anchorages for the central anchorage, octagon points, mooring circle and hauling points. It was somewhat unfortunate that the development of the bed proceeded simultaneously with the installation by the Air Ministry Works Directorate of permanent beds, and consequently earlier beds installed, mainly in the London area, did not include some of the refinements which later development prescribed. This led to rather expensive modifications having to be carried out later - at a time when the urgency of efficient balloon operations was no longer a matter of such priority. However, once the basic problems of the balloon bed had been overcome, it was a matter of more vital importance to ensure that all sites were provided with permanent bed anchorages at the earliest moment, rather than to hold up the work of installing these beds in order to be quite certain that all the final refinements were included.

Earthing of Central Anchorage

The Air Ministry Works Directorate designed a concrete central anchorage consisting of a mild steel eye bolt with a long shank and plate embedded in a 3 ft. cube of concrete and sunk in the ground.

Below the concrete block a metal plate was sunk in the ground. This plate was bonded by copper strip to the shank of the eye bolt. The eye bolt itself protruded from the top of the concrete block which was flush with the ground, allowing the central anchorage snatchblock to be shackled to this eye. Around the eyebolt on the surface of the ground was placed an earthing mat of expanded metal mesh. The earthing mat was generally laid on hard core grouted with cement, in order to ensure that it did not sink into the ground and that it would at all times provide suitable metallic contact for members of the crew who had to handle the flying cable. The earthing mat in turn was bonded to the eyebolt by copper strip and surrounded by a cement kerb to prevent its edges from lifting.

The octagon points consisted of rectangular concrete blocks sunk in the ground and were initially supplied with two ragbolts having flop rings at their upper ends. The ragbolts were embedded in the concrete block with the flop rings on the surface. The flop rings carried the octagon bed wires and the snatchblock through which the handling guys were reeved. Later it was found advisable to provide a third ragbolt and flop ring on each octagon point for the separate attachment of the bedding down block. Some very early beds provided only one flop ring on the octagon points to which both octagon wire and bedding blocks were attached, and a screw picket was relied upon at each point for the second octagon wire.

On the introduction, at a later stage, of the cradle bed and the tail guy mooring, the three flop ring design of the octagon blocks was universally adopted, and early beds with only one or two flop rings on these points had to be modified. In its final form, the octagon block carried on its inner flop ring a tail guy pyramid leg. The middle and outer flop rings carried a bedding down block and the octagon wire respectively. (The second octagon wire had been eliminated at this stage).

The 24 mooring points consisted of concrete blocks sunk in the ground with one flop ring as did the five hauling points. In some cases "U" bolts were supplied in place of rag bolts with flop rings. For the mooring and hauling points "U" bolts were to be preferred and in later editions of the Air Ministry Works Directorate drawings these were specified.

It should be understood that the installations of these permanent bed anchorages commenced early in 1940 and proceeded throughout the following nine months at a time when both labour and materials were in great demand for all other defence works. A great deal of the work was carried out by balloon crews themselves under the supervision of Clerks of Works.

As new squadrons were formed and barrages sited, work on bed anchorages was immediately commenced. The later barrages, therefore, had the inestimable advantage of up-to-date beds at the outset, and did not suffer the disadvantages of evolution which was the lot of earlier operational units.

Air Staff Instructions Part II

It was now necessary to ensure a great measure of standardisation in the methods applied to handling and mooring balloons. Experimentation had been successful in arriving at a sound bed and sites were being rapidly provided with this standard layout. Equipment had to be supplied to scale and not to the whim of the Flight or Squadron Commander. The barrage had overcome its basic teething troubles and experience made it clear that the standard scheme co-ordinated from countless trials and experiments was operationally sound and the best method yet devised.

Consequently a series of instructions and drawings describing the bed, laying down the methods to be adopted for handling balloons on this bed, and generally maintaining balloons on war sites was circulated.

The drawings of the various experimental beds were numbered serially T.1, T.2, etc. The seventh and last drawing illustrating the final design was T.7 and this became the designation of the bed.

The instructions and drawings laying down details of balloon moorings, the T.7 bed, balloon drills, inflation and deflation procedure, etc., were circulated to all units in the Command in serial numbers. As each new development or improvement in handling technique was evolved, a serial instruction was circulated in order to ensure that all units were informed and up-to-date with all developments, and also to ensure that standardisation was arrived at on all sites within the Command in this respect.

These instructions became known as Air Staff Instructions Part II (Training), and at a later date, when it was clear that a degree of finality had been arrived at in respect of the development of balloon moorings and handling procedure, the serials were issued in printed form down to sites.

Air Staff Instructions, Part II, in fact eventually became the Balloon Operator's complete handbook and the basic source of information and authority in connection with all matters of balloon operation and site management from the technical angle.

Balloon Drill

Even with the most perfect mooring equipment and methods, the handling of balloons to and from the bed in rough weather was a hazardous performance unless complete control was maintained at every stage of the operation. The handling of balloons can, with advantage, be likened to the sailing of a yacht. In calm weather in each case the operation is simple and can, without much danger, be carried out haphazardly with untrained personnel. In high winds and especially in darkness, the picture is very different.

A well-trained balloon crew in this respect could perform a balloon operation with comparative safety in the worst weather. It was, however, essential in the training of balloon crews that a definite procedure of operation should be laid down, and that no stage of the operation should be proceeded with until the previous stage had been properly completed. It was likewise essential that each member of the crew should have a job assigned to him at each phase in order to prevent overlapping and consequent confusion and waste of effort. Lastly, it was very necessary that only the minimum number of personnel should be detailed to form the crew. In calm weather the number of men required was obviously less than in storm conditions. Whatever the conditions and the number of crew, the basic principles outlined above must always be carried out.

Balloon drill was in fact good teamwork controlled by an intelligent N.C.O. i/c crew and performed by well-trained members. In bad weather and darkness, the highest degree of efficiency was essential if casualties were to be avoided. When crew training reached a high standard at a later date, the repetition of full sequence of orders became unnecessary. The N.C.O. i/c crew could merely give master orders, which in fact were those orders only involving the winch driver, and the crew automatically carried out the intervening evolutions without orders being given.

Turning the Balloon on the T.7 Bed

The great progress made up to the end of 1939, involving the T.7 Bed with mechanical bollard hauling, had revolutionised and greatly simplified the handling of the L.Z. Balloon and had gone far towards the desired goal of enabling the barrage to be operated and maintained in all weathers and conditions. Unfortunately however, it had not yet produced a satisfactory solution to one of the essentials of a perfect mooring, as set out earlier in these notes. This was the problem of turning the balloon ON THE BED in order to allow for wind changes whilst the balloon was bedded down and so maintain it in the only safe position, i.e. bow to wind.

In December, 1939, the Air Officer Commanding, Balloon Command authorised the expenditure of £100 per squadron for experimental purposes, in order to arrive at the best means of mooring and turning the balloon on the bed.

The trials and development of the T.7 Bed were already far advanced at this point, but this expenditure was authorised in order to ensure that full scope should be given to the inventive powers of all personnel and units, and by this means to arrive at the best possible solution. Also at this stage, the system of concrete anchorages for the T.7 Bed had not been worked out, but would obviously involve considerable expenditure on sites. With a view to ascertaining whether there was any solution which would eliminate or materially reduce the number of anchorage points required, or which might even reduce the number of personnel required per crew, the authorisation of this expenditure was amply justified.

In the course of January/March, 1940, blueprints, specifications and descriptive reports covering some thirty different schemes were received by the Committee. The assistance of many well-known firms of Engineering Contractors had been sought, and many ingenious designs had been produced.

Early in April, the Committee visited the various experimental beds, but after due and careful consideration, it was clear that although much hard work and ingenuity had been displayed, none of these schemes offered the advantages or simplicity of the T.7 Bed. Much attention had been paid to the question of turning the balloon on the bed. The schemes submitted included the germ of the idea of the Tail Guy Mooring and various other forms of close-haul for mooring the balloon in the flying position. All, however, were complicated and either required much non-available equipment or more Works Services than the T.7 Bed. It was, therefore, the unanimous opinion of the Committee that they could not recommend the adoption of any of the schemes submitted as the result of these experiments.

It should not be thought that those experiments produced no result. When dealing with close-haul methods of mooring, it will be seen that valuable suggestions resulted, which were later embodied in the Tail Guy Mooring.

Furthermore, during the period January/March, two further important developments had taken place in connection with the T.7 Bed which influenced the Committee's decision to recommend its universal adoption. The first of these developments was the promising nature of trials which were being conducted by the Balloon Development Establishment with windscreens placed to act as a wind break. The second was the ingenious suggestion submitted by Flight Lieutenant V.E. Vincent which described trials he had conducted with a rope cradle to facilitate the turning of the balloon on the T.7 Bed.

These two schemes, both of which were complementary to the T.7 Bed and to each other, required investigation as they approached the problem of maintaining a balloon on the T.7 Bed, from entirely opposite angles.

APPENDIX "H"

Windscreens

If a balloon securely moored on a T.7 Bed could adequately be protected or sheltered from the wind, turning to meet wind changes was less urgent and could be conducted with less risk. In this respect, a certain amount of experimental work was conducted by the Balloon Development Establishment at Cardington. At the outbreak of war, a few large windscreens as designed for observation balloons in the last war, were issued to sites for service trials.

Failing any suitable bed at this time or any means of safely altering the position of the balloon once bedded, it was natural that a clamour for windscreens should arise. At least they did, in some cases, allow balloons to be held out of wind, and in the early days appeared to offer a solution to maintaining inflated balloons in bad weather. In view of the demand for windscreens, the Balloon Development Establishment started at the end of 1939 to experiment with a more manageable form of windscreen of a small and more portable type. Sets were sent out for trial to the Scapa Barrage and later to Manchester.

Both these barrages reported favourably on the performance of these screens which undoubtedly did afford some protection at a time when otherwise, bedded balloons became certain casualties in any wind of gale force. In fact, the Scapa Barrage at the time regarded windscreens as an indispensable adjunct to saving balloons under gale conditions.

In December, 1939, Flight Lieutenant V.E. Vincent had submitted his suggestion for the use of a cradle in conjunction with the T.7 Bed and Central Anchorage as a means of permitting the balloon to be turned "in situ" on the bed. Trials conducted with this cradle had shown that it constituted a simple and promising scheme, but in its embryo form did not appear to be capable of allowing turning to be performed in gale conditions.

Furthermore, although the T.7 bed represented an enormous step forward, experience gained up to early Spring, 1940 tended to show that in extreme gale conditions, balloons could not be held on the bed as it then existed. Reviewing the situation and taking all the above factors into account, it was decided to place contracts for a considerable number of the new type portable screens. These contracts were placed in April, 1940, in the hope that they would be available for the Autumn gales.

The plan at this stage was to use the Vincent cradle in conjunction with the T.7 Bed and portable windscreens. As the balloon was turned on the cradle, so the portable windscreens placed in sets at the bow and stern of the balloon were also stepped around to take up their appropriate positions against the altered direction of the wind. The Air Officer Commanding, Balloon Command therefore directed in May, 1940, that the Vincent Cradle should be incorporated on all sites as an adjunct to the T.7 Bed.

The plan above described never materialised by reason of the fact that the windscreens ordered in April were not available in the Autumn of 1940 and actually did not begin to come off production in any quantity until the early days of 1941.

In the Autumn of 1940, therefore, in spite of the arrangements which had so carefully been planned to ensure that sites should be in possession of a satisfactory scheme for holding balloons in the autumn and winter gales, the Command found themselves in the position of having to face the worst weather with only half the scheme in action. In September and October, 1940, the seasonal gales took a serious toll of balloons which certainly would have been mitigated had windscreens been in use.

The casualties sustained in these gales, and the fact that it became clear that the screens would not be available in time, led to a new development involving the incorporation of the Vincent Cradle as an integral part of the T.7 bed which was eventually to render the use of windscreens not only unnecessary, but a positive disadvantage.

By the beginning of 1941, when invaluable experience had been gained in the operation of the T.7 cradle bed throughout the autumn and winter gales, the Command were forced to the conclusion that windscreens were no longer necessary to hold balloons on the bed. In these circumstances, it was necessary to take steps to curtail to the greatest extent the manufacture and delivery of the contracted screens, in view of the considerable quantities of material, labour and transport involved in their manufacture.

Accordingly at the beginning of March, 1941, the situation in this respect was communicated to all Groups, who were asked to state whether they still wished to receive the long-awaited windscreens, or whether their experience of the T.7 cradle bed appeared to them to warrant the abandonment of windscreens.

Only No. 34 Group, and in particular the Scapa Barrage, insisted that windscreens were required, with the exception of a few requests for screens for unidirectional sites elsewhere. The net result of this decision was that by stopping further production at this stage, it was calculated that there would be available just sufficient sets to supply the stated requirements.

It was not long, however, before it was universally established that windscreens were not only unnecessary when used in conjunction with the T.7 cradle bed, but constituted an actual handicap when turning balloons on the bed in high winds. By the end of 1941, no windscreens were in use in any barrage.

The Cradle

The principle of the cradle was to provide the balloon with a set of auxiliary rigging legs anchored at a central point below and close to the ballonet, which would hold the balloon on the centre of the bed, but allow it to be swung into the wind. It boldly accepted the fact that bedded balloons whether screened or not, must at all times be maintained head to wind and provided the means for permitting this to be done. The original cradle submitted consisted of twelve rope legs secured by wire strops to the central anchorage eye bolt, and of appropriate lengths to permit of their attachment, when the balloon was bedded, to each of the lower ton patches.

In rough weather only the cradle was attached to a normally bedded balloon. The attachment between the ends of the cradle legs and the lower ton patches was effected by means of secondary grommets and slips. When it became necessary to turn the balloon on account of a change in wind direction, the bed slips between the lower ton patches and the bed wires were cast off and the mooring slips on either side of the balloon stepped round the mooring circle points, one or two points at a time consecutively. It will be apparent that during turning the balloon was held on the cradle and revolved around the central anchorage. The bridle sandbags were left attached and extra sandbags were added to the ends of the cradle legs in order to give stability and control during the turning operation. With three men on either side of the balloon to move mooring slips and ballast bags, it was found that balloons could be turned under reasonable control in very high winds.

There were several disadvantages to the cradle in its original form:-

(a) Serious chafe to the ballonet fabric occurred if the cradle was left permanently attached to the bedded balloon. This meant that the cradle had to be attached only when the balloon had to be turned, or in very bad weather when turning was certain to be necessary and detached at all other times.

(b) The attachment of ballast bags to the cradle for the turning operation and their detachment at the conclusion of the operation occasioned a considerable effort on the part of the crew.

(c) The bedding slips also had to be detached from the bed wires and affixed in their new position after turning.

(d) Although the attachment of the cradle did allow the balloon to be turned into wind, it still only allowed it to be bedded down in one of the eight positions provided by the T.7 Bed, and on many occasions it was, therefore, impossible, for the balloon to be dead into wind.

(e) Although it was clear that the application of the cradle to the balloon introduced a remarkable advantage over any known method of holding the balloon on the bed, in that it permitted a beam wind to be withstood to a marked extent, no benefit could be derived from this important advantage with the cradle in its original form. The new feature introduced by the cradle in respect of withstanding a beam wind was that the leeward rigging patches on the balloon took the wind force instead of the windward patches as was the case with the T.7 Bed. In so doing, the leeward patches tended to be pulled down and under the balloon, thereby nullifying any tendency to strip off the patches, whilst at the same time, the strain on the windward patches (which tended to pull them off) was relieved.

These conditions, however, only obtained when the cradle was actually in position with the bed slips cast off and with the original cradle only offered a temporary advantage whilst the actual turning operation was being carried out.

In September, 1940, L.A.C. Ferguson, a Balloon Operator in the Glasgow Barrage, submitted the results of a trial he had been encouraged to make on his site. This consisted of a modification whereby the cradle was incorporated as a permanent part of the mooring arrangements of the T.7 Bed. In the trials carried out, the balloon was always bedded on to the cradle and by a re-arrangement of slips, the direct attachment between the bed wires and the lower ton patches was eliminated. Although far from perfect, it was immediately appreciated that this suggestion involved a principle which, if suitably developed, should eliminate the disadvantages possessed by the original cradle as enumerated above.

L.A.C. Ferguson had attached one slip from the eye on the end of each cradle leg to the octagon wire, and another from the same eye to the lower ton patch. The slip from the lower ton patch to the octagon wire was eliminated. He had in fact made the cradle part of the bed, thus employing it permanently without altering or detracting from any of its original principles and he had, by so doing, produced a truly all-directional bed instead of an eight-point bed.

With this arrangement, in principle the balloon could be placed in any direction on the bed with directional stresses properly distributed on the rigging patches, as the slip attachments to the rigging patches could lie in any position and were not limited in this respect, as was the case with the bed slips on the T.7 Bed (which could only be suitably attached if the balloon lay in one of the eight available positions). The rigidity of the rigging patch moorings which was a serious fault of the T.7 Bed had also been eliminated and a degree of elasticity substituted.

In this original arrangement, known as "tripod tensioning", chafe was still very bad and adjustments of slips difficult to maintain. The method of attaching the cradle legs to the octagon wires was complicated and the pull on No. 5 rigging patch was at an incorrect angle.

The scheme was immediately handed to Squadron Leader Vincent, the originator of the cradle, with a view to modification and improvement, as it clearly possessed great merit provided it could be brought into an operational form.

After making preliminary trials and certain alterations, it was decided to conduct extensive trials in No. 959 Squadron, Falmouth, where weather conditions were more searching and high winds could be anticipated. Squadron Leader Vincent, in conjunction with Squadron Leader Tiarks from Headquarters, Balloon Command, conducted these trials during which the following alterations to the tripod tensioning arrangements were made.

(a) To the eye on the end of each cradle leg, a nest of three sandbags was attached.

(b) From the nests of sandbags, a slip was attached to the appropriate rigging patch on the balloon and from the same point another slip was attached to the octagon bed wire. These slips were known as upper and lower cradle slips. This arrangement provided a complete cushioning effect in that the weight of the sandbags had to be lifted a considerable amount before any rigid strain could come on to the rigging patch. The attachment of these nests of sandbags also held the cradle leg and upper cradle slip away from contact with the balloon and so chafe was entirely eliminated.

(c) In order to rectify the direction of pull on No. 5 rigging patch, a cut splice was introduced at a suitable point on Nos. 2 and 5 cradle legs. This made the cradle completely symmetrical and permitted No. 5 upper cradle slip to be attached to the cradle at a point where the angle of pull on the rigging patch was correct.

(d) The inner octagon wire was removed altogether, being no longer necessary, and all lower cradle slips were attached to the outer octagon. This simplified the turning procedure in that the attachment of the lower cradle slips was always to the same octagon wire.

The result of trials with this modified Cradle Bed were so satisfactory at Falmouth that the scope of the trial was extended to include all the No. 32 Group area. Gale conditions fortunately coincided with these extended trials with such satisfactory results that in November, 1940, it was decided to introduce these later developments throughout the Command under the style of the "T.7 Cradle Bed".

Experience had to be gained and crews trained in the manipulation of the cradle bed, but there was no doubt that at last a bed had been designed embodying all the essential requirements which had so long been sought. As crews gained experience, balloons could be held and turned in winds of gale force. Confidence grew and as crews realised that the operation of turning balloons in high winds was no longer fraught with danger but was in fact a comparatively simple and safe operation, so the scale of casualties was reduced. The standard of balloon handling training required to be high and steps had to be taken to ensure that this was the case. A new series of balloon drills was circulated in Air Staff Instructions, Part II, and as a degree of finality had been reached, it was possible to settle down to the work of training crews on a standardised procedure.

Prior to the introduction of the T.7 cradle bed, changes and modifications to rig and drills had been so frequent and experimental work on sites had been so greatly encouraged, that it was never possible to settle down to a basic and standard handling procedure. The standard of balloon handling was therefore low and could only be raised providing the rig and drill procedures could be finalised.

The T.7 cradle bed was employed on all land sites throughout the Command from the time of its introduction in November, 1940, until the deployment of the "Diver" barrage in June, 1944, forced the operation of the barrage to an essentially mobile basis, and eliminated the vast majority of the static barrage sites.

Apart from minor improvements and modifications to the rig occasioned by the introduction of W.A.A.F. personnel as Balloon Operators, and modifications to items of equipment due to a shortage of essential materials, or from experience found to be desirable, the principle of the T.7 cradle bed, rig and site anchorages remained the same throughout. The efforts made by all concerned, the work done and enthusiasm displayed in the development of this mooring, were handsomely repaid in the succeeding years of the barrage's existence, by a great reduction in casualties to balloons, and a correspondingly great increase of general efficiency in the operation of the barrage which formed so essential a factor in the air defence of this country.

Close Haul Mooring

Having studied the lines on which the T.7 cradle bed was developed, it is necessary to return to the period immediately preceding the outbreak of war, in order to trace the development of the other form of mooring, viz. "close haul" which eventually, in the form of the tail guy mooring, reached a high degree of perfection, and which was employed on all suitable sites as a complementary form of mooring to the T.7 cradle bed.

At a very early stage, it was appreciated that if a balloon could be moored in the flying position from the point of attachment of the rigging wires, great advantages would accrue, in fact:-

(a) it would permit the balloon to be moored and released from its mooring operationally more quickly than was the case when bedded down;

(b) the balloon could be turned into wind much more easily, and in fact would tend to turn itself;

(c) the rigid securing of the slips to the bed would be eliminated;

(d) fin furling, always a tedious and laborious operation, would be unnecessary;

(e) the balloon would be more stable when paying out from the moored position by reason of the fact that the stabilisers would be inflated which was not the case when flying from the bedded position;

(f) probably less crew would be required; certainly less effort and less ground equipment;

(g) there would be less chafe to the fabric of the balloon.

On the other hand, the flying policy of the barrage on deployment in August, 1939, and the fact that the balloon had to be bedded for inspection at least once each day, tended to obscure the advantages of the close haul position as described above.

It must be appreciated that in order to carry out a satisfactory daily inspection, which was always an essential feature of the maintenance of inflated balloons on sites, the balloon must be bedded down. Topping up, accurate examination and inspection, and minor repairs and adjustments could only be carried out in the bedded down position.

Consequently, as the initial flying policy on the deployment of the barrage required balloons to fly at all times except when undergoing daily inspection, it follows that there appeared to be no real requirement at this stage for the close haul position.

When it became apparent that the policy of flying at all times had to be abandoned due to unacceptable casualties to balloons and loss of equipment, and when the serious failings of the initial bedding system were disclosed, it was clearly essential to find some satisfactory method which would permit the balloons to be held on the ground. In view of the advantages offered by the close haul form of mooring, it was natural that, as soon as the failure of the "fly through everything" policy became apparent, every effort was made to evolve a close haul that would stand up to high wind speeds and to avoid recourse to bedding.

The search for, and the development of the ideal close haul proved to be at least as long and arduous as was the case with the ideal balloon bed. The factors to be considered and the difficulties to be overcome were in most respects quite different from those which constituted the bedding problems.

The first close haul simply consisted of hauling the balloon down to its point of attachment where it was allowed to fly from the winch lead off gear, steadied to some extent by tying off the handling guys on either side to nests of sandbags.

The next step was again made by No. 906 Squadron, London, where W/O. Greenstreet devised a scheme whereby a wire strop was shackled to the crossover. The bow guys were passed over blocks attached to opposite bed points and their ends bent on to either end of this strop. A few feet of flying cable were paid out, and the winch driven forward a short distance. The balloon thus flew from a triangular pyramid formed by the flying cable and the strop shackled to the crossover. The pyramid was not rigid, but could oscillate as the balloon moved. The two storm handling guys were passed through snatch blocks on opposite bed points, and were in turn bent off to either end of a "handy-billy" purchase tackle. By tensioning and tying off the "handy-billy", the stern guys of the balloon were put under tension and the stern of the balloon pulled down, thus holding the bow of the balloon up to a greater degree. The midship guys were secured to nests of sandbags in the manner later adopted for the "interim" close haul.

By this means, the balloon rode more steadily. The stronger the wind, the greater was the tendency for the stern to lift on account of the kiting action of the stabilisers, but being restrained by the handling guys, a considerable measure of stability was gained, and yawing from side to side was curtailed.

This was an important step, as it formed the essential principle of the Tail Guy Mooring, later to become the standard and most successful form of close haul.

The lift of the balloon was distributed over the flying cable and the two wire strops, and by this method of triangulation the point of attachment was held steadily. This again tended to reduce the amount of yaw and represented the first sign of the evolution of the pyramid anchorage.

This rig allowed the balloon to swing into wind, within certain narrow limits, but larger changes of wind direction could be catered for very simply by altering the position of the stern handling guy anchorages. The actual operation of mooring, and releasing from the mooring, in order to fly the balloon, was very simple and speedy. The stabilisers remained inflated and when paying out from the moored position, the balloon possessed considerably greater stability than when being raised from the bedded position, as in the latter case, the stabilisers having been furled, took time to inflate at a point where ground turbulence required maximum stability.

The "Greenstreet" picket, as this mooring became known, never became operationally of importance, on account of its failure to stand up to anything but very moderate winds, but it is interesting as being the first attempt made to design a mooring of the close haul type.

The Beam and Wheel Mooring

This scheme was submitted by Wing Commander Wheelwright of No. 907 Squadron, and consisted of mooring the balloon to a stout wooden spar, anchored at one end to a wire pyramid attached to the octagon bed points and furnished with a motor car wheel secured at right angles to the spar at the other end. The balloon was moored from its point of attachment in the flying position on to the boom by an extremely complicated rig. In wind changes, the balloon and boom swung to and fro like a weather vane, pivotting from the anchored end of the boom and the wheel describing an arc on a circular track. Great efforts were made to perfect the scheme, but it suffered from serious complications, chiefly connected with the securing of the balloon to the boom in rough weather and from other serious drawbacks, not the least of which was the danger to life and limb in high winds. In gale conditions, the boom took charge and, in spite of efforts to ballast, the wheel frequently left the ground, threatening the lives of members of the crew. The result was that it was impossible for the crew to approach the balloon which had to be left until inevitably the balloon parted from the boom, or otherwise became a casualty.

Several sites in various parts of the country were equipped with this rig, but all without any conspicuous measure of success due to the inherent faults described above. The experiments carried out in connection with this scheme showed, however, that an essential requirement of a close haul rig was that in the event of any sign of the balloon getting out of control, the crew should have a reasonable chance of bringing the balloon down to the bed from the close haul position.

The Mooring Post

Towards the end of 1939, Major Spencer had been carrying on some very interesting experiments at Cardington which were based on the principle of holding the balloon from the stern by means of a storm rope secured to three extra ton patches, one of which was positioned between each of the three fins. At the end of the stern rope, a snatch block was attached and the sheave of this block was free to run on a flexible wire strop secured at each end to screw pickets. In order to allow for the stern rope to be anchored in this manner through all wind directions, a circle of screw pickets was positioned around the bed. It was found that the most satisfactory position for these screw picket anchorages was on the circumference of a circle, radius, approximately 90 feet and its centre at the central anchorage point of the bed.

By moving the position of the wire strop secured between these 90 feet circle anchorages, a different chord of the circle could be provided for the running snatchblock at the end of the stern rope. By this means, therefore, the direction of the balloon could be changed to conform to the wind direction. The length of the strop determined the limits through which the balloon could turn without altering the position of this strop.

The point of attachment of the flying rigging was anchored to the top of a 7-feet mast. This mast itself was fixed by means of a universal joint to a base consisting of cross plates which could be firmly secured to the ground at the central anchorage by means of pickets. Four sets of bungee support strops stayed the mast, which was itself telescopic, so that the upper end to which the point of attachment was secured could move upwards against the compression of a strong internal spring. The idea of the mooring mast was to give a firm but elastic support to the point of attachment, which could, cushioned by the shock absorbing effect of bungee and springs, move within limits to conform to the gyrations of the balloon. By this means, it was thought that the strains imposed on the lower ton patches could be alleviated satisfactorily.

The bow guys on the balloon were lengthened and secured to appropriate pickets on the 90 ft. circle. The securing of the stern rope and bow guys to the 90 ft. circle incorporated a length of bungee strop in order to give a certain amount of resilience and so to avoid shock loads on the top patches of the balloon.

The stern rope could be tensioned by means of a "handy-billy" in order to increase the angle of flight of the balloon by raising the bow and depressing the stern.

The lay-out of this mooring has been described in some detail because it embodies all the features of the tail guy mooring and was in fact the precursor of the tail guy.

It will also be noted that the principles of the "Greenstreet" picket were embodied, in that the point of attachment was anchored and the stern pulled down to increase the angle of flight of the balloon. Early in 1940, a number of sites in various parts of the country were equipped with the mooring post and extensive trials were conducted.

The general result of these trials was to prove that balloons moored in this manner would stand quite exceptional winds for short periods, but were very lively in gusty winds, and after a time, became casualties.

The mooring post itself was clumsy and difficult to secure firmly to the site, and in down draughts the balloon tended to impale itself on the mooring mast. The most common cause of casualties, however, was to be found in the balloon itself. The stabilisers at that time being constructed of single ply fabric and having a wind scoop in each, frequently burst or were torn away, leaving the balloon completely out of control.

It was however, apparent, that providing these difficulties could be overcome, there was no reason to believe that this form of mooring would not be capable of holding balloons safely through periods of gale conditions.

The stern rope (or tail guy, as it became known), gave the balloon a remarkable degree of stability when secured, suitably tensioned, to the 90-ft. circle anchorages. In fact, after a very short time, it was found that the bow guy attachments were quite unnecessary and were soon discarded.

The mooring post with the tail guy method of securing the stern was a most valuable contribution by the Balloon Development Establishment.

For various reasons, however, it was not possible to introduce this form of close haul on a large scale. These reasons can be summarised as follows:-

(a) the limiting factor of the mooring was first and foremost the strength of the fabric and to a lesser degree, the design of the stabilisers. In the early days, many balloons were lost whilst flying, due to the disintegration of the stabilisers. On balloons which had flown for even comparatively short periods, weathering and furling had weakened the fabric to such an extent that the internal pressure built up by the ingress of air through the windscoops on each fin caused them to burst even in very moderate winds. Ground wind turbulence was more searching in this respect than steady winds at altitude and even new balloons with single ply stabilisers after a time frequently became casualties on the mooring mast in high winds. As the only type of stabilisers available early in 1940 were those constructed of single ply fabric, this serious disadvantage could only be overcome if and when more robust stabilisers became available.

(b) The mooring post itself was a source of trouble when bedding down from the close haul position. It had to be collapsed as the balloon was being bedded down and completely removed if the balloon was to remain bedded in high winds, otherwise it was liable to cause damage to the ballonet. This was a serious disadvantage as an essential requirement of a satisfactory close haul was that when necessary, it should be possible to bed down during adverse weather conditions without undue difficulty.

(c) At this time, due to production difficulties, the provisioning of the mooring post itself on a large scale was bound to take a considerable time.

(d) The requirement of a second mooring circle at a radius of 90 ft. from the central anchorage and consisting of a minimum of 24 anchorage points would require a considerable extra expenditure in labour and materials at a time when these were extremely scarce.

(e) No running snatch block of suitable design for the tail guy was available. This demanded special design and production which would again take time and the problem of developing a satisfactory balloon mooring was urgent and could not wait.

(f) By the time that the service trials of the mooring post had been concluded and its limitations, as outlined above, had been appreciated (April/May, 1940), the T.7 Bed had been introduced to most sites in the Command, and although it was, at this stage, far from perfect, it did at least provide a reasonably safe mooring. In conjunction with the Vincent cradle and the prospect of windscreens, it appeared to satisfy the requirements which existed at the time.

As a result of the trials with the mooring post, a great deal of valuable information had been obtained as to the possibility of a tail guy controlled system of close haul mooring.

Steps were taken to ensure that further production of balloons would embody modifications to strengthen the stabilisers by the substitution of two ply fabric for the original single ply. The Balloon Development Establishment had also completely re-designed the stabilisers by reducing their size, substituting fabric curtains in place of internal lacing and introducing airducts between the rudder and the port and starboard stabilisers as a means of inflation instead of air scoops in each fin. Arrangements were made for all future supplies of balloons off contracts to incorporate these important modifications, not by reason of the close-haul requirements but entirely with a view to increasing the endurance of the balloon when flying.

The satisfactory progress made in respect of a solution to the bedding problem reduced the requirement of an alternative method, in the shape of a close haul mooring, to a desirable refinement rather than an operational necessity. The situation was not, however, to remain in this state for long.

In June and July, 1940, immediately after the evacuation from Dunkirk, it became clear that the enemy intended to make an all-out endeavour to destroy the Royal Air Force as a prelude to an invasion. Calls were made, therefore, for balloon protection for the more vulnerable aircraft production plants. Squadrons were formed to give barrage protection to aircraft factories at Filton, Yeovil, Eastleigh, Brockworth, Langley, Weybridge and later at Accrington and Weston-super-Mare.

In the case of all these barrages, an operational problem was immediately encountered, which had not previously been met. This was the need for keeping the barrage normally grounded and only flying on receipt of a hostile plot or air raid warning.

All these factories incorporated airfields, largely used for testing purposes. Consequently, there was a great deal of air traffic within the barrage area. The flying of balloons in the vicinity of these airfields constituted a serious danger to friendly aircraft and seriously interfered with the output and activities of the factories.

In the case of the other barrages where this did not arise, the policy was to fly balloons at all times when weather conditions permitted. Thus barrage protection was given at all times except during adverse weather conditions when raids were unlikely and when in any case the flying of balloons was probably impossible.

The aircraft factory barrages on the other hand required to fly in a raid and remain grounded at other times. This obviously required that these barrages should be capable of becoming fully operational and armed, from the grounded position, in the minimum amount of time, if any protection was to be given. This introduced a new factor in that the bedded down position did not satisfy the new set of conditions because the time taken to fly a balloon from the bed was not acceptable. Further, the raising of balloons from the bed in adverse wind conditions was a hazardous operation and one which might even be impossible to carry out.

Clearly, some form of stable close haul mooring would be required if the new conditions were to be met. The advantages offered by the close haul method of mooring as outlined earlier in fact covered just these deficiencies which rendered the bed unsuitable as a normal form of mooring for balloons in this type of barrage.

Tail Guy Mooring

The Balloon Development Establishment had, in the meantime, conducted some trials at Cardington, substituting a pyramid of four wire legs for the mooring post itself. These legs were attached at their lower ends to flop rings on alternate octagon points. Their upper ends were shackled together at one point and in turn when the balloon was moored, this point was shackled to a strop passing around the metallic link at the point of attachment.

This scheme had certain advantages over the mooring post in that it eliminated the necessity for provisioning the post itself, employed only existing equipment and anchorages, and provided a collapsible support for the point of attachment which could not damage the balloon in turbulent winds in the manner experienced when the mooring post was used. In addition, it was not necessary to remove the pyramid when the balloon was bedded down, as was the case with the mooring post.

Moreover, a great improvement which considerably simplified the process of turning a balloon on this mooring was introduced. Instead of a strop being secured between two points in the 90 ft. mooring circle, to provide a span for the tail guy block, a complete circle of flexible wire was installed. This was secured by means of retaining strops to each of the 24 anchorage points of the 90-ft. mooring circle. Thus if it was necessary to alter the position of the tail guy block on account of a change in wind direction, it was only necessary to remove a retaining strop and allow the block to run on to another section of the wire. The retaining strop was secured again by means of a "handy-billy". In this way, the operation was greatly simplified and carried out without releasing the tail guy block from the perimeter wire.

Commencing in September, 1940, authority was given to conduct service trials on this modified mooring which at this stage became known as "Tail Guy Mooring". Trial sites in about twenty different squadrons in various parts of the country were rigged in accordance with the latest modifications and reports were called for. It was realised that to equip all sites with this mooring would entail the provision of equipment which was not at the time available, and although in the main, satisfactory reports were received from most units as to the behaviour of balloons in high winds, it was clear that the system was by no means perfect. Many of the units conducting the trials were not faced with the new set of operational conditions which existed in the Aircraft Factory Barrages, and for this reason failed to appreciate to the full extent the operational advantages offered by this rig.

Balloons with two ply fabric stabilisers and airducts began to come off production in August/September, 1940, so that it became possible to contemplate the use of the Tail Guy Mooring with some better prospects of success. Unofficially, this form of mooring was introduced on most of the sites of No. 912 Squadron, Brockworth, during October/November, 1940. In extenuation of this unofficial departure from standard methods of bedding, it must be stated that circumstances in this barrage amply justified some initiative in this respect, and that this full scale service trial, although unofficial, produced some important results.

The 90-ft. mooring circle points were installed by using screw pickets; the ground being clay fortunately gave good holding powers. $2\frac{1}{2}$-ton rope snatch blocks were used as the running blocks at the end of the tail guy, and various other improvisations were resorted to.

In bad weather, certain balloons only were flown on "Tail Guy Mooring", the remainder being bedded down. In principle, although it was appreciated that balloons were safer on the bed in high winds, the operational requirements appeared to demand the risk of higher casualties being accepted on at least one category of the barrage in order to remain operational. It was found that balloons could be raised from tail guy mooring in weather conditions which precluded flying from the bedded position.

Many forms of pyramid were tried out in the squadron. Bottle screws or turnbuckles, borrowed from the General Post Office and attached at the ends of the pyramid legs, enabled the accurate adjustment of the pyramid, found to be so necessary, to be maintained. A central safety strop was introduced to strengthen the pyramid. Much experience was gained in handling balloons on this mooring, and various other modifications were made to the "B.D.E." rig as a result of this experience.

For instance, it was found necessary to lift the 90-ft. perimeter wire off the ground by means of short wooden posts placed beneath each retaining strop, and to coil the ends of the handling guys and secure them in a sandbag in order to prevent entanglements and fouling with ground obstacles when the balloon was moored. The attachment of the bow handling guys to the mooring circle was discarded and the balloon moored from the tail guy and point of attachment only.

Likewise it was found that not only could balloons be flown from the moored position in high winds with comparative safety, but that they could also be returned to the moored position with ease in conditions which rendered bedding down an extremely difficult operation. In every case, operations to and from and on tail guy mooring were carried out rapidly with much less effort on the part of the crew.

In spite of quite severe weather and much enemy activity calling for very frequent raising and lowering of the barrage, the number of balloon casualties sustained was low.

In March, 1941, as a result of the various trials carried out, particularly those in No. 912 Squadron, it was decided to introduce tail guy mooring officially on as many sites as possible within the Command. A modified and strengthened pyramid design had been produced by the Balloon Development Establishment, and a description of this latest form of tail guy mooring rig was circulated in March, 1941. It was decided that the wire pyramid strops, outer perimeter fittings and bungee tail guy strops should be made up to standard measurements at Balloon Centres by workshop personnel.

In many respects this was a sound decision as it ensured that all splices would be carefully made under supervision and equipment would be standard in every respect. On the other hand, it failed to take into account that the octagon anchorages on many beds were not truly laid, and that sites were not in all cases level.

When sets of equipment made up on Balloon Centres to standard, arrived on sites, it was found in many cases that they did not fit, and that pyramid legs were some inches too long or too short. Exact measurements were essential for every pyramid component if an even distribution of strain was to be achieved. Adjustment of measurements of pyramid components on sites was, therefore, in many cases necessary.

It was initially decided to introduce the tail guy mooring only on sites where a complete 90-ft. circle could be installed. This required sites which possessed this area of unrestricted ground around the central anchorage. As central anchorages had been sited without any supposition that an area of this size might be a future requirement, and in most cases, with a view to requisitioning the minimum amount of land; it was natural that returns from units at this time showed that not more than approximately 50% of the sites in the Command conformed to this requirement.

Fortunately the Aircraft Factory Barrages which had deployed since the mooring post trials, had the opportunity of taking this factor into account when beds were laid.

It soon became clear that a considerable advantage could be obtained even though only a partial 90-ft. circle could be installed, particularly if that portion covered the position of the tail guy block in the prevailing winds.

Consequently, authority was given for sites where not less than three-quarters of the circle could be installed, to use tail guy mooring, providing that the sector covering the prevailing wind was not in the missing portion. Authority was also granted for the installation of 80-ft. circles on sites where circles of 90-ft. radius could not be installed. These concessions to the original policy resulted in a high percentage of the total number of sites being fitted with tail guy mooring. On sites where, by reason of obstructions, it was impossible to instal the tail guy mooring, the interim closehaul, described later, continued to be employed.

Many of the innovations evolved by No. 912 Squadron were in the final scheme which was circulated in Air Staff Instructions, Part II in May, 1941.

Authority was also granted in March, 1941, for the installation of concrete blocks with "U" bolts as anchorages for the 90-ft. mooring circle where necessary, as it was clear from trials that screw pickets were unreliable for this purpose except in certain types of ground.

By the end of the summer of 1941, the great majority of sites in the Command on which either full or partial tail guy mooring could be installed had been completed in this respect.

A special hardened steel sheave snatchblock had been designed for the running block on the perimeter wire and put into production. Unfortunately the low priority accorded to the Command for technical equipment resulted in serious delay in the supply of these blocks and impaired the efficiency of the mooring. The only available block was unsuitable for the purpose and in use wore out rapidly, causing many minor difficulties.

In this form the tail guy mooring constituted the standard system of close haul in use throughout the Command until the mooring was re-designed and reinforced in 1943.

As operational control from Fighter Groups was introduced at the end of 1941, involving the grounding of most barrages at all times, except when ordered to fly by Fighter Control Rooms, the closehaul system of mooring grew in importance and use.

The tail guy mooring provided a safe mooring in all normal weather conditions. In adverse wind conditions, it permitted the Barrage Commander to remain in a position to fly a portion of his barrage, by accepting the reasonable degree of risk involved by leaving a category on tail guy mooring, and bedding down those balloons which it was not intended should fly in any circumstances. What was even more important, it allowed operations to be carried out more speedily and reduced the strain on crews which the ever-increasing degree of operational control would otherwise have involved.

The "Reinforcement" Policy

Although in September/October, 1941, the tail guy mooring had been installed as an adjunct of the T.7 Cradle Bed on all suitable sites, and was being operated with success, the seasonable gales during the Autumn and Winter of this year showed that there were many points which were inclined to give trouble, and which were capable of improvement.

As was the case with the development of the T.7 Bed where No. 959 Squadron at Falmouth was particularly responsible for the ultimate development work which led to success, so in respect of the final development of the tail guy mooring, No. 951 Squadron, Bristol (later No. 927 Squadron, Bristol/Avonmouth) carried on the experiment. Although instructions had been circulated with a view to curtailing experimental work except at Cardington, Balloon Command very wisely turned a blind eye to this departure from standard practice as long as it did not get out of hand.

It was realised that most of the detail development, and the practical innovations, which converted a theoretical design into an operational proposition, had been introduced in deployed squadrons, where those finer points were of necessity better appreciated, and where the best facilities existed for practical experiments. A careful study of the behaviour of balloons on Tail Guy Mooring on all types of sites in the Bristol area over a long period was made and the following main points emerged:-

(a) Balloons on open sites, where they were subject to a true wind were much more stable than balloons on enclosed sites or sites subject to turbulent wind conditions. The force of the wind did not seem to cause casualties so much as the turbulence of the wind.

(b) Balloons on Tail Guy Mooring would, generally speaking, withstand winds of gale force for a time but if the gale was prolonged, a high proportion often became casualties before the blow was over. This was due to the fact that the strain imposed on all gear due to the buffeting of the wind tended to wear out components of the rig. (This particularly applied to the bridles and tail guy attachments).

(c) The method of securing the point of attachment to the top of the pyramid was unsatisfactory, particularly on the introduction of the ripping link, and required re-designing.

(d) The stability of the balloon in high winds depended to a considerable degree upon the tensioning of the tail guy. In winds of gale force, the tail guy had to be tensioned down hard. The bungee strop, designed to give resilience and avoid severe strains on the Tail Guy ton patches, in practice allowed too much movement, particularly forward plunging on recovery from a heavy gust, and tended to make the balloon too lively on the mooring. The method of tying off the tail guy by means of a rolling hitch was not positive enough, and the method of joining tail guy and bridles by means of a double sheet bend seriously weakened the strength of the assembly at this point and gave rise to casualties.

(e) The strength of the pyramid depended largely upon the care taken in its fitting and adjustment. The pyramid leg towards the bow of the balloon took most of the strain. Once fitted the pyramid was difficult to maintain in correct adjustment on account of the stretch of the wire legs. The arrangements for adjusting the pyramid were clumsy and liable to vary considerably due to atmospheric conditions affecting the cordage tie off of the tensioning strops.

(f) The outer perimeter wire required to be maintained under considerable tension, otherwise the tail guy block tended to middle itself on the span in use and thus impose undue side tension on the tail guy ton patches and bridles. It was also necessary to provide an emergency insurance in the event of the main perimeter wire breaking.

(g) Although a balloon could be bedded down from the tail guy position, a proper procedure remained to be worked out whereby the balloon could be transferred from tail guy mooring to bed and vice-versa, under complete control the whole time.

(h) It was essential that the handling guys should be secured whilst the balloon was moored, otherwise they fouled bed obstructions or became inextricably tangled, but the method of securing these was unsatisfactory, causing difficulty both in securing and releasing. If the balloon was to be bedded down in an emergency from the tail guy mooring, it was essential that the handling guys could be released instantly, for reeving and bending.

During 1942 these problems were tackled one by one and in all cases modifications were designed which offered great improvements towards a final solution. The general performance of the tail guy mooring in spite of these imperfections was so satisfactory that it stimulated the Squadron to persevere with its aim of perfecting the rig. In many cases, balloons rode out gales with greater success than was the case in neighbouring squadrons, where bedding was resorted to. The strain on crews during periods of bad weather was much less than when handling bedded balloons and the operational efficiency of W.A.A.F. crews was undoubtedly higher. Statistics were taken which showed that casualties involving the replacement of the balloon on a site (apart from deflation due to low purity) occurred on the average only after 270 flying days. These statistics covered the period from January 1942/February 1943 and were on a par with results in other units where bedding down was resorted to much more frequently and always in gales.

The main modification evolved to improve the standard rig are fully described and illustrated in Air Staff Instructions Part II, Volume 2, Section B, Serial 1, dated 1st August, 1943.

Interim Closehaul

The development and installation of the tail guy mooring took almost twelve months to complete - September, 1940/ September, 1941. In the meantime, the demand for some alternative and more rapidly operated mooring called for some interim measures to be adopted which would permit balloons to remain closehauled at the central anchorage of the T.7 Bed.

The "Greenstreet" picket was based on the balloon flying directly from the winch and could not be used with the T.7 Bed and central anchorage.

Accordingly, several forms of closehaul were devised to correspond to the T.7 Bed and employing the 37-ft. mooring circle. The system eventually preferred and authorised for use throughout the Command was known as the Interim Closehaul; this was an improvement on the earlier design. The Interim Closehaul, as its name implies, was introduced in the Summer of 1940 to fill a gap until such time as a stable form of closehaul could be evolved. It so happened that when the new system in the shape of the tail guy mooring did materialise, it required a mooring circle of 80 or 90 feet radius, whereas the Interim Closehaul was based on the 37-ft. mooring circle of the T.7 bed and consequently could be installed on many sites on which the tail guy could not. Thus, not only did this mooring fill a gap pending the introduction of the tail guy mooring, but it also survived on sites where the tail guy could not be installed until 1943, when it was replaced on those sites by a modification known as the Midship Mooring.

The Interim Closehaul was unstable in winds over 20 m.p.h. and balloons had to be bedded down to avoid casualty when this was exceeded; consequently it was never possible to accept anything like the same degree of risk with this mooring as with the tail guy mooring.

Turning the balloon on the Interim Closehaul was a comparatively simple operation although it involved the manual handling around the bed of clusters of sandbags to which the bow guys were attached.

As with the tail guy mooring, the operation of transferring the balloon from closehaul to bed was an operation which offered no undue difficulty, and could be carried out when the surface wind speed had risen to the limit of safety for the mooring.

Midship Mooring

The employment of the interim closehaul was always limited by the fact that it was only capable of withstanding comparatively low wind speeds. In an attempt to improve its properties in this respect, the midship mooring was designed.

This mooring entailed certain modifications to the balloon in the shape of additional ton patches being affixed to carry a catenary which formed the anchorage for a loop of cordage assigned to control the stern of the balloon. This loop was suspended from the catenary on either side of the balloon. A snatchblock ran on the bight of the loop and was itself connected by means of an adjustable bungee strop to another snatchblock which ran on a circle of flexible wire secured by retaining strops to the 37-ft. mooring circle blocks. The point of attachment of the balloon, instead of being secured by means of an anchorage strop to the central anchorage, was held by a 4-legged wire pyramid of similar design to that used on the tail guy mooring. The bow guys were not secured.

The midship mooring was somewhat more stable than the interim closehaul, and was easier to handle by reason of the elimination of the bow guy sandbag anchorages. It did not possess the stability of the tail guy mooring and under no circumstances could balloons be left on this mooring in surface winds exceeding 25/30 m.p.h.

By reason of the elimination of the sandbag anchorages of the bow guys however, it could be satisfactorily employed on sites which were too restricted to permit of the operation of the interim closehaul.

The midship mooring superseded the interim closehaul early in 1943 and remained in use until the final elimination of the static barrages in September, 1944.

Centre Point Mooring

(i) Various schemes for overcoming the handling difficulties connected with reeving and bending the handling guys were submitted by personnel in squadrons. One of the methods, submitted by Flight Lieutenant C.E. Simons of No. 936 Squadron, Newcastle, consisted in joining together the three handling guys on either side of the balloon at a point from which, by attaching a single extension, an even pull could be obtained on the three handling patches. By this method only two guys had to be reeved and bent instead of six. There were, however, serious disadvantages in that the balloon had no longitudinal stability when hauling or paying out on the bollard, and also that by concentrating the strain on one octagon point on either side of the balloon instead of three, each of the eight points of the octagon would require strengthening. Further, the ten patches were subjected to an incorrect directional pull, and if they were modified to suit the pull when hauling, they would be at an incorrect angle to accept the pull when bedded. Rather than reduce the number of anchorage points required, this scheme tended to increase the Works Service requirement.

(ii) Squadron Leader M.A.H. Harris, of Eng. I, Headquarters, Balloon Command, evolved the idea of hauling the balloon straight down on to the bed by means of a wire attached to the ballonet of the balloon at the point of equilibrium. This wire was reeved through a secondary block secured to the central anchorage and then attached to the bollard hauling tackle. This idea obviously possessed great advantages, providing some suitable method of attaching the hauling wire to the ballonet could be devised.

Not only would this scheme eliminate the operation of reeving and bending the handling guys, but it would, at the same time, eliminate handling guys, as such, altogether and also eliminate the use of the eight bed blocks attached to the eight octagon points.

The balloon, being held on a single wire, could be hauled down or paid out from one fixed point whatever the direction of the wind, so that the movement of the hauling tackle in accordance with the wind direction was unnecessary and the five hauling points of the T.7 bed no longer required. The hauling tackle could at all times be operated directly from the bollard.

The problem was, how to attach the hauling wire to the centre of buoyancy on the ballonet. This presented difficulty in that the whole lift of the balloon and any extra strain due to wind force had, in the original scheme, to be taken on a small area of the ballonet.

A form of all-directional patch, similar to that previously used on certain types of airships for the attachment of mooring or towing ropes, was devised. This arrangement was termed a "cluster patch". (1)

(iii) Operational Trials

The trials of a modified balloon were carried out at No. 3 Centre, Stanmore, during May, 1942, by Engineering Services, Balloon Command. The original idea had been to haul the balloon down on to the bed from its position at point of attachment, or tail guy mooring by means of the hauling wire attached to the cluster patch and to continue to use the T.7 cradle bed as the means of holding the balloon in its bedded position. It was quickly realised that this method of hauling the balloon down rendered a certain amount of the gear used on the T.7 cradle bed unnecessary. For instance, it became immediately clear that the cluster patch attachment and the hauling wire would, if it remained attached to the bollard hauling wire when the balloon was bedded, act in a manner similar to the cradle on the T.7 bed. It would tend to hold the balloon on the bed whilst it was turned into wind. Admittedly, at this stage, it was far from perfect and by no means as safe as the T.7 cradle, but the idea was there.

Engineering Services therefore felt justified in dispensing with the T.7 cradle gear and its blocks and slips and recommending that the balloon should be held down by means of ballast bags attached to the bridles, and to four extra ton patches attached two on either side of the balloon bow and stern. The 37-ft. mooring circle was retained for the attachment of slips to lines from the upper ton patches.

These additional ton patches were also rendered necessary on account of the fact that the balloon, even when hauled down on its hauling wire to the fullest extent, was still too high up to permit of the attachment of ballast bags to the bridles. The employment of four extra ton patches, suitably positioned and furnished with suspended strops having beckets spliced in at intervals, permitted the balloons to be hauled right down manually by the following method:-

"When a balloon has been hauled down as far as possible by the hauling wire, two slips (attached to the bed wires or to a cluster of six sandbags

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(1) The "cluster patch" consists of four ton patches arranged like a four leaved clover at 45° to the fore and aft line of the balloon. They are stuck in gores F and G panels 9 and 10. Each patch is provided with a 38-cwt. G.P. wire strop 1 ft. long with an eye-splice at the outboard end. The four eye-splices are shackled together at the point of intersection. The D rings are accordingly 2-ft.6-ins. apart. The point of intersection will be on the centre line of the balloon, slightly abaft the centre of buoyancy.

beneath each bedding patch) are operated as follows - Slip No. 1 is hooked into the highest becket of the becket strop that the operator can reach and is hauled right down. Slip No. 2 is then hooked into a higher becket until the bridles are within reach for mooring operations to be completed in the normal way".

Having brought the balloon down in this manner, sandbags were attached to the bridles. Picketting lines had been substituted for the six handling guys, making a total of five picketting strops on either side of the balloon. These were attached by means of mooring slips to clusters of sandbags, or points on the 37-ft. mooring circle. The rudder and fins were then furled in the normal way.

A demonstration of handling and mooring a Mark VII balloon modified in this way was given at No. 3 Balloon Centre on 13th June, 1942. A number of officers including the Command Training Officer and Wing Commander Booth, (R.D. Arm), Ministry of Aircraft Production, were present. The advantages of this method of mooring for mobile deployments were no less obvious than was the saving in ground mooring cordage and equipment. The ease with which a crew consisting of an N.C.O. and six airmen could handle a balloon rigged and moored in this manner was fully demonstrated.

The use of the term "Centre Point Mooring" to describe this scheme was first used by Engineering Services at this stage.

On 11th July, 1942, the balloon which had been modified for the demonstration at No. 3 Balloon Centre was inflated on Site 6, No. 906 Squadron, Regent's Park, and the site crew instructed in the handling methods evolved during the trials at No. 3 Balloon Centre. The balloon was flown from a mobile anchorage of the wheel type which was installed on the site.

Owing to the lack of high winds or rough weather, it was not possible satisfactorily to assess the performance of the mooring, and the Operations Branch decided that they could not, without more reliable information, and experience under gale conditions, accept the mooring as it stood, for the mobile squadrons then deployed.

The Baedeker raids had ceased and the requirement for an improved mobile mooring did not, at this time, appear to be so urgent (July, 1942).

(iv) Service Trials, No. 929 Squadron

In spite of the less urgent nature of the requirement for a fully mobile mooring, the advantages offered by the centre point mooring scheme were so great that it was obviously necessary to proceed with further trials and development work. It was particularly essential to obtain experience of the behaviour of balloons moored in this way in high wind conditions. For this purpose, it was necessary to conduct further trials in a barrage more subject to high winds than the London Barrage. Experiments, however, continued in a somewhat leisurely fashion, as by reason of the guarding of balloon sites, any saving of personnel due to improvements in balloon handling methods could not result in a reduction of crew establishments.

On the introduction of the Pilot Balloon Scheme, early in 1943, however, the position changed in this respect and consequently the balloon was withdrawn from No. 906 Squadron and sent to No. 929 Squadron, Queensferry, where it was inflated on Site No. 929/40, on 2nd April, 1943. The N.C.O. i/c Site No. 906/6, was attached to No. 929 Squadron to instruct the new crew in the method of handling.

A report on the behaviour of the balloon during a gale of about 36 hours' duration in April, 1943, showed that handling to and from the bed in high wind conditions still presented considerable difficulty, but that once the balloon was down on the bed and the ballast attached, it rode extremely well. During this gale, one great advantage of the Centre Point Mooring became apparent, namely the ease with which the balloon could be turned to meet wind changes. The following extract from the report is of great interest in this respect:-

> " Although the wind veered through almost 180 degrees, during the heaviest part of the gale, the only attention needed was to follow the balloon by moving the outer mooring slips as required. This balloon was moored entirely by sandbags and the centre point cluster, no attachment being made to concrete bed, and it was obvious that the more flexible anchorage was damping out the shocks and putting much less strain on the balloon fabric than was the case with balloons moored on the T.7 bed. Further, during very strong winds, the balloon required no human assistance in keeping head to wind, as the bags were continually lifting an inch or so and coming to rest again in a slightly different position while the balloon itself slowly pivotted round on its centre point mooring, the whole action rather resembling that of an elephant slowly stamping round its stall. In lighter winds this was not so marked and it was necessary to assist turning by easing the sandbags round, but even so the labour entailed was considerably less than that with a normal cradle bed."

Trouble was experienced on account of the tendency of the cluster patch components to peel off when subject to severe strain, and also due to a certain amount of distortion of the ballonet fabric around the point of attachment of the cluster patch.

Authority was given to No. 929 Squadron to carry out any experiments in order to overcome the handling difficulties experienced in raising or lowering the balloon from the bed in high winds, and the tendency of the cluster patch to pull off. The handling difficulties arose in high winds mainly on account of the necessity for manhandling the balloon down on to the bed from the lowest point to which it could be hauled down by the hauling wire. At its lowest position on the hauling wire, the fins could not be furled nor could sandbags be attached to the bridles.

No. 929 Squadron considered that if they could, by means of the hauling wire itself, bring the balloon down sufficiently low to attach ballast bags to the bridles and secure the balloon without having to manhandle down the last few feet, and at the same time eliminate the extensive distortion of the ballonet at the cluster patch when the strain was on the hauling wire, the handling problem would largely be eliminated.

The method adopted by No. 929 Squadron was to eliminate the cluster patch and to apply ton patches in gores "E" and "G" panels 7 and 12 (i.e. two-thirds up the ballonet). To each of these patches, a strop of KB.38 wire was attached. The four strops were brought together and shackled to a metallic link, to which in turn the hauling wire was shackled. It was found by attaching the hauling wire in this manner that when the balloon was hauled down to the maximum extent on the bollard, the balloon was lower on the bed than was the case when the cluster patch was employed. This was due to there being less distortion of the ballonet when the four ton patches were given a greater spread. The addition of two or three cotton grommets on each bridle, larksheaded together to form a short strop, allowed ballast bag-lines to be attached without difficulty when the balloon was hauled down to its lowest position on the bollard.

In normal weather conditions the fins remained inflated, in high winds they were furled in the normal manner. Fin furling still presented some difficulty on account of the height of the stern. In order to allow the rudder to remain clear of the ground when inflated, the balloon had to be trimmed into a position which permitted the ballonet windscoop and the lowest portion of the rudder to be clear of the ground, i.e. the ballonet windscoop approximately 1 ft. to 1ft.6 ins. from the ground and the stern reasonably well up.

In October, 1943, after considerable experience of the No. 929 Squadron Centre Point Rig had been gained in all weather conditions, it was decided to ask the Balloon Development Establishment at Cardington to examine and if possible, make further improvements on this rig.

For this purpose, the N.C.O. i/c of the experimental site at No. 929 Squadron was attached to Cardington in September, 1943, where he modified a balloon in exactly the same manner as on his own site, and demonstrated the method of handling and mooring evolved for use with this rig.

(v) <u>Development of Centre Point Mooring by the Balloon Development Establishment, Cardington</u>

The Balloon Development Establishment were quick to realise that the weakness of the rig offered by No. 929 Squadron still lay in the method of attaching the hauling wire to the balloon, which, although a considerable improvement on the cluster patch, still relied on only four patches. It was estimated that in a wind speed of 35/40 m.p.h. during the operation of hauling down or paying out on the bollard, there was every likelihood of the patches being pulled off. The rig was therefore modified by utilising the lower ton patches (carrying the winch rigging of the balloon) for the attachment of the hauling wire. This was done in the following manner. Strops of KB.32a of appropriate lengths were reef-bent by their upper eyes to the wire grommets on the winch rigging below the sector thimbles on the lower ton patches. These strops were attached to Nos. 2, 4 and 5 lower ton patches on either side of the balloon and brought together at their lower eyes on two shackles attached to a metallic link. In this manner an auxiliary set of rigging consisting of six legs was suspended from the lower ton patches inside the normal winch rigging. This auxiliary rigging formed a second point of attachment close beneath the lowest part of the ballonet, and the hauling wire was attached thereto. The balloon was hauled down to the bed by the hauling wire in the manner previously described.

The great advantages of this modification were as follows:-

(i) No extra patches were needed for the attachment of the hauling wire, existing patches being utilised.

(ii) The lift of the balloon was taken on six patches which were attached to a stronger section of the balloon envelope than the ballonet, and more widely distributed over the envelope, as compared with the cluster patch or the method adopted by No. 929 Squadron.

(iii) When the balloon was hauled down to its lowest position on the hauling wire, and ballast applied, the six auxiliary rigging legs acted as a form of cradle which permitted the balloon to be turned head to wind, functioning in a similar manner to the action of the cradle on the T.7 bed. The "cradle" action of the auxiliary rigging developed in this way was much more positive than with either the cluster patch or the 929 Squadron method of attaching the hauling wire.

The position of the balloon when hauled down by the hauling wire was still high with this rig, so that the furling of rudder and fins with the balloon in this position remained a difficulty. The greatly increased strength of the hauling wire attachment to the balloon eliminated any danger of the balloon being lost when hauling down to, or paying out from, the bed. The Balloon Development Establishment suggested that the fins and rudder should remain unfurled and inflated, whilst the balloon was moored, under all conditions. Ballast was applied in the same manner as before, i.e. to the ballast bag strops suspended from the four extra ton patches and to the bridles. The picketing strops were attached to the 37-ft. mooring circle and furnished with snubber bags. No suggestion was made by the Balloon Development Establishment of hauling the balloon any further down on the bed, or of furling rudder and fins in the event of high winds. These modifications were submitted to Balloon Command during December, 1943, and approved by the Engineering Branch, insofar as actual modifications to the balloon were concerned.

At this stage, the modified rig was handed to the Training Branch in order that the method of handling could be worked out. The Training Branch immediately expressed their opinion that a balloon moored on this rig with rudder and fins inflated would not stand wind speeds of over 40 m.p.h. This was eventually agreed and at a later date, proved by experience to be substantially correct. It was considered by the Training Branch that unless the balloon could be pulled down much lower on to the bed and the rudder and fins furled, winds of gale force could not be withstood.

(vi) The "Curtain" Requirements

Since the initial impetus the "Baedeker" raids had given to the search for a more mobile form of mooring, there had been a long period of comparative inactivity on the part of the Luftwaffe, except for spasmodic raids on coastal targets. These raids were successfully met by the development of small Mark VI barrages such as the one deployed at Dartmouth. In consequence the tempo of the development of the Centre Point Mooring, lacking further incentive, had been slow.

In December, 1943, however, the Command was faced with a completely new problem in the form of information from Headquarters Air Defence of Great Britain regarding the obvious intention of the enemy to make up for the impotence of the Luftwaffe by means of attacking by some form of pilotless aircraft. Clearly the main target was likely to be London, and the Command was asked to suggest what part could be played by balloons in the general scheme of defence measures against this weapon.

Acting on the information given, a reconnaissance was made of an area in Kent, south of London, where it was desired to site a curtain of balloons so spaced in depth and frontage as to give the maximum chance of pilotless aircraft launched from sites on a sector of the French coast colliding with balloon cables.

The constitution of balloon crews for this operation depended entirely upon the form of mooring to be adopted. In the first place the manpower available within the Command precluded the normal establishment of a balloon crew of nine airmen which was the minimum number of crew acceptable for operating balloons on the T.7 cradle bed. It was essential that crews for this operation should consist of a smaller number of men if the required number of balloons was to be deployed and maintained. Works Services for the construction of 500 T.7 Beds would be out of the question in the time limit imposed. Clearly the requirement for a completely mobile form of mooring which could be operated by a much smaller crew had crystallised in a most urgent form.

From preliminary experiments with the modified Centre Point Mooring, the Training Branch had already concluded that the simplicity of this form of mooring would allow many of the handling precautions, which had always been considered essential when dealing with handling procedure on the T.7 cradle bed, to be discarded. For instance, the N.C.O. i/c crew could become a working member of the crew. The winch driver could, at an early stage in the mooring operation, leave the winch and assist with the attachment of ballast and the use of the megaphone could be waived during the actual operation of handling the balloon on the mooring. This, combined with the general straightforwardness of the rig, allowed a handling procedure to be worked out which permitted the balloon to be efficiently and speedily handled by a basic crew of three airmen. All the problems presented by the curtain barrage requirement could, therefore, be met if Centre Point Mooring was adopted, but not otherwise.

The situation was presented to the Operations Branch in this manner. In deciding the form of mooring to be adopted, careful consideration had been given to all factors, not the least of which was the risk of adopting a new form of mooring. The Training Branch pointed out their apprehensions about the mooring in winds of over 40 m.p.h. but also the great advantages which it offered for the special nature of the requirement. There was, in fact, no alternative if the requirement for balloons stated by Headquarters, Air Defence of Great Britain was to be met, and the Centre Point Mooring became an operational reality.

In January, 1944, instructions were given to proceed with all necessary Works Services and to implement the plans for the curtain barrage. Balloons were not to be deployed, but everything was to be in a state of readiness for the immediate deployment and operation of 500 balloons by 20th February.

(vii) Dead Man Central Anchorage

The Engineering Branch devised a form of "Dead Man" Central Anchorage suitable for installation in the type of land in the curtain area and also suitable for the Centre Point Mooring. This consisted of two crossed sleepers sunk to a depth of about 4 feet. Around the intersection of the sleepers, a length of KB 85 flying cable was passed twice and its free ends secured by a 6 bolt clamp. A large thimble was seized into the bight of this wire which protruded from the ground to form an eye to which the central anchorage block and the auxiliary block could be attached. To prevent a crater forming around the central anchorage strop eye, this was secured in position by passing two screw pickets cross-wise beneath the eye just below the surface of the ground.

The first 500 sites were furnished with Dead Man Central Anchorages of this type. When deployment took place in June, 1944, it was found that the anchorage strop required reinforcement and in later anchorages the strop was formed by taking four turns of KB 85 cable around the sleepers, instead of the original two turns. These latter anchorages proved to be completely satisfactory.

(viii) Handling on Centre Point Mooring

During December and the early part of January, 1944, the Training Branch of Headquarters, Balloon Command were engaged in working out a procedure for handling balloons on Centre Point Mooring.

It was found necessary to tidy up the rig and ground mooring equipment in order to reduce the essential items of equipment for this mooring to the absolute minimum, and to ensure maximum simplicity and ease of handling.

This development work was carried out by the Balloon Training Sections at No. 3 Balloon Centre, Stanmore, No. 11 Balloon Centre, Pucklechurch and at Cardington, under the direction of the Training Branch of Headquarters, Balloon Command. The great need for the elimination of all complications in drill procedures and in the balloon and ground mooring cordage was kept fully in mind during this development work. It was realised that simplicity must be the keynote for the purposes of (a) training of personnel,

(b) modifications to the balloon rigging, (c) items of cordage and equipment to be made up by workshops or by crews, (d) site requirements, (3) ensuring efficiency from a minimum operational crew of three airmen, (f) speed of deployment and possibly re-deployment in other areas, and (g) ensuring the minimum requirement in ground equipment.

(ix) Service Trials on the Centre Point Rig

Although all preliminary work on sites, squadron headquarters and balloon centres for the curtain barrage of 500 balloons had been completed by 20th February, and units had been formed, equipped and trained, no order to deploy was received until 16th June, when the flying bomb attacks commenced.

It was fortunate that immediate deployment did not occur, because the intermediate period allowed service trials on the latest form of centre point mooring to be continued. A full-scale trial was conducted by converting balloons in the Chelmsford barrage, 911/13/5 Squadron, to Centre Point Mooring. This barrage was chosen because it had originally been deployed as a "Crittall" squadron and no Works Services had been carried out on the beds. Therefore, it was possible to make a trial in this unit under conditions similar to any curtain deployment. Central anchorages at Chelmsford were of the portable type.

In an attempt to overcome the objections raised by the Training Branch, due to the lack of a storm bedded position which could be relied upon to hold the balloon in a full gale, the Balloon Development Establishment, in conjunction with the Engineering Branch, produced a modification of the auxiliary wire rigging forming the centre point attachment. This consisted of shortening the auxiliary rigging legs and introducing a running block on one side of the centre point, over which the closehaul pennant ran, attached to the rigging legs on the opposite side. The advantage of this arrangement was that after having stopped in the normal position when hauling down by means of bollard and closehaul pennant, the balloon could be hauled still further down, in fact, hard down on to the bed so that the rudder and fins could be conveniently furled and extra ballast added, without having to resort to man hauling. With the normal rig the balloon was still 2/3 ft. from the bed at its centre point when the metallic link on the closehaul pennant was hard against the pennant block. Only manhandling could bring the balloon lower. Another advantage of this scheme was that the closehaul pennant could be maintained under tension even with the balloon hard down on the bed, and so would tend to hold the balloon centrally on the bed. In the case of the normal rig, having pulled the balloon down on to the bed by manhauling, the closehaul pennant was completely slack, allowing the balloon to move around the central anchorage to some extent. This new rig was known as the "B" rig.

After a short time, it became clear that the "B" rig possessed an insuperable disadvantage in that it was liable to cause severe damage to the ballonet, which persisted in being drawn into the block. Also severe chafe from the auxiliary legs occurred when the balloon was pulled down into its lowest position. The balloon was distorted preventing the ballonet from properly filling with air. Trials with this rig were abandoned in May, 1944.

Progress was, however, made in devising a fairly satisfactory procedure for hauling the balloon hard down on the bed by attaching more ballast and furling rudder and fins. It was found that by attaching nests of sand-bags to Nos. 2, 3 and 4 lower ton patches on either side of the balloon by means of "purchase" slips and by the judicious use of "purchase" slips on the ballast bag strops, it was a reasonable proposition for a crew of three or four men to storm bed a balloon in this way. The "purchase" slip was merely a simple form of hand hauling tackle.

The arrangement was not ideal as it involved the employment of upwards of 100 ballast bags and rendered turning operations somewhat of a ballast-heaving job. Experience in wind conditions during the service trials, however, went to show that the "storm bedded" position with the addition of a nest of six sandbags by means of a purchase slip on No. 4 lower ton patch provided a very stable mooring which would, if the balloon was maintained head to wind, withstand surface winds of up to 40/45 m.p.h. It was therefore decided that although the low bedded position with rudder and fins furled was by no means ideal for the reasons described above, it did provide a safe mooring in high winds and failing any suitable alternative, must be accepted.

The service trials also disclosed one or two essential points, in particular that the ballast and not the close-haul pennant was the main factor in holding the balloon down on the bed and that the trimming of the balloon to ensure that this was the case formed an all-important element in the success of the Centre Point Mooring.

During the service trials, no really severe weather conditions were experienced, but sufficient knowledge was gained to show that Centre Point Mooring in its latest form was a speedy, simple and labour saving method of mooring L-Z. balloons and that what extra risks may be involved with the large-scale employment of this mooring, they could be freely accepted. At the same time it was decided to continue to employ the standard T.7 cradle bed in conjunction with tail guy mooring in all static units, and to reserve centre point mooring for the curtain barrage commitment and for any other mobile operations which might arise. The claims made for its mobility were amply justified in the initial deployment.

Later Developments during the Operation of the Curtain Barrage

(i) Rigging Normally on static barrages, the making up of ground mooring cordage and, in the majority of cases, balloon cordage also, had in practice become the responsibility of the crew. The nature of the present operation, however, rendered it virtually impossible for each crew to be responsible for producing reserve and replacement cordage. Furthermore, the old system of giving crews a roll of cordage for the manufacture of slips, etc, was wasteful and uneconomic.

With 1,750 balloons deployed in the field, the consumption of cordage equipment was high, particularly as a successful collision with a flying bomb was liable to result in the complete loss of the balloon and its attached cordage and wire rigging.

It was decided, therefore, to turn over the Balloon Repair Section at No. 6 Balloon Centre, Wythall, almost exclusively to the production of cordage and wire rigging.

Two types of "pack-up" sets were produced:-

(a) A complete set of cordage for a site, including both made-up ground mooring cordage and balloon rigging cordage. This pack-up was for issue to sites on initial deployment.

(b) A complete set of balloon rigging cordage only. This pack-up was for issue to sites which had lost their balloon through breakaway.

(ii) Wire Centre Point Rigging

In the initial stages of the operation, sets of wire Centre Point Auxiliary Rigging were only available for initial equipment balloons with a small reserve held at Flight and Squadron Headquarters. This involved the removal of the auxiliary wire rigging legs whenever a balloon was deflated and returned for inspection or repair, and their attachment to the new balloon to be inflated. This was an inconvenient and unsatisfactory method, as the rigging legs suffered damage each time they were removed and transferred.

As soon as sufficient sets of rigging legs had been produced to supply all balloons, instructions were given by the Engineering Branch that auxiliary centre point wire rigging legs were to be treated as part of the balloon and were to be dealt with, when packing, in the same manner as the winch rigging. All new balloons were fitted with auxiliary rigging legs when passing through workshops, as were balloons returned from the curtain barrage for repair.

The 40-ft. hauling wire (or closehaul pennant) strop, complete with metallic link and/or shackles, was not supplied as part of the balloon, but was included in the "pack-up".

The shortage of metallic links made it necessary to substitute a shackle, fitted to connect with the auxiliary centre point rigging and closehaul pennant. In practice this shackle attachment was found to be simpler and in every way, more convenient than the metallic link and two shackles originally employed.

On proceeding with the modification of American D.8 balloons for centre point mooring, it was found that a number of these balloons were fitted with a different form of ton patch terminating in cordage passed through a ring instead of the normal webbing and sector thimble. These "finger" patches were not attached to the balloon in the same position as the normal sector type patch, which meant that the normal D.8 auxiliary centre point rigging would not fit balloons with "finger" type patches. Balloons of this type were supplied with "tailored" auxiliary centre point wire rigging when passing through workshops.

Service Trials at TORPOINT

Although the Centre Point Mooring used in connection with the 'Diver' barrage proved such an enormous success, its employment was restricted to the summer months of 1944. The simplicity, operational speed and mobility of the mooring were amply demonstrated but its efficiency under adverse weather conditions had yet to be proved. Balloon Command, before it was finally eliminated, was anxious that clear-cut conclusions should be reached as to which of the various types of balloon moorings was the most efficient. To this end, the Air Ministry was asked to sanction service trials under what was hoped would be very exacting weather conditions.

KBC/358768/ Org. Enc.1A 24th February, 1945

Early in February, 1945, having received the necessary authority, Headquarters, Balloon Command decided to prepare eight sites at Torpoint, Cornwall, lately operated by No. 964 Balloon Squadron. At this time, the United Kingdom balloon barrages were non-operational and had been largely disbanded, but various balloon units were standing by against sudden unforeseen commitments. One of these - No. 978 Squadron - was selected to carry out the trials and provided a normal balloon flight to operate eight L.Z. balloons. Each balloon crew consisted of two Corporals and 7 AC Balloon Operators. In addition, certain selected technical personnel were sent to the trials as technical observers from the Balloon Technical Training Unit and the Balloon Development Establishment. All were attached to No. 13 Balloon Centre for the period of the trials, which were to commence on 1st March, 1945, and continue until cancelled by Headquarters, Balloon Command.

In a letter sent to all units concerned, Headquarters, Balloon Command outlined the scheme and stated:-

> " If it can be proved that this mooring is as reliable in bad weather as the standard T.7 bed used in conjunction with the tail guy mooring - without it being necessary to introduce modifications which will detract from its simplicity of operation and mobility - the case for adopting the C.P.M. as the standard form of balloon mooring, to the exclusion of all other schemes, is clear."

The trials were carried out between 7th March and 17th April, 1945, with four balloons moored on "A" rig and four balloons moored on "B" rig.

On 20th April, 1945, a meeting was held at Cardington to discuss the results, the minutes of this meeting being reproduced below:-

AM/A.766077 Encl.20A

"Minutes of a Meeting held at the Balloon Development Establishment, Cardington, at 1400 hours on Friday, 20th April, 1945, to discuss the results of Service Trials of Centre Point Mooring of L.Z. Type Balloons carried out by Balloon Command at Torpoint, Plymouth, from 7th March, 1945 to 17th April, 1945.

Present:	S/Ldr. Anns	R.D. Arm. 7. (In the chair)
	W/Cdr. Thomson	Balloon Command
	W/Cdr. Town, D.F.C.	Balloon Command
	W/Cdr. Bellhouse	B.D.E.
	F/Lt. Gibson	S.M.14
	F/Lt. Mayo	B.T.T.U.
	F/Lt. Soppitt	B.D.E.
	F/O. Ward, M.B.E.	B.T.T.U.
	Mr. Purves	B.D.E.
	Mr. Long	B.D.E.

1. INFORMATION

(i) The trials were carried out at Torpoint, Plymouth between 7th March, 1945, and 17th April, 1945, with 8 balloons.

(ii) 4 balloons were moored on "A" rig.
4 balloons were moored on "B" rig.

(iii) 2 balloons on each rig were permanently moored at Storm Close Haul throughout the trials, a period of 942 hours in all.

(iv) The remaining 2 balloons on each rig were Storm Bedded in wind speeds greater than 25 m.p.h. Each of these balloons was storm bedded for a period of 40 hours and at Storm Close Haul for 942 hours.

(v) On the conclusion of the trials, the balloons were returned to Cardington for technical examination.

2. DELIBERATIONS

(i) The Committee, after inspecting the returned balloons which had been re-inflated for the purpose; examining the weekly technical reports; hearing W/Cdr. Thomson's review of the development of C.P.M. and his conclusions following several visits to the Balloon Sites during the trials; and following full discussions, during which it was stated that the period the balloons had been moored represented approximately the average time which experience had shown a balloon was likely to remain at close haul throughout its entire life, agreed that C.P.M. on both rigs proved satisfactory under the weather conditions experienced during the trials and noted the following defects:-

(a) The distortion of the balloon caused by the restriction of the auxiliary rigging wires resulted in chafing of fabric on both rigs. Although the distortion of the balloon is greater on "B" rig than on "A" rig, the amount of chafe on "B" rig is, if anything, less than on "A" rig, and in both cases is restricted to the air fabric of the ballonet envelope only.

(b) The running block on "B" rig caused excessive wear on the close haul pennant.

(c) Screw pickets - unsatisfactory.

Note: See paragraph 4 (vi). This is not peculiar to Centre Point Mooring, but has been a constant source of trouble in all types of mooring.

(ii) Further considerations of the two rigs established:-

(a) Rather less chafe on "B" rig.

(b) "A" rig simpler in principle.

(c) Mechanical hauling from the Close Haul to Bed on "B" rig assures quicker operation and safer bedding of balloon in stormy weather.

(d) Maximum number of men required to operate a balloon on other rig under any weather conditions is one N.C.O. and three men.

Note: This is the actual number required to handle a balloon at any time and must not be confused with the establishment of personnel for an operational balloon site.

(e) Fully trained men are essential, but the amount of time needed for training is less than for other forms of mooring.

3. CONCLUSIONS

(i) The Committee, having regard to the following considerations, are satisfied that C.P.M. is superior for operational deployment to the T.7 Cradle Bed or any other form of Close Haul, i.e. Tail Guy or Midship Mooring.

(a) Reliability in high winds

All experience so far during the "Diver" development service trials at Torpoint, and experimental work at Cardington goes to show that balloons moored on C.P.M. in the Storm Close Haul position stand up to high winds to the same extent as balloons moored on the reinforced Tail Guy Mooring, and that the C.P.M. Storm Bed represents the same degree of reliability in high winds as the T.7 Cradle Bed.

(b) Speed and safety of operations

Balloons can be operated to or from the C.P.M. Storm Close Haul at least as quickly as when Tail Guy Mooring is employed; and to or from the C.P.M. Storm Bed quicker than when the T.7 Bed is employed. Balloons can be operated from the C.P.M. Close Haul position in at least as unfavourable weather conditions as on the Tail Guy Mooring. The C.P.M. Storm Bed on "B" rig permits operations to be carried out under worse weather conditions than does the T.7 Cradle Bed.

(c) It is more mobile.

(d) Equipment cost is lower.

(e) Works services for installation or reinstatement of sites are negligible.

(f) Pack-up is considerably less.

(g) Manpower required is less.

(h) Less space is required than for any other form of mooring, i.e. it can operate on more restricted sites.

(ii) The advantage of mechanical hauling on "B" rig outweighs the complications introduced by the use of a running block, and therefore makes "B" rig preferable to the slightly simpler "A" rig.

4. RECOMMENDATIONS

(i) That the C.P.M. "B" rig, which represents the most practicable form of mooring for L.Z. balloons yet devised, be adopted for any future operational deployments.

(ii) That B.D.E. investigate forthwith the possibility of re-designing the Running Block for the Close Haul pennant.

(iii) That B.D.E. design a suitable protection patch for the belly of the balloon to prevent damage by the Running Block.

(iv) That B.D.E. in co-operation with the Balloon Training Unit, Cardington, produce standard drawings, dimensions and handling instructions for the "B" rig. (In this respect, the amount of sandbag ballast required for the "B" rig Storm Bed needs to be finally settled).

(v) That chafing patches to meet requirements be applied by the crew on sites as they become necessary.

(vi) That B.D.E. explore the possibilities of producing a substitute for the screw picket. (A stake driven in at an angle, similar to those supplied for Sommerfeld Tracking, might serve as a starting point for experimentation)."

It is clear that Centre Point Mooring will revolutionise balloon operations. The ease of control afforded, the saving in personnel plus the increased safety of the bedded balloon in the most adverse weather conditions, are factors that cannot be ignored when planning for the future. Had the scheme been introduced early in 1942, the vast amount of work involved in W.A.A.F. substitution might have been avoided, as the number of men per site could have been so much reduced as to make the policy of W.A.A.F. substitution most unprofitable.

ANNEX I to APPENDIX "H"

CENTRE POINT MOORING

BALLOON COMMAND

JUNE, 1944.

K.B.C./1456/44 TRG.

Text Revised. 1.7.44.

CENTRE POINT MOORING

1. INTRODUCTION

(a) The principle of the Centre Point Mooring is to attach a set of auxiliary wire rigging to the balloon forming an additional point of attachment at a centre point of suspension close under the ballonet. A wire pennant secured to the Centre Point enables the balloon to be hauled down by the winch bollard into its moored position, which is somewhat higher than the normal bedded position on a T.7 Bed. The auxiliary rigging is suspended from six of the lower Ton Patches on the balloon and is connected to the wire pennant by means of two shackles and a metallic link. The free end of the pennant which is eye spliced, is reeved through a block shackled to the Central Anchorage eye bolt and then attached to the bollard hauling wire. Hauling in or paying out on the bollard thus lowers or raises the balloon from or to its normal point of attachment.

(b) With this rigging the operation of reeving and bending handling guys on to the spider, as is the case with the standard method of bedding is eliminated.

(c) The Central Anchorage forms the only necessary hauling point on the site, as against the five hauling points required in the case of the T.7 Bed. In view of this fact, it will be seen that this type of mooring lends itself with advantage for mobile operations, as the quantity of ground equipment and the number of anchorages required are considerably less than is the case with the normal T.7 Bed.

(d) The essential principle of this rig is that when moored, the balloon is held on the bed by ballast and NOT by the close haul pennant. When the balloon is close hauled in either the normal or storm position (see para. 5 and drawings T.29 or T.29C) the close haul pennant should only remain under sufficient tension to allow the bollard purchase block to be lifted just clear of the ground. When the balloon is storm bedded (see Drawing T.29H) the pennant is of course normally completely slack and the bollard block resting on the ground.

2. BALLOON MODIFICATIONS

Balloons to be used with Centre Point Mooring will normally be modified in Station workshops, but it may on occasion be necessary to carry out these modifications in the field. The modifications to the balloon consist of:-

(a) The attachment of the auxiliary rigging. This consists of six legs of KB.32A wire (Stores reference 44/932) which are suspended from Nos. 2, 4 and 5 lower ton patches on either side of the balloon. These legs are brought together under the balloon and attached permanently to a 40 ft. pennant of one inch circ. G.P. wire

(Stores Reference 29/2072) by means of a metallic link and two shackles. (Stores Reference Shackle and Link Group 44/1630). The dimensions of these six legs are given on Drawing T.29G. The spliced eyes at the bottom ends of the legs are seized with wire and soldered as for ordinary rigging legs. The upper eyes are of the standard type and are reef bent to the existing lower ton patch beckets of patches No. 2, 4 and 5. The close haul pennant is spliced around the metallic link and the three legs on either side of the balloon are shackled to the link. The lower end of the close haul pennant is furnished with a four-inch eye splice.

(b) The attachment of 4 ton patches (Stores Reference 44/101) which carry the forward and aft ballast bag strops. These patches are positioned in accordance with Drawing T.29E, two on either side of the balloon. The two forward patches are furnished with ballast bag strops of No. 4 line 12 ft. in length overall, with beckets (or marline spike hitched grommets) at 2 ft. 6 ins. and 4 ft. 6 ins. respectively from their upper ends. The two stern patches are likewise furnished with ballast bag strops of No. 4 line having an overall length of 14 ft. with beckets (or marline spike hitched grommets) at 4 ft., 8 ft. and 10 ft. respectively from their upper ends. These ballast bag strops are double sheet bent to the ton patch strops.

NOTE: The grommet at 4 ft. from the upper end on the stern ballast bag strops is not shown in drawing T.29D. This grommet is used for attaching the purchase slip-hook when STORM BEDDING.

(c) Six chafing strips each approximately 8 inches wide, (200 m.m.) are positioned and stuck to the balloon after it is inflated so that they cover the area of the ballonet which is shown to be chafed by the auxiliary rigging legs. The position of these chafing strips is approximately as illustrated in Drawing T.29 F.

(d) Two locating patches (Stores Reference 44/1250) to position the two forward rigging legs are affixed to the balloon after it is inflated. The position of these patches being approximately as illustrated in Drawing T.29 F.

(e) The handling guys and picketing lines are removed and substituted with, or modified to, 10 picketing strops each 22 ft. long of No. 4 line with standard eye splices at each end. The picketing strops on Nos. 1 upper ton patches are furnished with beckets at 16 ft. from their upper ends, and the picketing strops on Nos. 2 upper ton patches are similarly to be furnished with beckets at a point 19 ft. from their upper ends.

(f) Suspension Strops of No. 5 line substitute are to be attached to each bridle line as illustrated in Drawing T.29. Nos. 1, 2 and 3 bridles are to be provided with strops 2 ft. 6 ins. in length, and Nos. 4 and 5 bridles with strops 3 ft. 9 ins. and 6 ft. respectively. These suspension strops are attached to the bridle lines in the following manner:-

A grommet is larksheaded to the centre of each bridle line and the Suspension Strop is reef bent on to this grommet. No. 4 lower ton patch is also provided with a 3 ft. 9 ins. suspension strop which is reef bent on to a grommet larksheaded around the throat of the eyesplice of the rigging leg below the sector thimble.

(g) The balloon will be provided with a tail guy of the unreinforced type and cotton extension piece, for handling when close to the ground, and for attaching the close haul pennant when the balloon is flying.

3. MOORING

The balloon having been hauled down as far as possible by means of the close haul pennant is held on the bed by the application of ballast in the form of sand bags. The amount of ballast applied and its method of application is governed by the wind speeds in force at the time. There are three progressive stages of mooring as follows:-

(a) CLOSE HAUL (normal)(Drawings T.29 and T.29A)

In normal weather, it is sufficient to add nests of six sand bags to the ballast bag strops which are suspended from the extra ton patches on each corner of the balloon and also to attach purchase slips to the bow picketing lines, which in turn are anchored to screw pickets on the mooring circle.

(b) CLOSE HAUL (Storm) (Drawing T.29C)

In windy conditions, two or three ballast bags are attached to each bridle and the remaining 22 ft. picketing strops are made fast by means of slips to the mooring circle of screw pickets. Additionally, if necessary, a nest of six sand bags may be attached to No. 4 lower ton patch on either side of the balloon. The method of attachment of this nest of sandbags is by means of a purchase slip (as used on the ballast bag strops) which is hooked into the 3 ft. 9 ins. suspension strop attached to No. 4 lower ton patch.

NOTE:- IN EACH OF THE ABOVE FORMS OF MOORING, THE RUDDER AND THE FINS ARE NOT FURLED AND REMAIN INFLATED. THE CLOSE HAUL (STORM) DESCRIBED AT (b) ABOVE SHOULD BE SATISFACTORY FOR SURFACE WIND SPEEDS UP TO APPROXIMATELY 45 M.P.H.

(c) STORM BED (Drawing T.29H)

In extremely high winds when balloons are grounded, and it is unlikely that they will be required to fly, the following action may be taken. The balloon should be pulled down onto the bed by tensioning the purchase slips and mooring slips and adding extra ballast bags as described below, until it assumes a position as shown in Drawing T.29H. The extra ballast bags are attached progressively up to the following maximum amounts:-

(i) 4 Bags to each ballast bag strop, making a maximum of 10 bags to each.

(ii) Nos. 2 lower ton patches on either side, 4 bags.

(iii) Nos. 3 lower ton patches on either side, 6 bags.

(iv) No. 4 lower ton patches on either side, 6 bags (If not already attached).

The method of attachment of the nest of sandbags to the lower ton patches is by means of purchase slips hooked into grommets larksheaded around the throat of the eyesplice of the rigging leg below the sector thimble. In the case of No. 4 patch, the grommet to which the suspension strop is attached (see para.3(b)) is used.

4. GROUND EQUIPMENT

The following Ground Equipment is required for Centre Point Mooring - all cordage being No. 5 line substitute (Stores Ref. 44/5059).

(a) 8 standard 25 ft. mooring slips with metal tensioners. If slips have to be made they should be 16 ft. in length.

(b) 2 purchase slips for the bow picketing lines, 36 ft. long, with hooks ground mooring large at either end.

(c) A number of ballast bags filled to a weight of 40 lbs. and seized at the mouth with normal suspension lines.

(d) 4 ballast bag grommets 2 ft. in circumference with heart shaped thimbles seized to form a loop as illustrated in Drawing T.29D. These are required for fastening together the nests of sand bags which are attached to the ballast bag strops. (6 Extra ballast bag grommets will be required if the Storm Bed position is used. These are for attaching the nests of sandbags on the lower ton patches).

(e) 4 ballast bag purchase slips, each 16 ft. in length with hook ground mooring large at one end, as illustrated in Drawing T.29D. These are used for tensioning the balloon down to the nests of sand bags on the ballast bag strops. If the Storm Bed position is used, 6 more of these purchase slips are required for attaching and tensioning nests of sand bags on Nos. 2, 3 and 4 lower ton patches.

(f) 10 bridle bag lines each 7 ft. long with toggle at one end (for attaching bridle bags). The ends of these bridle lines should be whipped only (not back spliced or knotted) in order to permit of quick release when removing these lines from the strops or grommets.

(g) Three standard balloon ground sheets (Stores Reference 44/5012). When close hauled one ground sheet should be laid diagonally under the rudder and one folded under the ballonet scoop. When storm bedded an extra ground sheet should be drawn under the balloon.

(h) A Central Anchorage of the portable "deadman" or screw picket and crow bar type, (as illustrated in Drawing T.26, A.S.I. Part II, or Eng. Drawing KBC/1494/44/Eng.) is to be installed on the site and suitably earthed. The winch should be positioned at a distance of not less than 60 ft. from the Central Anchorage and in line with the C.A. eye bolt or strop. The bollard hauling wire (approximately 150 ft. of one inch circ. G.P. Wire (Stores Reference 29/2072) eye spliced at each end) is run out and reeved through a single sheave block. (Stores Reference 4 L/2000 or 44/5064). Its outboard end is passed over the chassis towing hook, where available, or may be shackled to a strop passed around the cross member of the winch, behind the fairlead trunnion. The Central Anchorage Block is shackled to the Central Anchorage eye bolt or strop and in addition, a block (Stores Reference 44/5064) is also shackled to the same strop or eye bolt. This block must be shackled to the Central Anchorage so that it is nearer to the winch than the Central Anchorage block, thus permitting the C.A. block to lie away from the direction of pull when the pennant is in use. This is clearly shown on Drawing T.29B.

(i) A mooring circle of 24 screw pickets placed at equal distances around the circumference of a circle having a radius of 32 ft. from the Central Anchorage is to be installed.

5. MOORING A BALLOON ON CENTRE POINT MOORING

The balloon is close hauled on its flying cable in the normal manner, leaving the lower 6 bolt clamp about 18 inches from the C.A. block. The close haul pennant, which when the balloon is flying is attached to the tail guy (see para. 6 and Drawing T.29B) is detached and reeved through the pennant block at the Central Anchorage. The free end of the C.H. pennant is shackled on to the bollard purchase block. The rip link is switched off, the rip line unbent and manned, the winch disengaged and the bollard engaged. The winch driver now hauls in on the bollard until the metallic link on the close haul pennant is as close as possible to the pennant block. On the order "STOP BOLLARD", the winch driver, having applied the bollard brake, switches off the engine and is available to assist in the operation of ballasting the balloon. The rip line is bent on to a suitable anchorage consisting of a screw picket (or three sand bags).

NOTE:- The closehaul pennant is always to be reeved and unreeved through the block and the snatch arm of the block is not to be used for this purpose other than in an emergency. Prior to each operation a check should be made to ensure that the jockey pin is located correctly and that the wing locking nut is screwed firmly home.

(a) CLOSE HAUL (Normal) See para. 3(a)

To bring the balloon into this position, the 36 ft. purchase slips are attached to the grommets on Nos. 1 picketing strops on either side of the balloon and tensioned to bring the ballonet scoop into its correct position as indicated below.

(b) Nests of ballast bags are then attached by means of the 16 ft. purchase slips to the lower grommets on the 4 ballast bag strops. The lift of the balloon is then taken on the ballast by suitably tensioning these purchase slips. The correct position of the balloon is as follows:- Ballonet wind scoop - lower edge 21 inches from the ground, bottom of rudder inflated 18 inches from the ground. (These measurements are based on the balloon being normally inflated and with ballonet, rudder and fins filled with air). Drawing T.29 shows the balloon moored in this manner.

(c) CLOSE HAUL STORM MOORING See para. 3(b)

Having moored the balloon as above, mooring slips are then attached to the remaining picketing strops, and two or three sand bags are attached to each bridle suspension strop. These bridle bags are secured together by means of a bag line and toggle through their suspensions in the same manner as for the T.7 bed and attached to the eye splice at the end of the bridle strops by a half hitch on the bight. Drawing T.29C shows the balloon moored in this manner.

NOTE:- (a) Extra nests of 6 sand bags may, if required, be attached to Nos. 4 lower ton patches as described in para. 3 (b).
(b) In gusty weather the picketing strop grommets or eye splices should be attached to the hooks on the mooring slips, by means of a blackwall hitch, in order to prevent the hooks becoming detached by the movement of the balloon.

6. TO FLY FROM THE CLOSE HAUL POSITION

The sequence of the procedure for carrying out this operation is the reverse of that described in the preceding paragraph. The mooring slips and ballast bags are cast off in the manner indicated in Appendix H. 'A'. The rip line is unbent and manned and the bollard paid out until the balloon is flying from its flying cable. The rip line is bent on, the rip link switched on, and the close haul pennant unshackled from the bollard purchase block and unreeved from the pennant block. The bollard is disengaged and the winch engaged. The 8 inch eye of the tail guy is reeved through the eye of the close haul pennant and locked in position by a "Boston Hitch" formed by a bight of the cotton extension (See Drawing T.29B). The tail guy is manned at this point until it is clear of the ground as the balloon is paid out on its flying cable.

THE DRILL AND PROCEDURE FOR FLYING FROM, OR MOORING TO THE CLOSE HAUL POSITIONS EMPLOYING 1 N.C.O. AND TWO (OR THREE) AIRMEN IS LAID DOWN CLEARLY AT APPENDIX H. 'A' AND WILL BE CONFORMED TO AT ALL TIMES.

7. TURNING THE BALLOON IN THE CLOSE HAUL POSITION

This operation follows almost exactly the method laid down for turning a balloon on the T.7 Bed. The orders given are the same. The mooring slips are moved one or two points at a time and tensioned in accordance with instructions contained in A.S.I. Part II, Vol. I., Section B, Serial 3. With the normal crew of three men, the winch driver will move the ballast strop bags as the mooring slips are moved, commencing with the leeward bow bags. Bridle bags, if attached, need not be moved until the turn has been completed. Balloons moored in the close haul position are very sensitive to changes of wind direction and must be kept exactly in to wind.

8. STORM BED (see para. 3(c))

The balloon will always be storm bedded starting from the close haul (Storm) position. This will be done by the application of the extra ballast and the tensioning of purchase slips progressively from bow to stern. Thus, firstly the extra bags are added to the bow ballast bag strops, the purchase slips are tensioned down and tied off, (having re-positioned the purchase slip hook in the upper grommet on the ballast bag strop if necessary the bridle bag lines on Nos. 1 bridles are removed from the bridle suspension strops, reeved through the bridle grommets, tensioned down and tied off. 4 sandbags are attached to Nos. 2 rigging patches and tensioned, and so on progressively as indicated in para. 3(c) to the stern ballast strops, when the balloon should have assumed the position shown in Drawing T.29 viz.: Lower edge of ballonet wind scoop a few inches off the bed and junction of rudder and ballonet 2/3 ft. from the ground. The rudder and fins are then furled and tied off in the normal manner, employing the rudder protection sheet. The balloon is raised from the storm bedded position by detaching Nos. 2, 3, 4 and 5 mooring slips in that order and then by detaching all ballast bags, working from stern to bow. Lastly, detach Nos. 1 picketing strop purchase slips and unbend the rip line. The balloon can then be paid out on the close haul pennant.

9. AMERICAN MK.VIII D.8 TYPE BALLOON

This balloon is modified for use on Centre Point Mooring by the attachment of auxiliary rigging legs of KB 32A wire (Stores Reference 44/932) which are attached to Nos. 2, 3, 4 and 5 lower ton patches on either side of the balloon in exactly the same manner as illustrated in Drawing T.29G.

The measurements of these rigging legs are as follows:-

For attachment	to	No.2	Lower	Ton	Patches	- 2 legs 15ft.4ins.
"	"	" No.3	"	"	"	- 2 legs 13ft.6 ins.
"	"	" No.4	"	"	"	- 2 legs 14ft.6½ins.
"	"	" No.5	"	"	"	- 2 legs 18ft.2½ins.

The 4 ton patches for the ballast bag strops are attached in similar positions to those on the MK.VII British Type balloon. The attachment of these patches is not to be carried out on sites, all D.8 balloons for use on Centre Point Mooring will be supplied with Ballast bag strop patches already affixed.

Otherwise all rigging measurements and ground equipment for use with D.8 balloons on Centre Point Mooring, is exactly as described and illustrated in these notes, and the method of handling is the same in every respect.

NOTE:- Bridles (Handlines) on the D.8 balloon must be kept adjusted to:-

No. 1 (bow)	-	8 ft.
No. 2	-	8 ft. 6 ins.
No. 3	-	9 ft. 6 ins.
No. 4	-	10 ft.
No. 5 (stern)	-	12 ft. 6 ins.

10. MAINTENANCE OF CORRECT MEASUREMENTS OF BALLOON RIGGING

It is of considerable importance to ensure that the measurements of picketing strops, ballast bag strops and the position of the grommets in the ballast bag strops are correctly maintained as described and illustrated in these instructions.

11. The provisions of A.S.I. Part II contained in the following serials are to be observed when using Centre Point Mooring insofar as they apply:-

Vol. I Sec. A. Serial 1....	Inflation Procedure.
Vol. I Sec. A. Serial 2....	Deflation Procedure.
Vol. I Sec. A. Serial 3....	Topping up - Conservation and use of Hydrogen.
Vol. I Sec. A. Serial 4....	Method of Topping Up - Purity.
Vol. I Sec. B. Serial 3....	Procedure for Turning the Balloon.
Vol. I Sec. C. Serial 1....	Action to be taken when the Balloon is paid out or hauled in.
Vol. I Sec. C. Serial 2....	Precautions against danger due to electrical conditions.
Drawing T.25	Use of Metal Tensioners.
Drawing T.10A	Method of Securing Bollard Hauling Cable.
Drawing T.25 and attached instructions	Use of Emergency Rope Brake.
Drawing T.19A and B	Fin and Rudder Furling.
Appendix to Vol. II, Item I	Winch Notes for Balloon Operators.

DRILL AND PROCEDURE FOR BEDDING DOWN - CENTRE POINT MOORING

Bedding Down	Basic Procedure i/c Crew and 2 men (i/c Crew - Starboard (Mate - Port)	Duties of 4th Man i/c Crew and 3 men
Stop Winch, Prepare to Moor Disengage Winch engage bollard	W.D. - Repeats order and stops winch I/c Crew - Switches off rip link Mate - Detaches close haul pennant I/c Crew and Mate - Reeve and shackle c.h. pennant Mate - Mans P. of A. Report "Port Ready" W.D. - Repeats order, disengages winch and engages bollard I/c - Unbends rip line	4th man - detaches pennant and mans tail guy
Haul in bollard	W.D. - Repeats order and hauls in bollard I/c - Mans rip line and watches blocks Mate - Mans P. of A. and watches blocks	4th man - mans tail guy
Stop Bollard On Slips	I/c - Bends on rip line. Attaches No. 1 M.Slip Mate - Attaches No.1 M.slip reports "Port Ready" *W.D. - Attaches both stern ballast slips reports "Stern Ready"	4th man - mans tail guy
Tension Down Check	I/c and Mate - Tension Nos. 1 M.Slip I/c and Mate - Attach and tension bow ballast slips W.D. - Tensions stern ballast slips	4th man - tensions port stern ballast slips
On Storm * Slips and Bags	W.D. - Attaches and tensions bridle bags working from bow starboard I/c and Mate - Attach and tension M.Slips 2, 3, 4 and 5 in that order and then assist W.D. if necessary	4th man - attaches and tensions bridle bags working from bow Port

* Only given when the close haul (Storm) position is used.

*W.D. does not leave winch until all brakes are firmly on and the engine switched off.

19.6.44.

NOTE:- When the Balloon is to be Storm Bedded it will be moored in the Close Haul (Storm) position, using the above procedure and then brought down to the Storm Bed position with fins and rudder furled in the manner described in para. 8 of the accompanying notes.

APPENDIX H 'A'

SECRET

DM 1247/1(102)

DRILL AND PROCEDURE FOR BED TO POINT OF ATTACHMENT OR FLYING - CENTRE POINT MOORING

Bed to Point of Attachment	Basic Procedure i/c Crew and 2 men (i/c Crew - Starboard (Mate - Port)	Duties of 4th man i/c and 3 men
Prepare to fly	W.D. - Starts up Winch - reports in full I/c Crew and Mate - detach slips and bags in the following order:- (1) M. slips 2, 3, 4 and 5 (2) Stern Ballast Slips (3) Bridle bags 5, 4, 3, 2 and 1 (4) Bow Ballast slips (5) M. slips No. 1 Mate - Mans P. of A. reports "Port Ready" I/c - unbends rip line	4th man - detaches Storm ballast slips
Pay out Bollard	I/c - Mans rip line and watches blocks Mate - Mans P. of A. and watches blocks W.D. - repeats order and pays out bollard	4th man - mans tail guy
Stop Bollard Disengage Bollard - engage Winch	W.D. - Stops bollard repeats order I/c - Bends on rip line and switches 'on' rip link Mate - Unshackles close haul pennant I/c - Unreeves c.h. pennant and connects tail guy W.D. - Disengages bollard, engages winch and reports in full	4th man - mans tail guy
Pay out Winch	W.D. - Repeats order Mate - Mans storage Drum I/c - Clears tail guy and pennant from ground	4th man - clears tail guy and pennant from ground

NOTE: When flying from the STORM BED position - on the order PREPARE TO FLY all slips and bags are detached and the fins and rudder unfurled in the manner described in para. 8 of the accompanying notes.

19/6/44.

SECRET

Annex II to Appendix H

16th August, 1944.

SUPPLEMENTARY NOTES TO CENTRE POINT MOORING PAMPHLET

Note 1

American D.8 Balloons The measurements given in paragraph 9 of the Centre Point Mooring Pamphlet for the auxiliary wire rigging legs for American D.8 balloons apply only to this type of balloon when fitted with normal ton patches having sector thimbles. A variation of this type of balloon has finger patches with rings in place of ton patches with sector thimbles. On this type of balloon the finger patches are fitted higher up, which consequently necessitates longer auxiliary rigging legs than is the case for the sector type of patches. All balloons having finger type patches will be fitted with wire rigging legs of KB 32 A wire, having the following dimensions:-

No.2 rigging legs	-	15' $11\frac{1}{2}$"	overall from crown to crown.
No.3 " "		13' 11"	do.
No.4 " "		14' $11\frac{1}{2}$"	do.
No.5 " "		18' $10\frac{1}{2}$"	do.

Note 2

The auxiliary Centre Point wire rigging legs on all types of balloons will not be removed from the balloon after fitting. These balloons returned to workshops for repair and inspection are to be packed with the auxiliary rigging legs carefully coiled and parcelled in exactly the same manner as for the winch rigging legs. All balloons arriving on sites will either be fitted with rigging legs, or accompanied by a set of legs for fitting on sites. The upper eyesplices will not be whipped in the case of those sets of legs which are not fitted. These eyesplices are to be carefully whipped immediately after fitting to the balloon. Close-haul pennants, metallic "V" and shackles are to be retained on sites and not returned with balloons sent in for inspection and repair.

Note 3

The shortage of metallic links necessitates the employment of an alternative method of securing the close haul pennant to the auxiliary wire rigging. Where metallic links with shackles are not available the following rig will be used:-

The eyesplice on the inboard end of the close haul pennant will be furnished with a heart shaped thimble (Stores Ref. 44/153). The auxiliary rigging legs will be attached by their lower eyesplices to the bow of a shackle (Stores Ref. 16H/123). The eyesplices will be threaded on to the shackle bow alternately from the port and starboard side in the correct order, so that in the case of Mark VII balloons the shackle bow will hold 6 rigging leg eyes and in the case of D.8 balloons the shackle bow will hold 8 rigging leg eyes.

The thimbled end of the close haul pennant is passed over the shackle pin, which is screwed home tightly. The shackle should be positioned bow to stern with the head of the pin nearer the bow. Drawing KBC/1566/44.Eng. refers.

Note 4

Central Anchorage The approved form of Central Anchorage for centre point mooring sites consists of two crossed sleepers sunk to form a "deadman".

A length of K.B.85 wire is given four turns around the intersection of these sleepers to form a loop, the top of which is flush with the level of the ground. The two ends of the K.B.85 cable are brought together and secured tightly by means of a 6 bolt clamp. The 6 bolt clamp should be positioned at a point about half way between ground level and the sleepers. The loop, consisting of four thicknesses of K.B.85, is seized together with wire seizing round a metal thimble (Stores Ref. 16H/300). The point of seizing may be reinforced by means of a shackle (Stores Ref. 44A/2061). Just below the ground two 3' 6" screw pickets are crossed at right angles so that the point of intersection of these pickets is just below the seized eye and separates the four thicknesses of K.B.85 on each side. These screw pickets are so placed to prevent the K.B.85 wire from pivoting from its anchorage and so forming a crater round the anchorage. Two trenches are dug in the form of a cross not less than 4/5ft. deep. A sleeper is placed in each of these trenches so that they intersect at right angles. Each trench should be under cut laterally so that the sleepers can each be turned a few degrees to ensure that their ends are beneath undisturbed ground. (Drawing KBC/1565/44/Eng. refers). Crews arriving on Sites on deployment will normally find a trench dug, the sleepers in position with K.B.85 wire placed four times round their intersection. It will be the job of crews arriving on sites to complete the anchorage by securing the 6 bolt clamp, the metal thimble, the two screw pickets and filling in the hole.

Position of Winch in relation to Central Anchorage

The thimble eye on the central anchorage should be in line with the winch. This means that a line drawn from the central anchorage to the winch will bisect to the right angle formed by the inter-section of the two sleepers. On sloping sites the winch should be positioned down-hill if possible.

Note 5

Earthing of Central Anchorage All central anchorages of the type described above must be earthed in the following manner:-

Two mats slatted, large (Stores Ref. 44/483) are placed one on either side of the thimbled eye of the central anchorage strop. One end of a length of wire earthing, tinned copper (Stores Ref. 44/1348) or K.B.20, is secured by two bulldog grips (Stores Ref. 44/483) to each earthing mat, thus bonding the two mats together. Care must be taken to obtain a good metallic contact between the wire and the mats. In addition a 2' 6" length of earthing wire is attached at one end to each of the earthing mats by bulldog grips in the manner described above, and the other end of each of these lengths is secured (also by bulldog grips) to one of the turns of the K.B.85 strop forming the central anchorage strop. These wires should run underground from the mat to the Central Anchorage strop. In this manner both mats are bonded together and each in turn is bonded to the central anchorage strop. Bulldog grips should be examined regularly for tightness and bonding wires replaced if strands become broken (Drawing T.26 Appendix to A.S.I. Part II refers).

Note 6

Bollard Hauling Pennant The winch should be positioned at a distance of not less than 56' from the central anchorage and it is advisable to keep as near to this position as possible. Bollard hauling pennants should be cut to a length to suit the position of the winch. This should be determined by positioning the bollard hauling block at its maximum pay out position and leaving 4 or 5 turns (not more) of the pennant on the bollard. It is most important that the bollard pennant should not be any longer in length than necessary, in order to avoid building up on the bollard and consequent kinking.

Note 7

Winch warning bells as described in E.S.S.I. WIN/GEN/17 are optional on all Centre Point Mooring Sites. Where held they may be used but where not held they should not be demanded.

Note 8

Use of Megaphones Megaphones are provided as a standard item of centre point site equipment and are to be used by the i/c crew on all occasions to give orders to the winch driver when hauling down the balloon either by means of the winch or the bollard.

Note 9

Inflation Procedure on Centre Point Mooring

(a) The balloon is rigged in the normal manner and the auxiliary legs reef bent to their respective ton patches, if not already attached. The pennant is reeved through its block and coupled to the bollard cable.

(b) The balloon must be positioned head to wind on ground sheets prior to inflation. The 36 ft. purchase slips and the mooring slips are hooked into the mooring circle pickets, and hooked into Marline Spike Hitches at a convenient position on the picketing strops, altering them as the inflation proceeds and reaching the final position with the mooring slips hooked into the eyes or grommets of the picketing strops.

(c) Bridle Bag Lines are, in the first instance, to be attached to each bridle grommet, starting at No.5. On completion of inflation these bag lines will be attached to the bridle suspension strops.

(d) The 16 ft. Purchase Slips are attached to the upper grommets of the ballast bag strops and on completion of the inflation are then attached to the lower grommets.

(e) As the balloon is inflated the auxiliary legs are shackled to the pennant.

(f) When inflation is completed the balloon will then be in the close-haul storm-moored position.

(g) The winch rigging legs are then uncoiled and shackled on the metallic link on the flying cable.

Note 10

Suggested Methods of Releasing Entangled Balloons

Method A Station 3 or 4 men between the sites to relay orders. Pay out the upwind balloons as far as possible, using the winch engine to pay out if necessary.

Haul in the downwind balloon not more than 500 ft. very slowly. With luck this should separate the balloons.

Method B If the above method is unsuccessful the following action should be taken if the lie of the land between the two Sites permits the balloons to be transferred.

(i) Station 3 or 4 men between the sites concerned to relay orders.

(ii) Pay out both balloons until all lift is lost. At least 5000 ft. should be paid out on the downwind balloon, if possible.

(iii) Attach a carpenter's stopper to the cable of the downwind balloon above the central anchorage. Attach a 200 ft. rope transfer leg by middling and larksheading to the shackle on the carpenters stopper.

(iv) Cut the flying cable at the winch lead-off gear and walk the balloon to the upwind site, using the transfer leg to negotiate obstacles where required. Sandbags may be attached as ballast if necessary.

(v) The length of cable between the central anchorage and the winch may be used as a trailing earth, but if this is not long enough a suitable length of G.P. wire must be used instead. Under no circumstances must the flying cable or the trailing earth be handled by personnel during the transfer, but must be allowed to trail in good contact with the ground.

(vi) Secure the winch end of the flying cable and drive the winch to the upward site, positioning it alongside the other winch.

(vii) Connect the cut ends of cable in the normal reeving manner and haul on to the drum. Reverse the winch lead-off gear on the downward winch.

(viii) Haul in both balloons together slowly. It may be found necessary to transfer the upwind balloon from the central anchorage to the winch lead-off gear during this operation. When both balloons are sufficiently low to see how they are entangled drive one winch around the other to disentangle or handle the one balloon around the cable of the other. The upwind balloon should then be moored.

(ix) The downwind balloon should be close-hauled to examine its cable and then transferred to its own site. The method of transferring depends largely on the obstacles which may exist between the two sites.

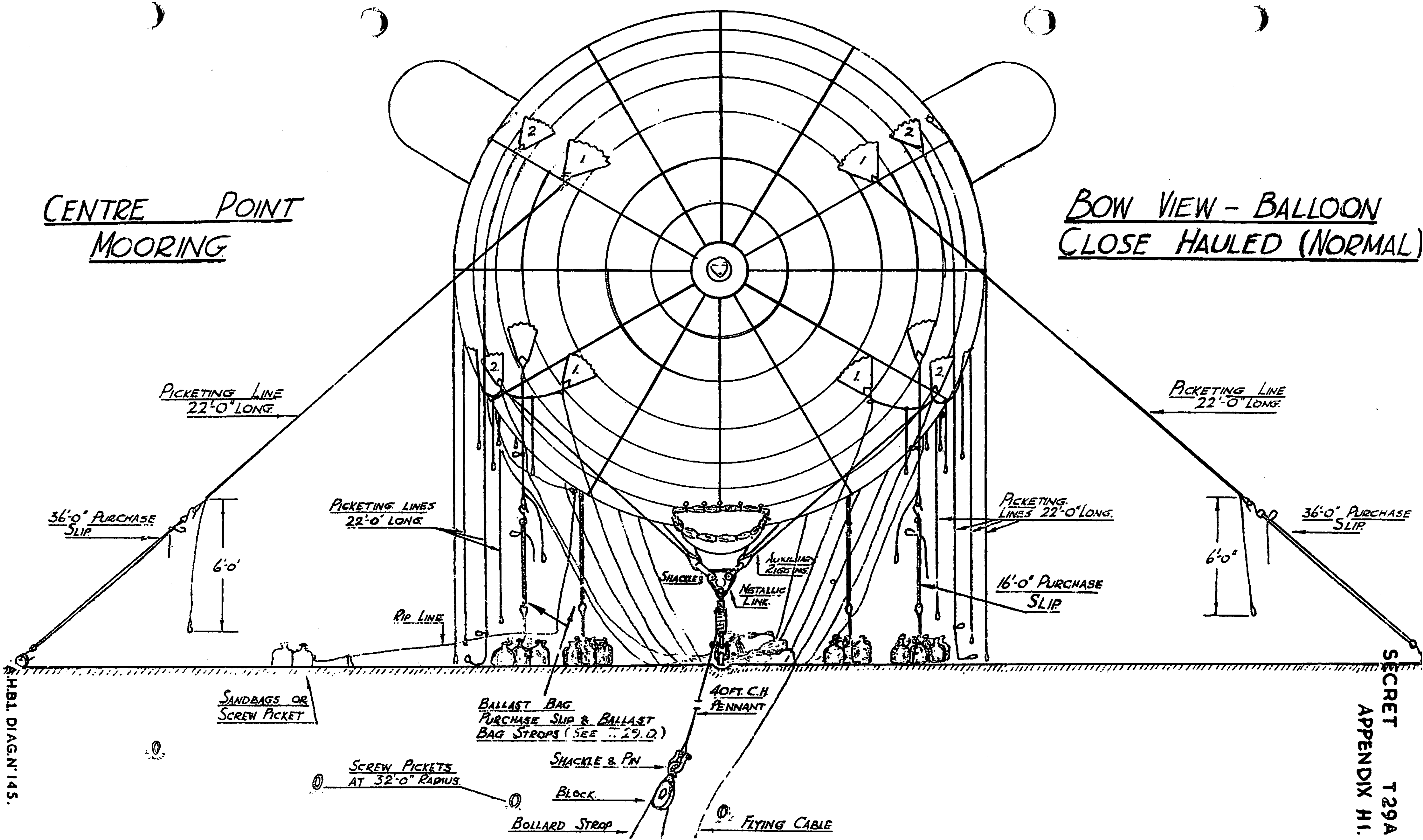
(x) If the cable of the downwind balloon is, on examination, found to be undamaged it will not be necessary to reeve on a fresh cable - providing that at least 5000 feet have been paid out before cutting.

(xi) This operation must only be attempted in calm weather and when the lightning risk is low or non-existent.

N.B. These instructions are to be inserted in the Centre Point Mooring Pamphlet.

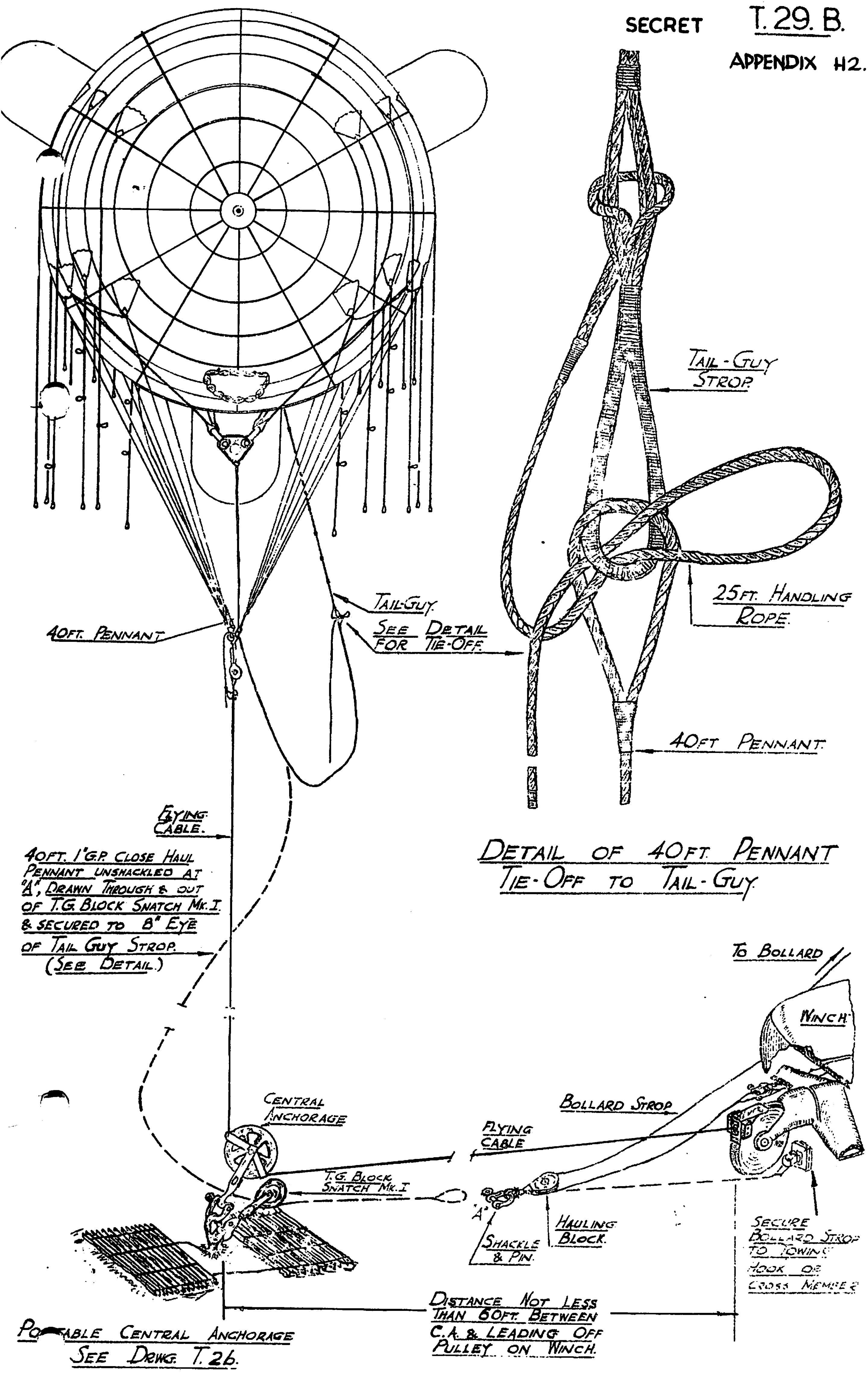
CENTRE POINT MOORING

BOW VIEW - BALLOON CLOSE HAULED (NORMAL)



A.H.B.1. DIAG.Nº 145.

SECRET T29A APPENDIX H1.

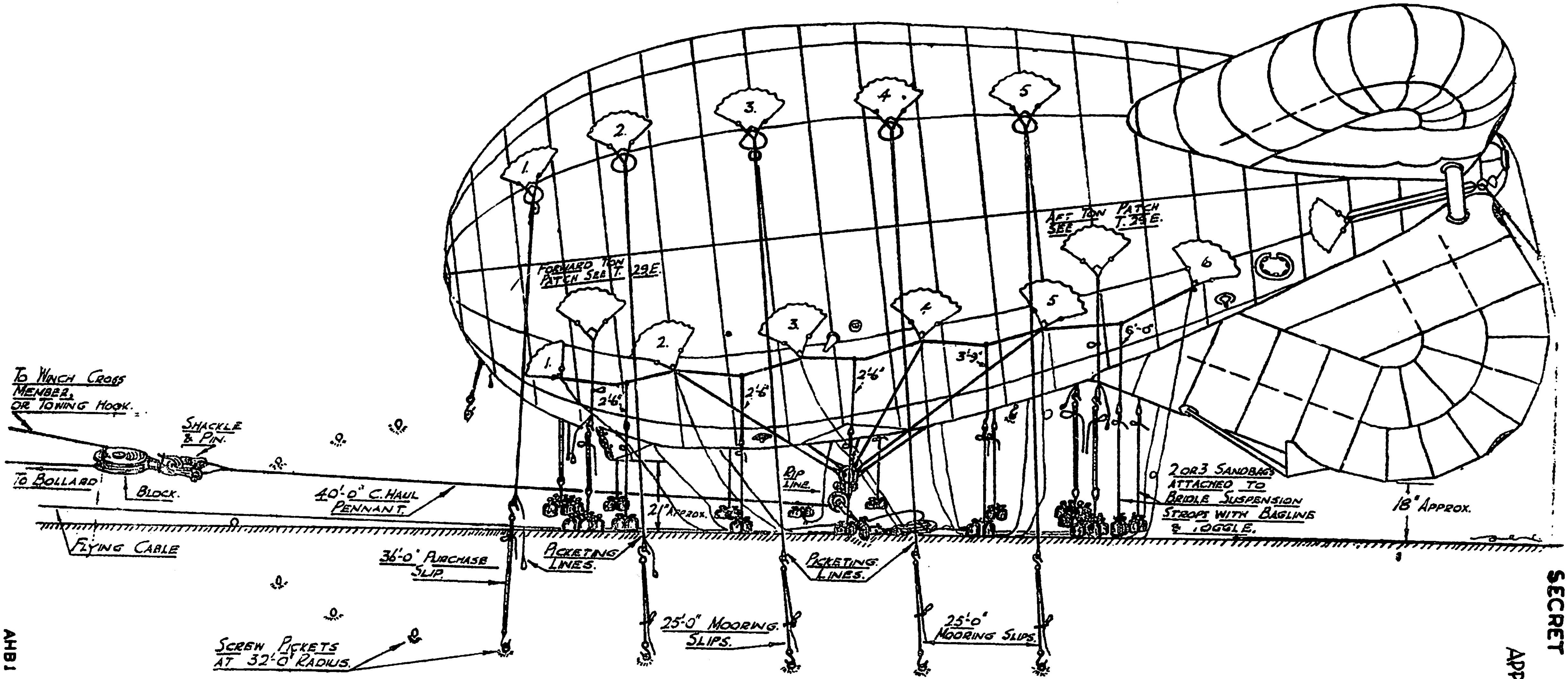


CENTRE POINT MOORING – ILLUSTRATION OF BALLOON IN FLIGHT – TAIL GUY TIE OFF

AHB1 DIAG N°146.

SECRET

APPENDIX H3. T29C



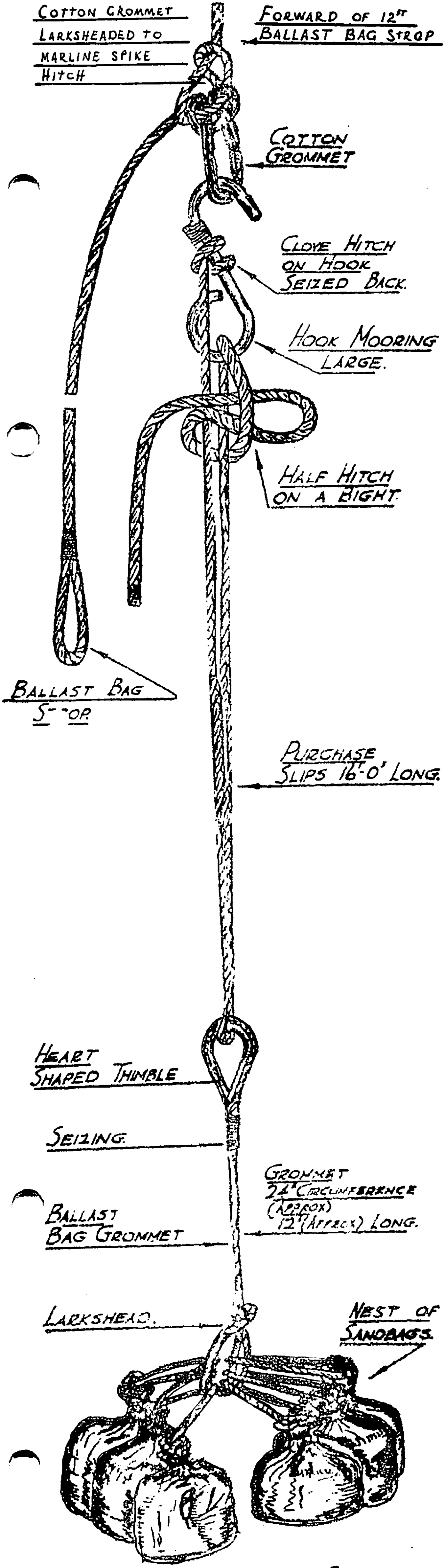
CENTRE POINT MOORING – BALLOON CLOSE HAULED (STORM.)

AHB1 DIAG. N° 147.

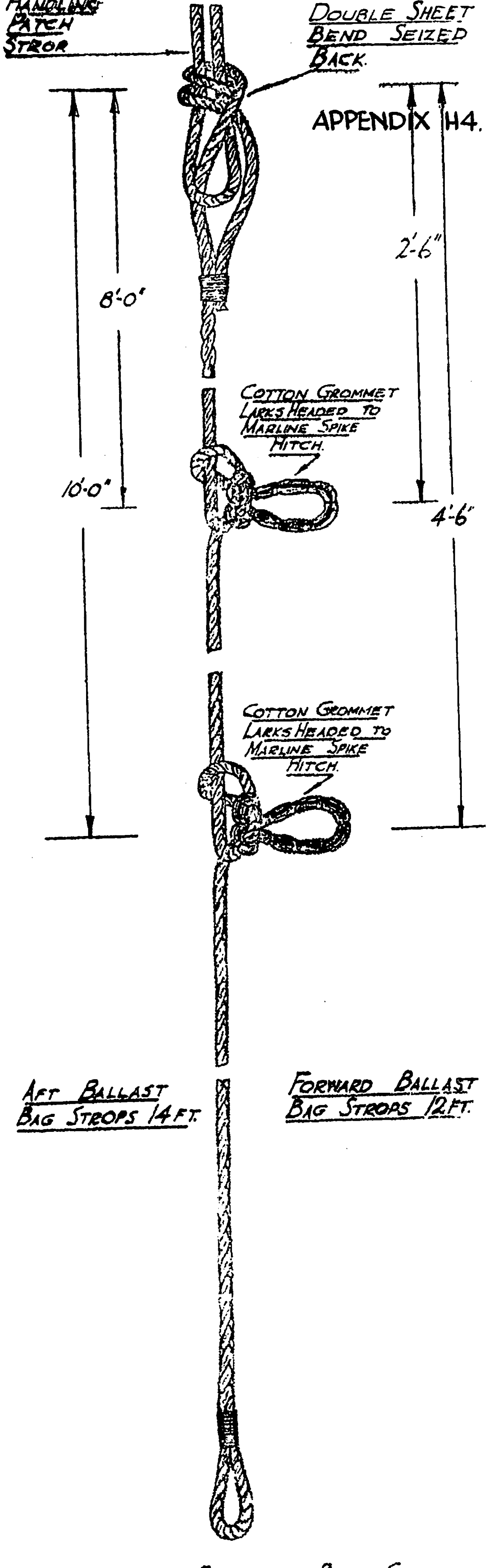
SECRET

T. 29. D

APPENDIX H4.



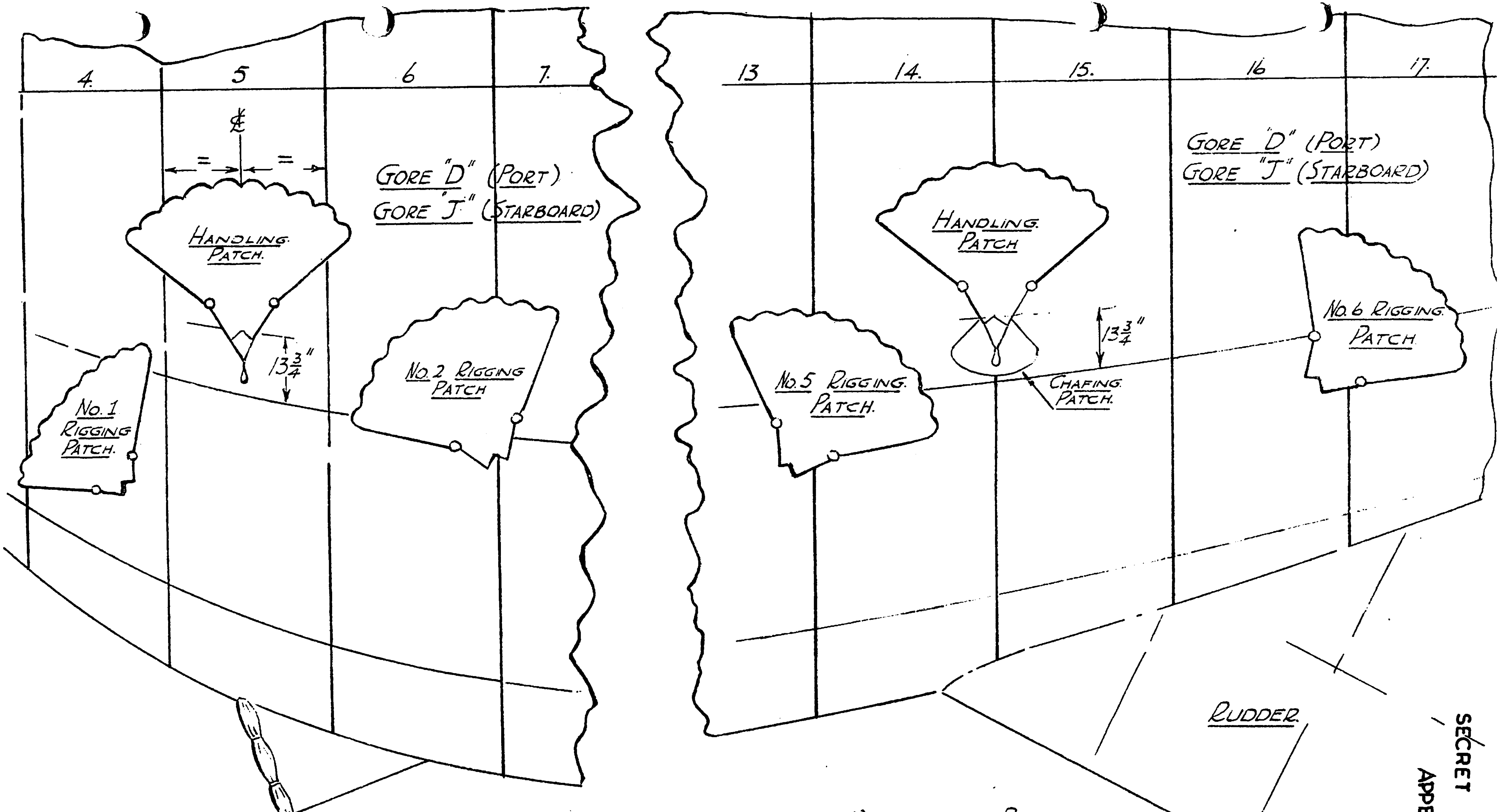
DETAIL OF PURCHASE SLIPS, BALLAST BAG GROMMET, & SAND BAGS.



DETAIL OF BALLAST BAG STROPS.

NOTE:- POSITION OF GROMMETS ON FORWARD STROPS SHOWN ON RIGHT HAND SIDE OF DRAWING. POSITION OF GROMMETS ON AFT STROPS SHOWN ON LEFT HAND SIDE

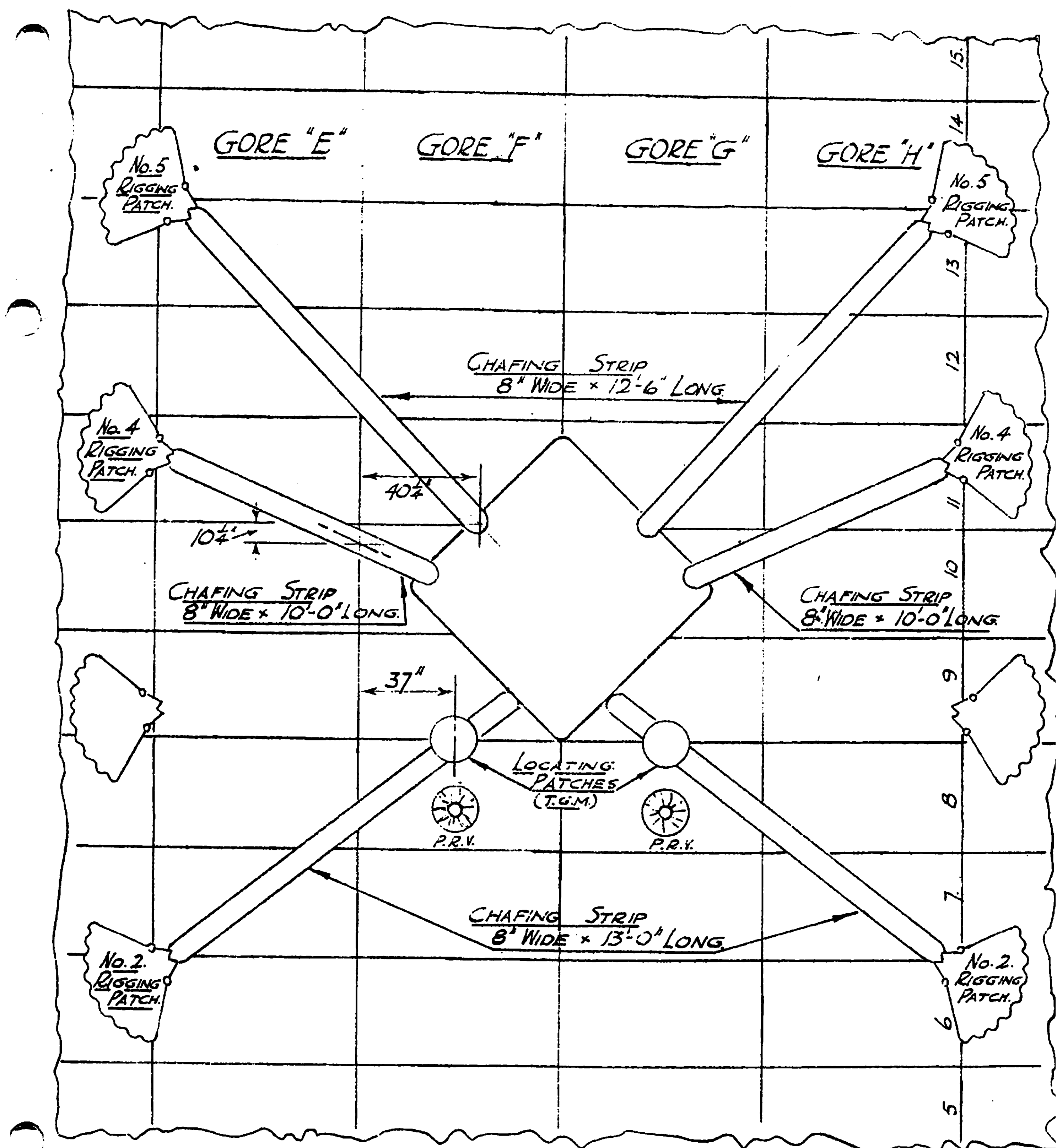
A.H.B.I. DIAG N° 14



POSITION OF PATCH FOR FORWARD BALLAST BAG STROP

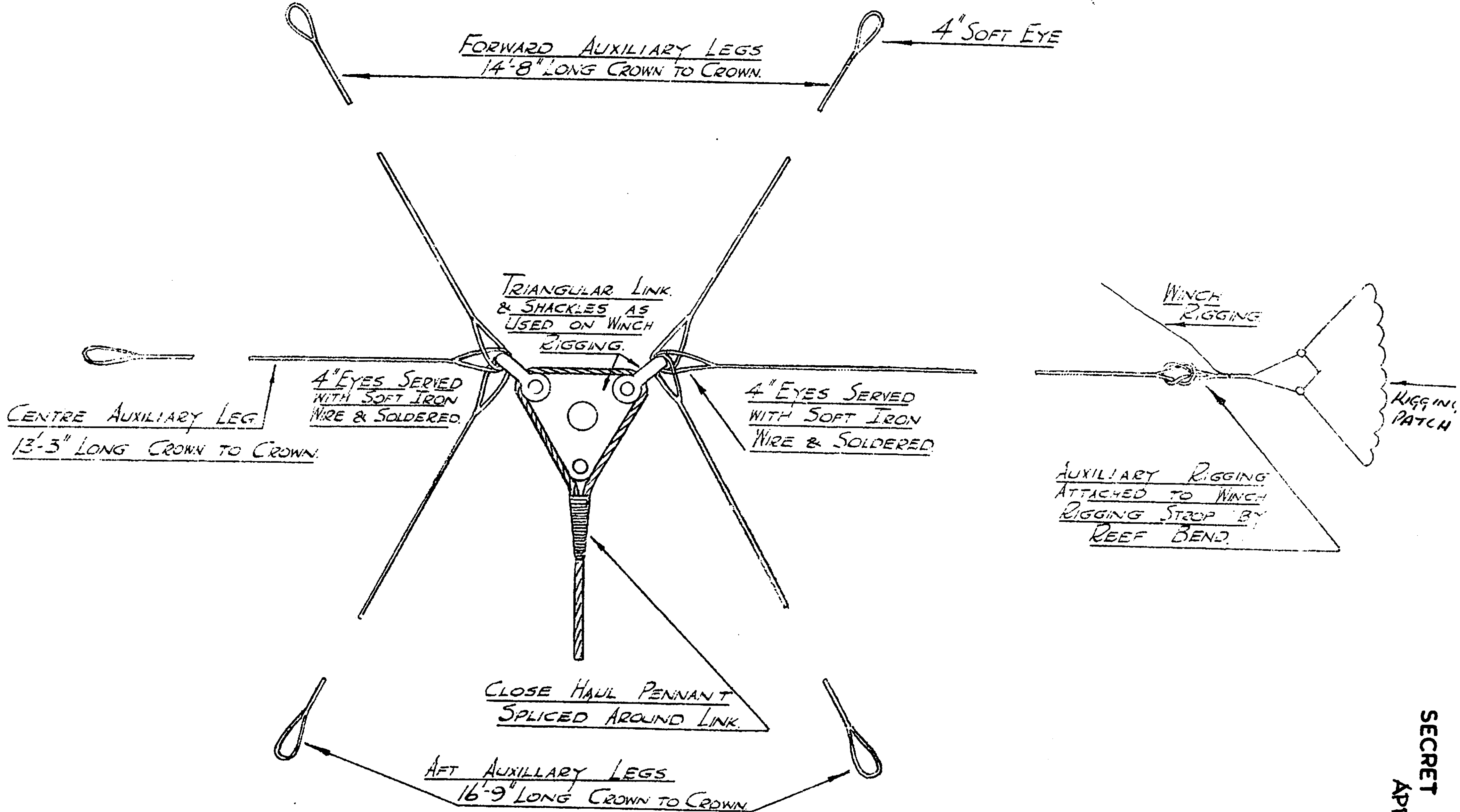
POSITION OF PATCH FOR AFTER BALLAST BAG STROP

CENTRE POINT MOORING



CENTRE POINT MOORING

POSITION OF LOCATING PATCHES AND CHAFING STRIPS.

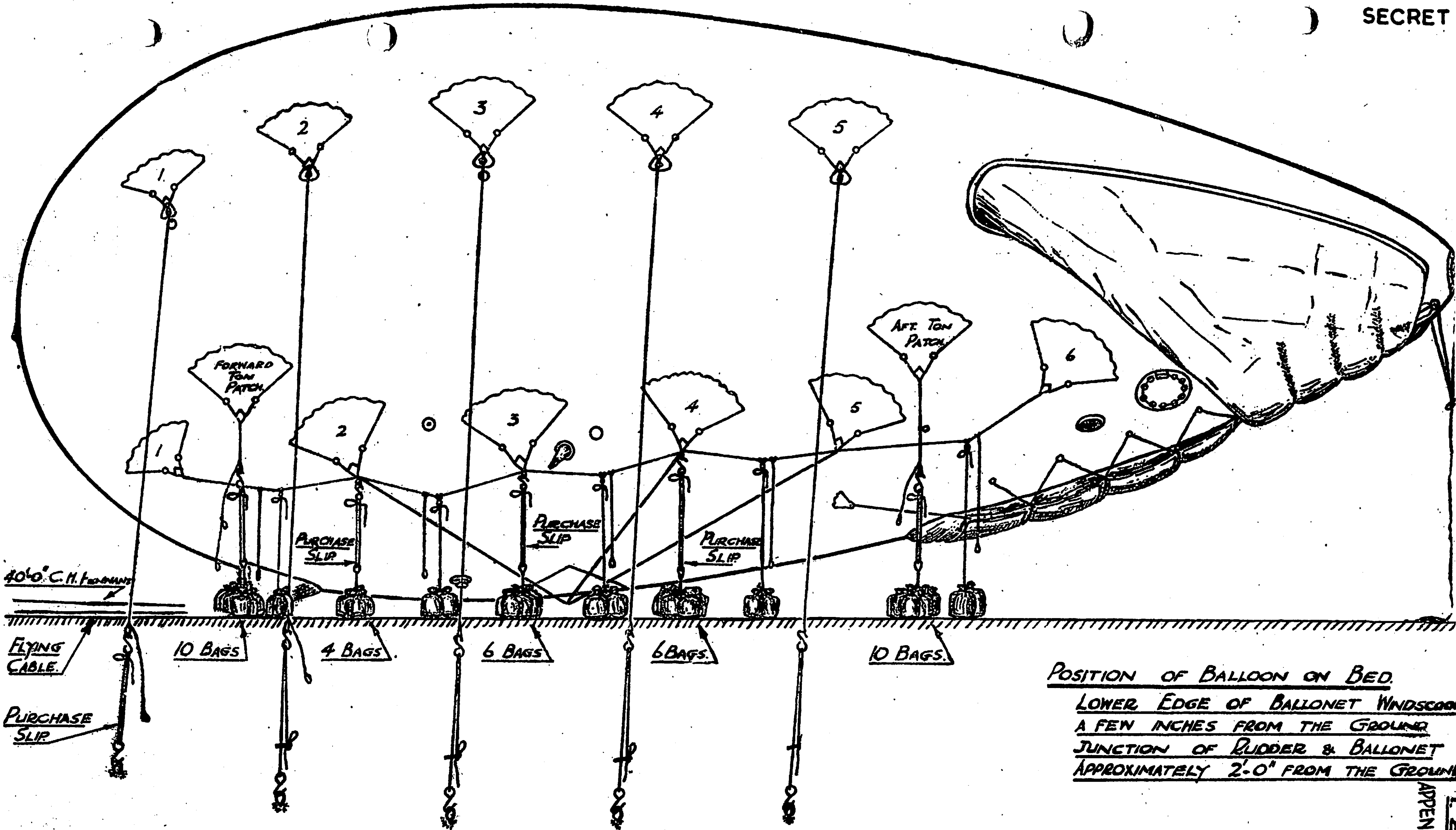


CENTRE POINT MOORING – DETAILS OF AUXILIARY RIGGING LEGS. K.B 32A (STORES REF. 44/5

SECRET T29G
APPENDIX H7.

AHBI DIAG N°144.

SECRET

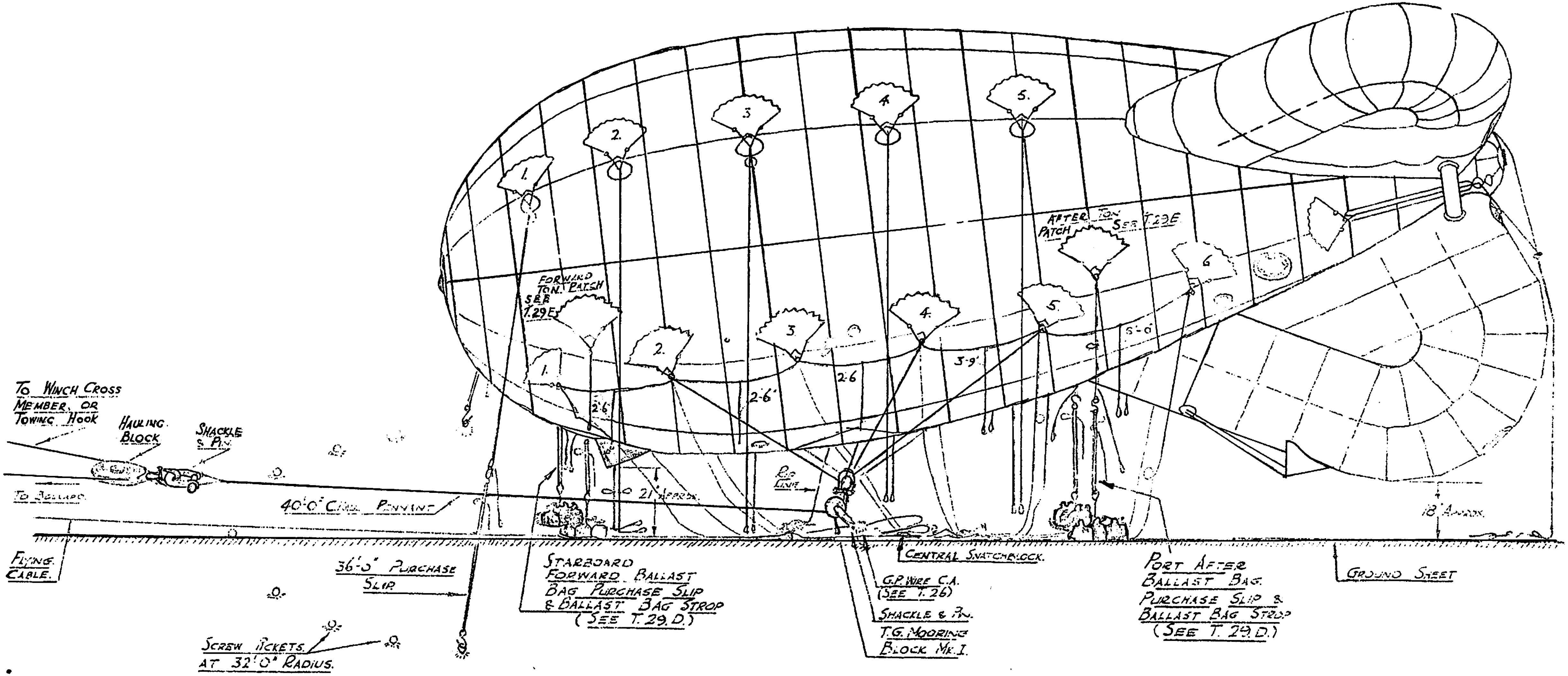


POSITION OF BALLOON ON BED.
LOWER EDGE OF BALLONET WINDSCOOP A FEW INCHES FROM THE GROUND
JUNCTION OF RUDDER & BALLONET APPROXIMATELY 2'-0" FROM THE GROUND

CENTRE POINT MOORING BALLOON STORM BEDDED.

APPENDIX H8

T.29H

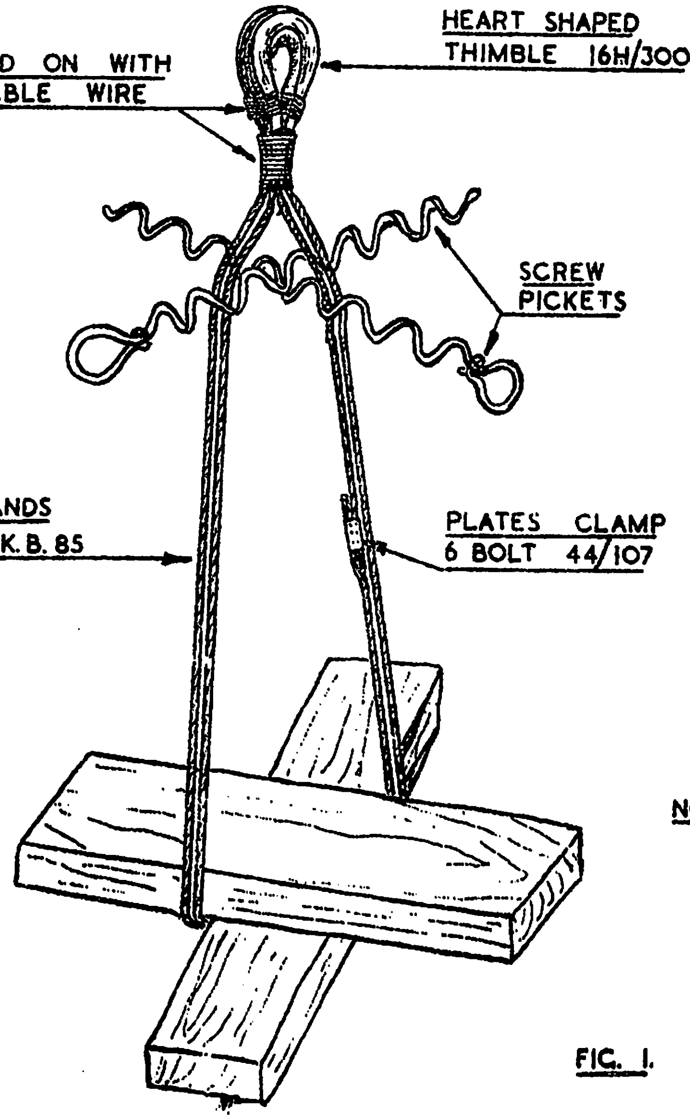


Centre Point Mooring – Balloon Close Hauled (Normal)

AHBI DIAG N° 143.

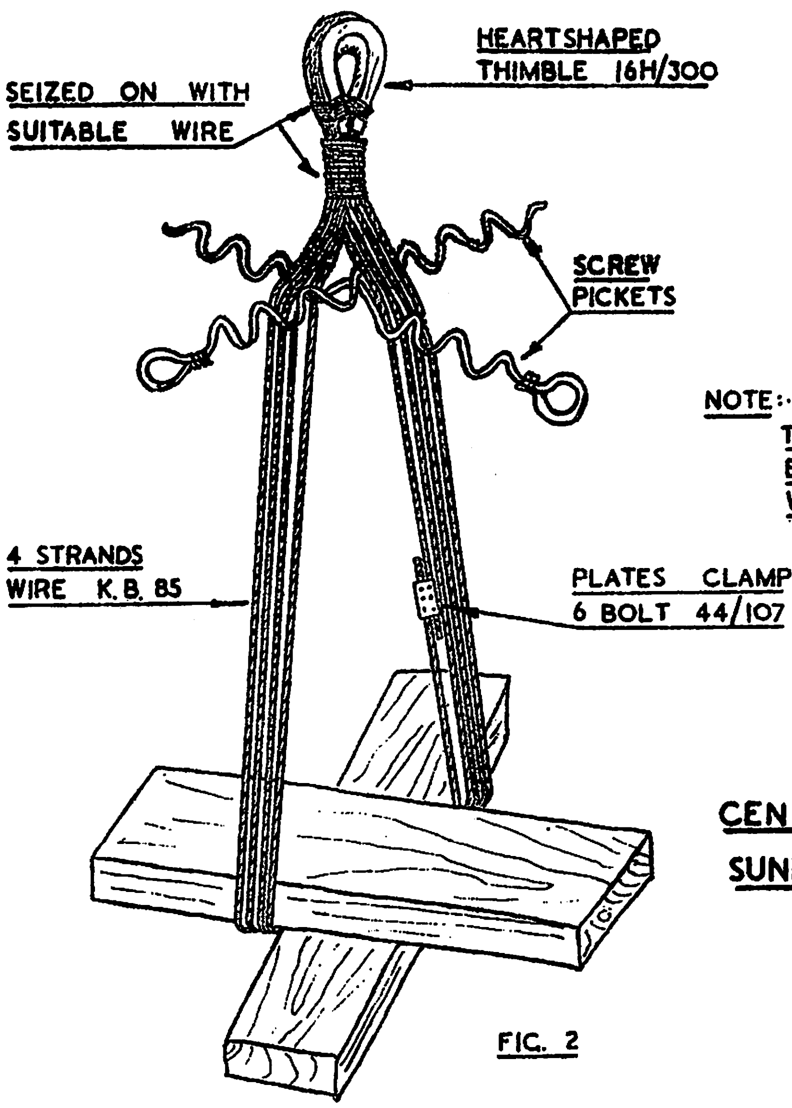
SECRET
APPENDIX H9

CENTRAL ANCHORAGE
SUNKEN DEADMAN
(REVISED DRG. No KBC/1494/44ENG.)



NOTE:-
THE CROWN OF THE
EYE TO BE FLUSH
WITH GROUND LEVEL

FIG. 1.



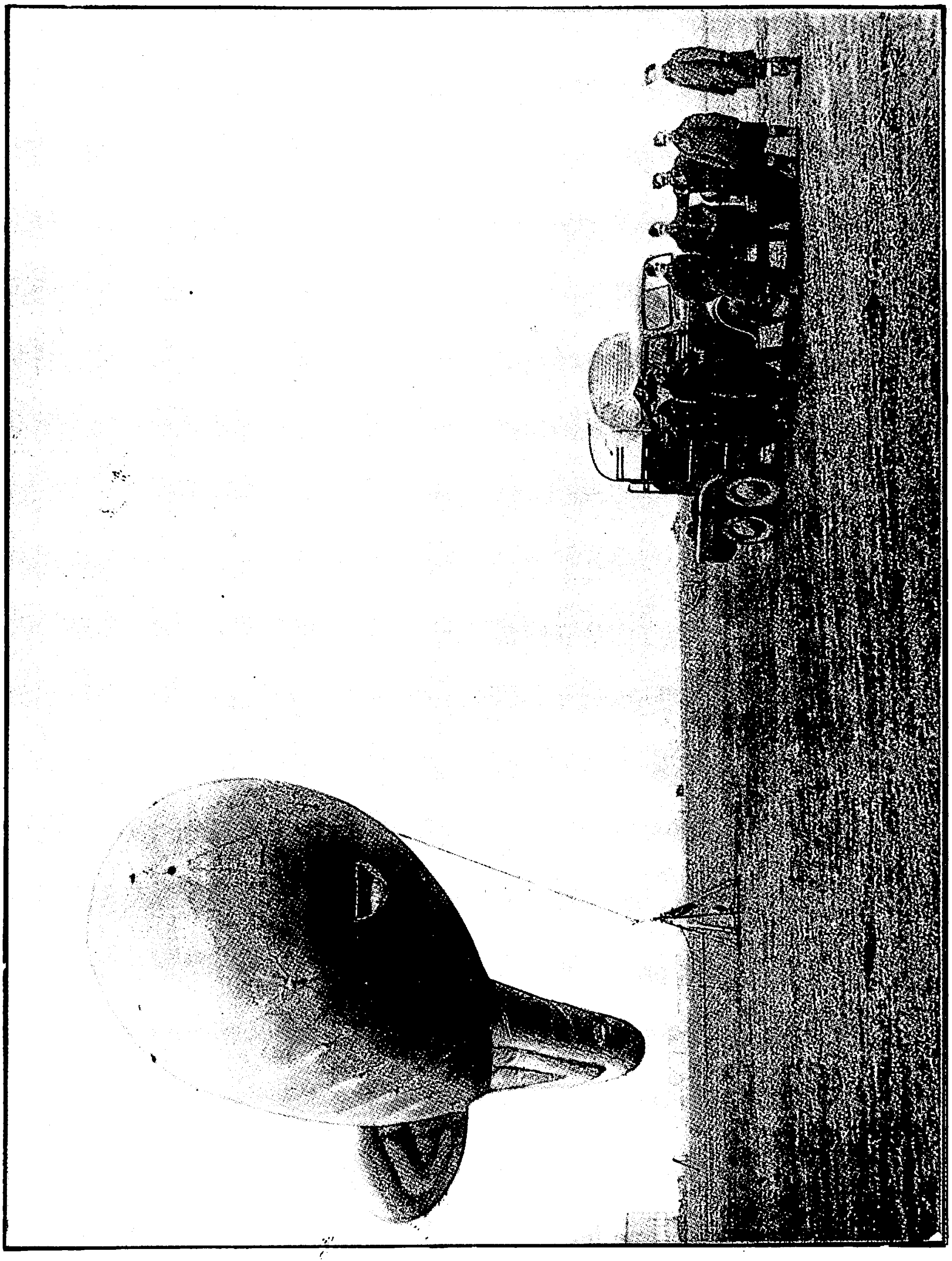
NOTE:-
THE CROWN OF THE
EYE TO BE FLUSH
WITH GROUND LEVEL

CENTRAL ANCHORAGE
SUNKEN DEADMAN
RE-INFORCED

FIG. 2

SECRET

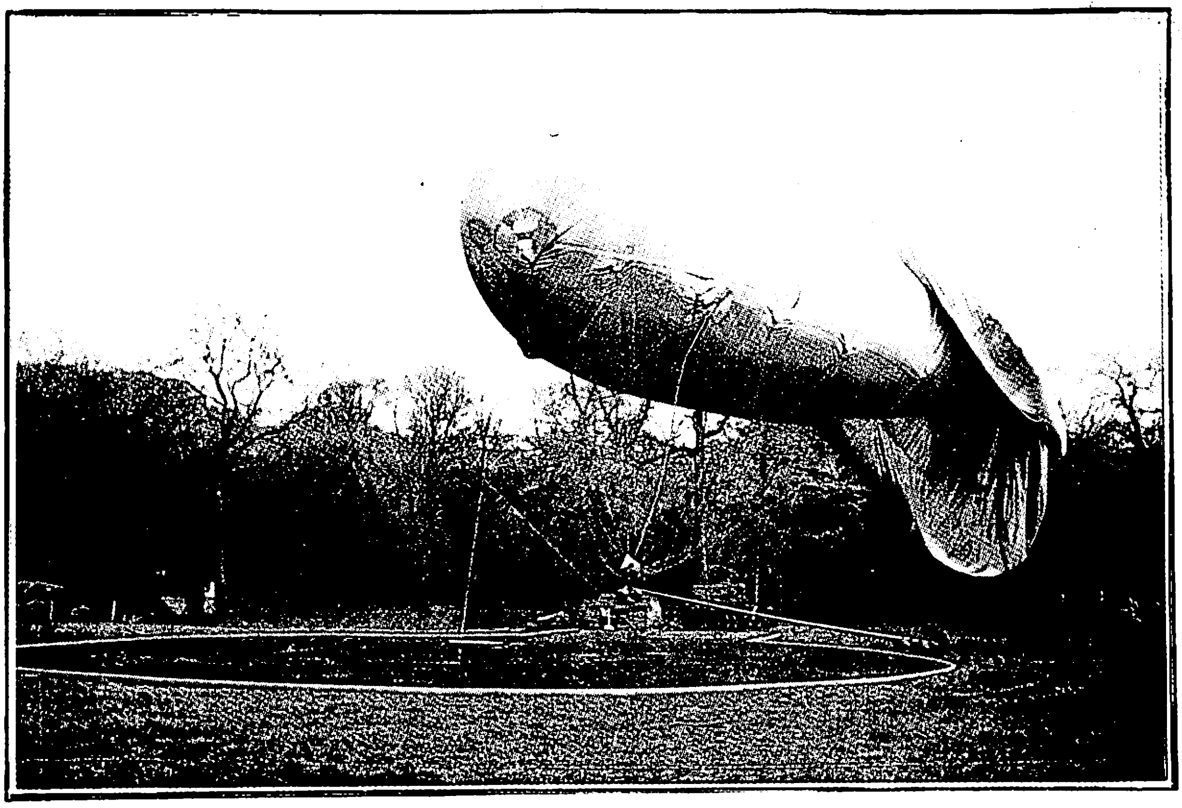
APPENDIX H.11.



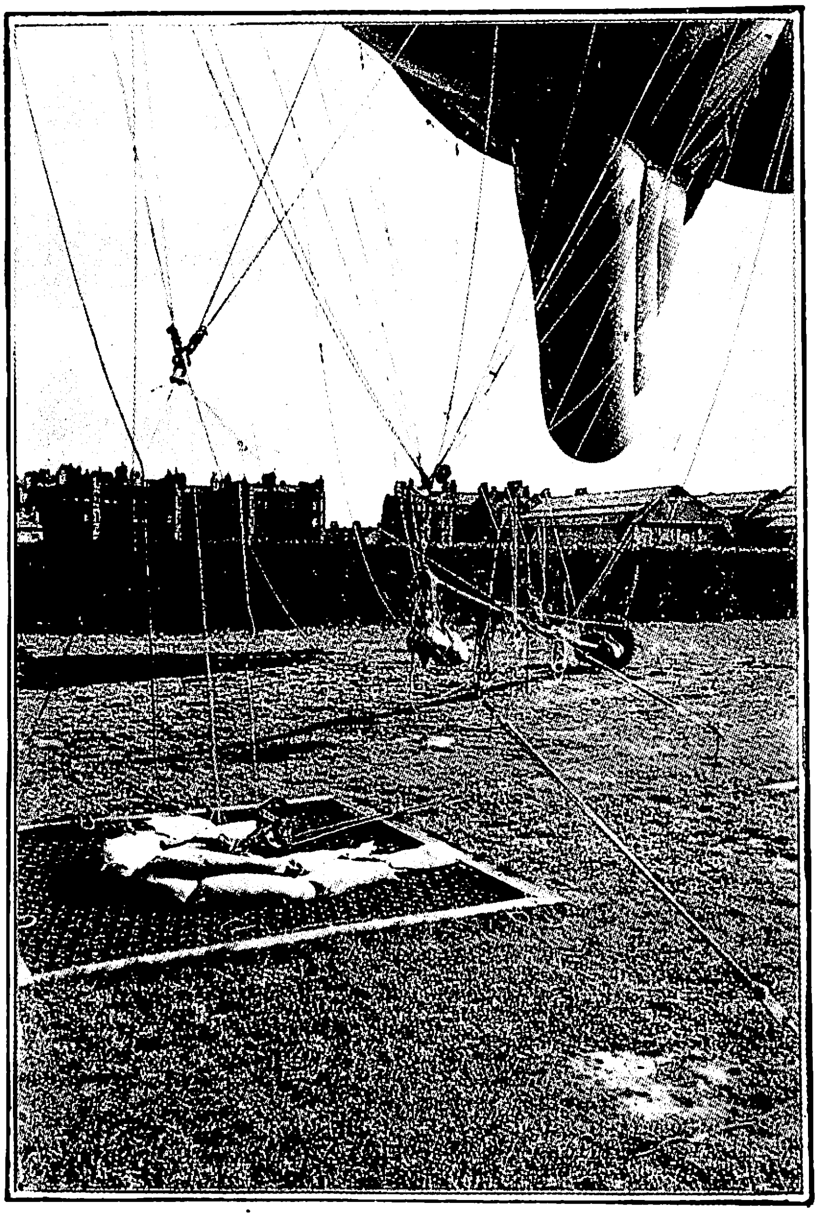
MOORING PYRAMID OF FOUR WIRE LEGS

SECRET

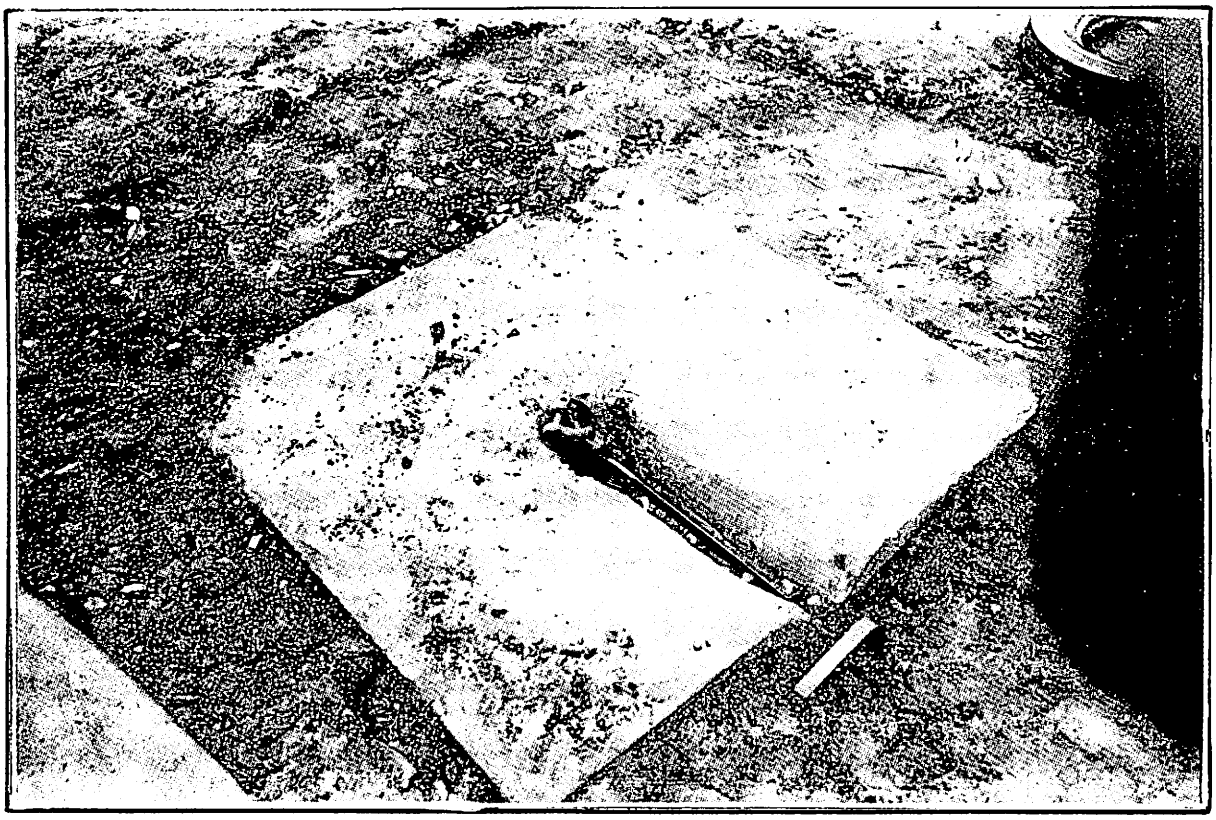
APPENDIX H.12.



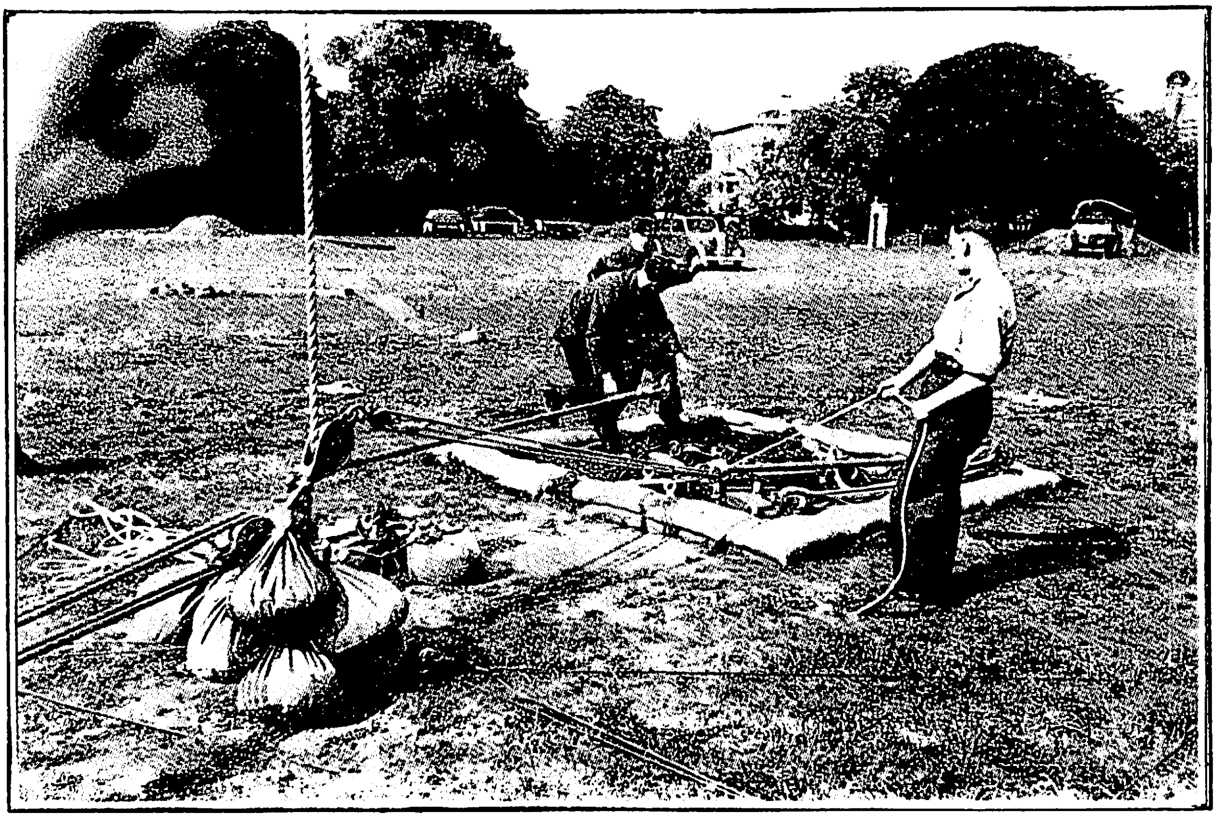
THE "WHEELWRIGHT" MOORING, showing the system of attachment.



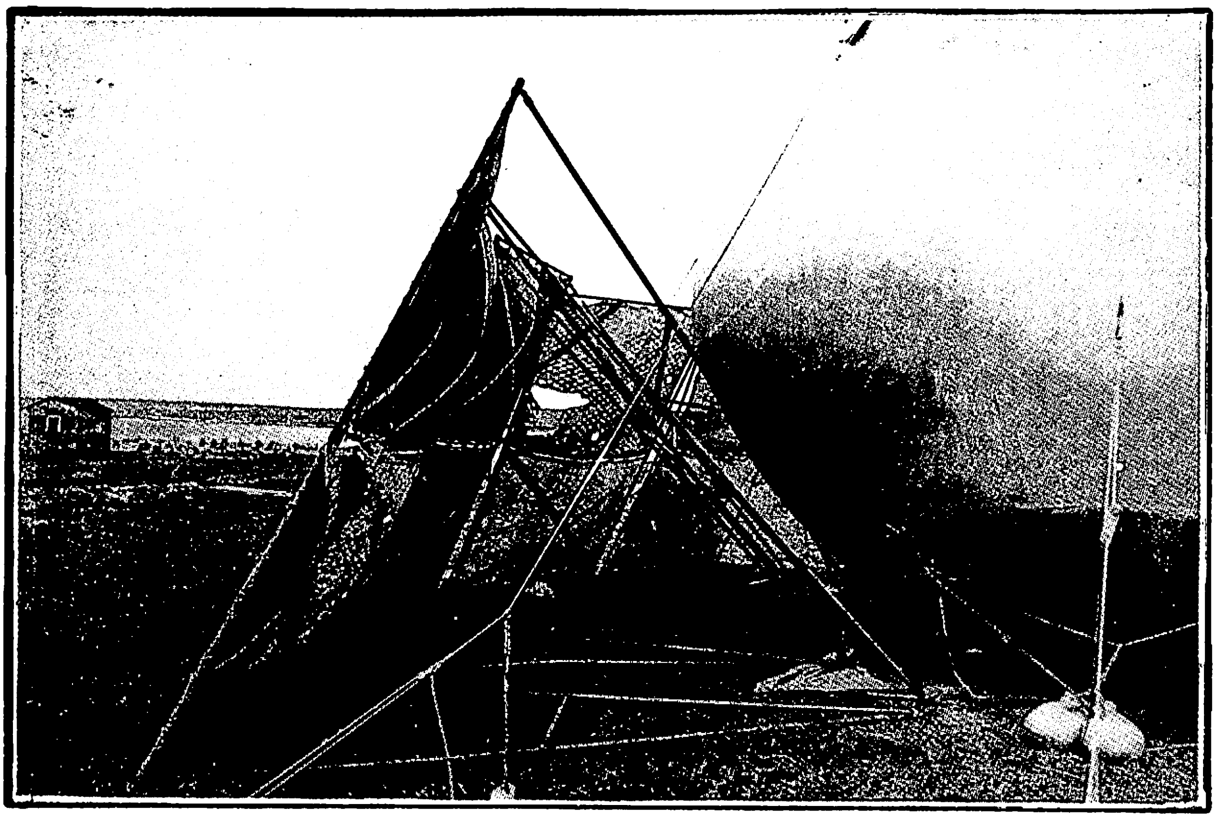
THE "WHEELWRIGHT" MOORING.



CENTRAL ANCHORAGE showing copper earthing strip.



CENTRAL ANCHORAGE ("DEADMAN" TYPE)
Showing lay-out of Anchorage and Balloon Bed.



WIND SCREENS AT SCAPA.

COLLISIONS - ENEMY AIRCRAFT AND BALLOON CABLES APPENDIX "I"

DATE AND TIME	BARRAGE	TYPE OF AIRCRAFT	RESULT
4th June, 1940 (0035 hrs.)	Le Havre	JU.87 ?	Crashed
20th June, 1940 (Night)	Billingham	Heinkel	Crashed in sea
18th July, 1940 (0011 hrs.)	Harwich	Unknown	Proceeded (Force landing in France)
3rd Sept., 1940 (2235 hrs.)	Bristol	Unknown	Uncertain (pieces of Wing found)
13th Sept., 1940 (0330 hrs.)	Newport	Heinkel III	Crashed and burnt out
16th Sept., 1940 (2358 hrs.)	Coventry	JU.88	Crashed and burnt out
16th Oct., 1940 (2235 hrs.)	Harwich	Heinkel III	Crashed in flames
24th Oct., 1940 (0150 hrs.)	Liverpool	Unknown	Crashed in Estuary
9th Nov., 1940 (2000 hrs.)	London	Unknown	Proceeded
18th Nov., 1940 (2050 hrs.)	Thames	Unknown	Uncertain (Spun round by collision, last seen losing height
19th Nov., 1940 (2205 hrs.)	London	Heinkel III	Struck two cables and crashed
23rd Nov., 1940 (2100 hrs.)	Southampton	Unknown	Uncertain
24th Nov., 1940 (2251 hrs.)	Plymouth	Dornier 17	Crashed and burnt out
30th Nov., 1940 (1938 hrs.)	Plymouth	Unknown	Uncertain
15th Dec., 1940 (2150 hrs.)	Sheffield	Unknown	Uncertain
5th Jan., 1941 (0048 hrs.)	Southampton	Unknown	Proceeded
8th Jan., 1941 (1510 hrs.)	Coventry	Unknown	Proceeded
5th Feb., 1941 (2230 hrs.)	Hull	Unknown	Proceeded
16th Feb., 1941 (0025 hrs.)	Newcastle	Heinkel III	Crashed

DATE AND TIME	BARRAGE	TYPE OF AIRCRAFT	RESULT
22nd Feb., 1941 (1412 hrs.)	Avonmouth	Heinkel III	Crashed
24th Feb., 1941 (0010 hrs.)	Hull	Unknown	Proceeded
6th March, 1941 (1910 hrs.)	Bristol	Unknown	Proceeded
11th March, 1941 (0205 hrs.) (0222 hrs.)	Crewe	Unknown	Uncertain - believed to have proceeded after striking two cables
11th March, 1941 (2315 hrs.)	Bristol	Heinkel III	Crashed
12th March, 1941 (2212 hrs.)	Runcorn	Unknown	Crashed
22nd March, 1941 (2000 hrs.)	Hull	Heinkel III	Crashed
31st March, 1941 (1914 hrs.)	Falmouth	Unknown	Crashed
31st March, 1941 (2119 hrs.)	Falmouth	Unknown	Crashed
10th April, 1941 (0145 hrs.)	Birmingham	Heinkel III	Crashed
23rd April, 1941 (2359 hrs.)	Plymouth	Unknown	Proceeded
4th May, 1941 (0010 hrs.)	Liverpool	Heinkel III	Crashed
8th May, 1941 (0355 hrs.)	Barrow	Unknown	Crashed in sea
8th May, 1941 (0015 hrs.)	Yeovil	Unknown	Uncertain
15th May, 1941 (0415 hrs.)	Falmouth	Unknown	Crashed
20th May, 1941 (0420 hrs.)	Harwich	Unknown	Proceeded
29th May, 1941 (0120 hrs.)	Hull	Unknown	Proceeded
19th June, 1941 (0315 hrs.)	Harwich	Unknown	Proceeded
12th Sept., 1941 (0403 hrs.)	Harwich	Unknown	Proceeded

SECRET

APPENDIX "I"

DATE AND TIME	BARRAGE	TYPE OF AIRCRAFT	RESULT
14th Jan., 1942 (2151 hrs.)	Harwich	Unknown	Proceeded
15th Jan., 1942 (1810 hrs.)	Billingham	Dornier DO 217	Crashed
17th April, 1942 (0243 hrs.)	Southampton	Unknown	Proceeded
1st May, 1942 (0240 hrs.)	Tyne	Unknown	Proceeded
9th May, 1942 (0120 hrs.)	Norwich	Dornier DO 217E	Crashed
20th May, 1942 (0001 hrs.)	Humber	Unknown	Proceeded
20th May, 1942 (0030 hrs.)	Hull	Unknown	Crashed
28th June, 1942 (0130 hrs.)	Weston-Super-Mare	Unknown	Proceeded
8th July, 1942 (0158 hrs.)	Billingham	Unknown	Proceeded
26th July, 1942 (0122 hrs.)	Billingham	Unknown	Proceeded
27th July, 1942 (0801 hrs.)	Derby	Dornier	Struck two cables Proceeded
31st July, 1942 (0305 hrs.)	Birmingham	Unknown	Proceeded
31st Oct., 1942 (1708 hrs.)	Canterbury	Focke-Wulf	Crashed
14th May, 1943 (0220 hrs.)	Chelmsford	Unknown	Proceeded
30th May, 1944 (0049 hrs.)	Falmouth	Unknown	Crashed in sea
18th July, 1944 (2330 hrs.)	Normandy	JU.88	Crashed

SECRET

APPENDIX "J"

COPY NO.

SUPPLEMENT NO.2 to
AEAF/MS.686/Admin.

OPERATION OVERLORD

ALLIED EXPEDITIONARY AIR FORCE

ROYAL AIR FORCE ADMINISTRATIVE PLAN

PLAN FOR BRITISH BALLOON PROTECTION OF BEACHES MULBERRY AND PORTS

LIST OF APPENDICES:

J(A) - Chart showing craft sailing with R.A.F. Balloons.

J(B) - Schedule showing anticipated number of Balloons flying on the Continent.

INTRODUCTION

1. The object is to provide V.L.A. balloons on the Continent flying at 2,000 ft. for the protection of:-

(a) Assault Beaches and beach maintenance areas.

(b) MULBERRY B.

(c) Various ports as the Operation develops.

METHOD OF PROTECTION

Beaches

2. Beaches will be protected from D Day and crews will bring in their balloons flying as soon as possible after the Assault and deploy forthwith.

MULBERRY

3. Although it will be possible in the early stages to provide a limited degree of protection from beach resources the main MULBERRY protection cannot be brought in until D + 4, when a Coaster will carry across uninflated balloons, ancillary equipment and hydrogen, so that a barrage of 60 Balloons can be deployed immediately by personnel who have been brought in on D + 3.

Ports

4. Port protection will be provided as the Operation progresses. It will be the responsibility of 21 Army Group to request balloons on the scale required from A.E.A.F. through Second T.A.F. All port units are designed so as to be self-contained, and port balloons will always be transported deflated in craft arranged for by 21 Army Group together with the necessary hydrogen, ancillary and administrative equipment and personnel.

BEACH BALLOON SQUADRONS

Requirements

5. 3 Squadrons of 60 Balloons each under a S/Ldr. will be transported to the Continent on D Day. These will be allocated as follows:-

No. 976 "B" Balloon Squadron to No.1 Beach Squadron.
No. 974 "B" Balloon Squadron to No.2 Beach Squadron.
No. 980 "B" Balloon Squadron to No.4 Beach Squadron.

Administration

6. Balloon Squadrons will be administered by their appropriate Beach Squadron and Second T.A.F. will arrange for their rationing and necessary medical services from the Army.

Method of transporting balloons

7. It is not possible, owing to Radar objections, to fly balloons on D Day on any craft reaching the lowering position before H-15 mins. Furthermore, on that day balloons cannot be flown across at a height of more than 100 ft. until an increased height is authorised by A.N.C.X.F. (1) through N.C.E.T.F.(2) As L.C.T. and L.S.T. are the only available craft on which balloons can be transported flying, the total number of balloons which can be carried over on D Day is 199 allowing for the Radar restriction, comprising 95 on the first tide and 104 on the second. This is sufficient to provide 180 balloons together with their crew of 2 and one light portable winch per balloon plus 19 unmanned balloons flying crew shore stay which will be used to replace some of the anticipated casualties on the voyage. Second Army has undertaken to detail 2 men to each of the 180 balloons carrying winches to assist in the loading and unloading of the winch and the transfer of the balloons from disembarkation point to site. A.N.C.X.F. has instructed N.C.E.T.F. that L.S.T. will carry a R.A.F. balloon in addition to the Naval balloon which is carried for their own protection.

Build-up

8. After D Day R.A.F. balloons will be flown across channel to replace casualties on every L.S.T. and on 2/3rds of the L.C.T. sailing from this country. It has been decided by A.N.C.X.F. that the remaining 1/3rd of the L.C.T's must carry a Naval balloon for their own protection on the homeward voyage. At Appendix "A" is a chart showing the total number of craft available for deployment and build-up, together with their dates and ports of sailing as far as is known at present. The variations in these dates and ports are not expected to be material.

---

(1) Allied Naval Commander Expeditionary Force.

(2) Naval Commander European Task Force.

Casualty Rate

9. It is estimated that casualties to balloons are likely to occur on the following scale:-

(a) While flying during transit........20%

(b) While deployed during first seven days 30% daily

(c) While deployed thereafter........15% daily

At Appendix "B" is a schedule showing the number of balloons which can be expected to be flying up to the time when the full extent of Beach and MULBERRY protection can be built up by the sole process of flying balloons across channel, allowing for the fact that 60 Balloons for MULBERRY are being brought in uninflated on D + 4 (para. 16 refers).

Implications of build-up rate

10. Inflated Balloons. It will be apparent from a study of Appendix "B" that the full number of 180 balloons on the beaches cannot be built up by the ferrying method by D + 4, and that there will be times when the number of balloons flying is reduced to about 100. There is no method of obtaining a greater supply of balloons before D + 4, and this reduced protection at times in the early stages will therefore have to be accepted. It is, however, considered that if balloons can be maintained to the minimum extent shown at Appendix "B", the barrage will be sufficient to provide an adequate deterrent effect to low flying aircraft.

11. Uninflated Balloons. It is most desirable to raise the barrage to the full strength of 180 balloons for beaches and 60 for "MULBERRY" as rapidly as possible, and Second T.A.F. will therefore arrange the "phasing in" on D + 4 and thereafter as necessary of sufficient packed balloons and hydrogen to raise the daily total from that shown in Appendix "B" to 240. Second T.A.F. will be responsible for estimating requirements of balloons and hydrogen for inflation and topping-up purposes, and informing Air Ministry who will make the necessary provisioning arrangements with Balloon Command. It will be necessary for the Balloon Staff Officer on the beaches to make most careful arrangements for the return of empty hydrogen cylinders to this country, as the entire success of the hydrogen supply chain depends on this being carried out efficiently.

12. With a view to increasing further the rate of build-up, two further possibilities are being explored by 21 Army Group, A.N.C.X.F. and Balloon Command:-

(a) Whether it is practicable to carry over a balloon inflated and flying from short stay in addition to the one already flown for craft protection on Merchant vessels which will be sailing from this country to the Continent.

(b) Whether a quantity of hydrogen and packed balloons can usefully be carried over on block ships. In this connection it is to be remembered that packed balloons can only be carried where dry storage space can be guaranteed and that the supply of hydrogen cylinders available for the Operation is limited so that unnecessary loss of cylinders by sinking or damage by prolonged immersion should be avoided.

As both these possibilities are uncertain, they have not been taken into consideration when estimating the hydrogen and packed balloon requirements mentioned in para. 11 above.

Vehicles

13. Four 3 - ton servicing vehicles per "B" Balloon Squadron will be "phased-in" on the second tide of D + 1 and two additional 3 - tonners per Squadron on D + 5 or as soon thereafter as possible.

MULBERRY BALLOON SQUADRON

Requirements

14. 60 balloons are required for protection of MULBERRY B and these will be supplied by No.991 "B" Squadron which combined Nos. 56 and 57 "B" Balloon Flights of 30 balloons each.

Administration

15. As no R.A.F. Beach Squadron exists to which this squadron can be attached No. 991 "B" Squadron H.Q. has been established for the purposes of administration.

Method of transporting MULBERRY Units

16. The Balloon and Squadron Headquarters personnel, together with the Unit vehicles, will be "phased-in" on D + 3. Packed balloons, hydrogen, rear party personnel and ancillary equipment to the scale agreed between Balloon Command, Second T.A.F. and Second Army, will be transported on a suitable Coaster and unloaded through the MULBERRY organisation on D + 4.

Casualty Rate

17. As for Beach Balloons, see para. 9 above.

CONTROL OF BALLOONS

18. Control of balloons will be vested in the A.A.D.C. of the area protected and all applications in respect of controls will be made to him. Lanes for aircraft approaching Landing Strips will be arranged as necessary by Second T.A.F. when the detailed siting of balloons is being decided. It must be realised that controls can only be implemented on a pre-arranged plan. Inter-site communications do not exist except by runner and the bedding of a barrage by hand winch cannot be accomplished in less than an hour from the time of receipt or orders at sites. Control by hand winch will be necessary on the night of D/D + 1 and possibly D + 1/D + 2. As soon as practicable, control by powered winch will be instituted owing to the labour involved in hand winching and the fact that it may be impossible to haul down the balloons by hand winch in

high winds. The normal method is for the balloons to be hauled down by power provided by the servicing tenders which move from site to site for the purpose, one vehicle servicing 15 balloons. The time taken to ground a barrage will vary between $1\frac{1}{2}$ and $2\frac{1}{2}$ hours according to the difficulty in getting the vehicle round the circuit of sites. Balloons cannot be bedded when flown from craft, and it has been accepted by Second Army that balloons on Phoenix and Block Ships can be considered close-hauled when flying at a height not exceeding 100 ft.

Responsibility for Bidding

19. The "phasing-in" of all balloon equipment, hydrogen and personnel will be the responsibility of 2nd Army in consultation with Second T.A.F.

Density of protection

20. Theoretical balloon siting has been carried out for the Beaches, Beach maintenance and MULBERRY areas, and the full scale of protection involves a distance of 300 to 350 yards between each balloon. It has been found in this country that siting of balloons at intervals of 500 or more yards provides an adequate deterrent to low flying, but the difficulties of maintaining a barrage at anything like full strength under the conditions anticipated have been taken into consideration when the rather dense siting mentioned above was recommended.

Balloons on Phoenix and Block Ships

21. Balloons will be flown on Phoenix and Block Ships for protection of MULBERRY and GOOSEBERRIES. These Balloons will be supplied from the 240 balloons provided for Beach and MULBERRY protection. The Navy has accepted responsibility for ferrying inflated balloons and balloon personnel from the beaches to provide for initial deployment and subsequent casualty replacements. Arrangements will be made between 21 Army Group and Balloon Command for the installation of a light portable winch on each of the 36 Block Ships. In the case of Phoenix a winch will be taken out from the shore and installed on the Phoenix at the time the balloon is deployed on to the vessel.

Establishment of Units

22. Beach and MULBERRY Squadrons are at present established on Balloon Command and will be transferred to the establishment of Second T.A.F. prior to Squadrons entering the concentration area.

PORT UNITS

Requirements

23. 21 Army Group have estimated requirements for port protection as follows:-

Approx. date of disembarkation	No. of Balloons
D + 8 (to be confirmed between R.A.F. and Second Army)	25
D + 20	15
D + 50	45
D + 70	10
D + 70	15
D + 80	50
D + 90	50
	210

Not only must the dates mentioned be considered highly speculative and subject to very material alteration, but it is anticipated that the requirement will almost certainly be increased as the Operation progresses.

Existing resources

24. Balloon Command have formed for overseas ports requirements 5 Squadrons containing 11 flights, totalling 190 balloons. In addition 3 Squadrons, comprising 9 flights and 165 balloons are being deployed to ports in this country for protection during the early stages of the "OVERLORD" Operation. Any balloons, therefore, in excess of 190 required on the Continent can only be provided in the following ways:-

(a) By withdrawing balloons deployed at home ports.

(b) When the stage has been reached at which Beach Balloon Squadrons are no longer required, by withdrawing them and re-forming them on a Port basis provided the necessary additional equipment is available.

A.D.G.B. will be requested by A.E.A.F. at the appropriate time to consider and report on the priority of withdrawals from this country and the estimated time at which such withdrawals can be carried out.

Organisations of resources

25. Port Units are able to operate in multiples of 5 balloons. In view of the impossibility of giving a reliable estimate of the tasks or the dates of deployment, it is necessary that Port Balloon Formations be maintained on the most elastic possible basis, so that they may be employed at short notice on any task in any required numbers.

Responsibility for Nominating Port Requirements

26. 21 Army Group will be responsible for requesting from A.E.A.F. through Second T.A.F. port protection as it is required, and for providing suitable transport to carry the Port Balloon organisation overseas.

Administration

27. All port Squadrons and flights are provided with sufficient personnel to be self-contained except for medical services. These services, petrol, oil and all normal maintenance equipment will be supplied as arranged by Second T.A.F.

Hydrogen supplies

28. It is impossible to transport Port Balloons from this country inflated, owing to the impracticability of carrying inflated balloons to their deployment area from points of disembarkation. For port protection therefore, it is essential to bring hydrogen cylinders or a hydrogen plant and deflated balloons. Loading schedules for hydrogen cylinders and hydrogen plants for Balloon Port Units of the various sizes have already been supplied to 21 Army Group, who will be responsible for arranging through Second T.A.F. with Balloon Command for initial supply of hydrogen cylinders to ports and for transport of hydrogen plants and necessary chemicals when it is considered desirable to produce hydrogen in deployment areas and provided that sufficient chemicals can be made available at the time.

Control of Balloons

29. Control will be vested in the A.A.D.C. of the protected port. The measure of control which will be possible is:-

(a) Grounding of balloons from 2,000 ft. This will take 1 - 1½ hours approximately.

(b) To fly balloons from grounded position to 2,000 ft. will take 3/4 to 1 hour approximately.

NOTE. In cases where balloons are flown from Breakwaters, piers or buoys, it is probable that in some cases they could not be closehauled within any period acceptable to the controlling authority.

Casualty Rate

30. Balloon casualties are in the main caused by A.A. shell fire and breakaways through weather conditions. Very little reliable data from active operations in ports is available, but it is reasonable to assume that casualties will be highest and replenishment most difficult immediately after deployment, and that casualties may decline sharply thereafter, The following estimate is based on the above factors:-

X + 1 to X + 3	=	50% daily)	
X + 4 to X + 9	=	20% daily)	
X + 9 to X + 17	=	12½% daily)	Where X is date of capture of port
X + 17 to X + 31	=	7% daily)	
X + 31 onwards	=	5% daily)	

Establishment

31. Port Units are at present established on Balloon Command and will be transferred, prior to embarkation, to the establishment of Second T.A.F., or 85 Group, whichever is in control of the base area at the time the Unit is embarked from this country.

SUMMARY OF RESPONSIBILITIES

32. Detailed planning covering the "phasing-in" of Beach and Port balloons, hydrogen, equipment and personnel, together with their deployment on the Continent, will be carried out between Second T.A.F. (until such time as this responsibility is assumed by 85 Group) and initially Second Army, thereafter 21 Army Group.

33. (i) Detailed planning covering organisation and requirements in United Kingdom for producing inflated balloons, their equipment and hydrogen for all purposes at the ports as required will be carried out by Balloon Command in consultation with Second T.A.F., N.C.E.T.F. and initially Second Army, thereafter 21 Army Group.

(ii) A.E.A.F. will give Balloon Command the maximum notice for the transfer of "B" Balloon Squadrons and "B" Units to Second T.A.F. who will arrange for the movement of these Units from their present locations to the concentration areas, together with the equipment I.E. and I.R. except as detailed in (i) above.

34. Estimates of overall requirements, such as balloons, balloon equipment, hydrogen and transport, are the responsibility of Balloon Command who will make arrangements with the appropriate departments of Air Ministry.

APPENDIX "J(A)"

L.S.T. and L.C.T. available for carriage of R.A.F. Balloons

These figures must be treated as approximate and liable to alteration

Arriving on 1st Tide	Loads at	Loads on	Force
L.C.T. 20	Gosport or Stokes Bay	D - 2	J
L.C.T. 30	Newhaven	D - 2	S
L.C.T. 20	Shoreham	D - 2	S
L.S.T. 3	Southampton	D - 3	J
L.S.T. 9	Southampton	D - 2	J
L.S.T. 5	Gosport	D - 4	S
L.S.T. 3	Southampton	D - 4	G
L.S.T. 5	Southampton	D - 3	G
95			

Arriving on 2nd Tide	Loads at	Loads on	Force
L.C.T. 50	Tilbury	D - 2	L
L.S.T. 12	Southampton	D - 2	J
L.S.T. 1	Gosport	D - 4	S
L.S.T. 11	Gosport	D - 3	S
L.S.T. 12	Southampton	D - 3	G
L.S.T. 18	Tilbury	D - 3	L
104			

Arriving on 3rd Tide	Loads at	Loads on	Force
L.S.T. 5	Gosport	D - 2	S
L.S.T. 2	Tilbury	D - 3	L
L.S.T. 5	Tilbury	D - 2	L
L.S.T. 22	Felixstowe	D - 2	L
34			

After D Day Sailings of craft carrying R.A.F. Balloons will be roughly as follows:-

Day	Type	Loads at	No.	Type	Loads at	No.
D + 1	L.C.T.	Newhaven	14	L.S.T.	Gosport	12
		Gosport	97		Southampton	9
			111			21
D + 2	L.C.T.	Nil	Nil	L.S.T.	Tilbury	6
					Gosport	12
					Southampton	13
						31
D + 3	L.C.T.	Gosport	32	L.S.T.	Tilbury	6
					Gosport	12
					Southampton	12
						30
D + 4	L.C.T.	Gosport	32	L.S.T.	Tilbury	6
					Gosport	12
					Southampton	10
						28

Thereafter as D + 4

SECRET

APPENDIX "J(B)"

DAY	No. of Balloons sailing from U.K.	20% Casualties on voyage	No. of Balloons arriving	No. of Balloons available after arrival of fresh supply	Casualties during succeeding 24 hours at 30% daily	No. of Balloons remaining after Casualties
D	199	39	160	N.A.	48	112
D + 1	34	7	27	139	41	98
D + 2	132	26	106	204	61	143
D + 3	31	6	25	168	50	118
D + 4	62 + 60 for MULBERRY	12	110	228	68	160
D + 5	60	12	48	208	62	146
D + 6	60	12	48	194	58	136
D + 7	60	12	48	184	55	129
		CASUALTIES HEREAFTER CALCULATED AT 15% DAILY				
D + 8	60	12	48	177	26	151
D + 9	60	12	48	199	30	169
D + 10	60	12	48	217	32	185
D + 11	60	12	48	233	35	198
D + 12	60	12	48	246	37	209

ET. SEQ. The above estimated uild-up does not allow for inflating balloons n the Cont. nent (other than 60 for MULBERRY) from D + 4 onw. rds. See paras. 10 and 11.

OPERATION ANTI-DIVER

NOTES ON LIGHT SUSPENDED WIRE ARMING

1. When considering the implication of balloons as an Anti-Flying Bomb barrage, it was appreciated that the Flying Bomb could be made to crash in four ways.

(a) By causing a yaw beyond the ability of the automatic control to rectify and thus rolling the bomb into a dive.

(b) By applying a drag on the flying bomb which will reduce its speed below the stalling speed, or which will be sufficient to prevent height being maintained although it may not be sufficient to cause the bomb to stall.

(c) A combination of both the above factors.

(d) Direct impact of warhead of the flying bomb with balloons or cable causing it to explode in mid-air.

Evidence of impacts on KB5B cable went to show that with a normal or direct impact the amount of yaw caused was insufficient to crash the bomb for reason (a). With an oblique impact however, there were greater chances of a roll being developed sufficient to crash the bomb.

All the evidence went to prove that lighter wires would have less chance of causing a lethal yaw on impact.

2. On the other hand another factor required consideration. The critical impact speed of a wire depended to some considerable extent upon the tension of the wire. The main balloon cable being subject to the lift and pull of the balloon was therefore always liable to be under considerable tension, but light wires suspended from the balloon would be subject to no such tension and would, therefore, be more likely to withstand an impact without breaking.

3. From this it may be deduced that the chances of killing an F.B. by method (a) were somewhat slim. That the heavier wire had the best chance providing it did not shear due to the speed of impact on the cable under tension. The light wire was much less likely to shear, but equally unlikely to produce the necessary amount of yaw.

Method (b) therefore seemed to offer the best chance of success.

The amount of drag which could be applied to a flying bomb depended upon

(i) The breaking strain of the wire employed.

(ii) The size of parachutes employed.

(iii) The speed of the bomb.

(iv) The point of impact in relation to the centre of gravity of the bomb.

(i) and (ii) were, of course, inter-related and it followed therefore, that for all speeds and types of impact the greater the breaking strain of the wire the greater the drag which could be imposed.

4. To obtain the maximum efficiency in this respect with any wire, the parachutes must be carefully designed to give a pull in relation to the breaking strain of the wire and the average speed of the bomb.

5. It was a further factor to consider, that each type of wire used would, on account of the different breaking strains which determined the amount of drag which could be applied, take a period to reduce the speed of the bomb of its stalling speed in exact proportion to the breaking strain of the wire.

6. As the object of the Diver Barrage was to destroy by crashing flying bombs before they reached a built-up area, there was obviously a limit to the time (distance) which could be accepted between the point of impact and the point at which the speed was reduced to stalling. This clearly limited the types of wire which could be used.

7. Of the wires available, 19 S.W.G. was a doubtful starter on account of its low breaking strain. Experiments proved that the drag which 19 S.W.G. was capable of imposing in conjunction with appropriate parachutes was unlikely to stall a flying bomb within 20 miles. 15 S.W.G. was, from experiments carried out by the Royal Aircraft Establishment, Farnborough, thought to be capable of bringing down bombs within a distance of 6/9 miles from the point of impact.

KB1A was, likewise, considered by the Royal Aircraft Establishment to be capable of stalling a flying bomb after it had travelled 3/4 miles. In this case it was thought that the distance might even be slightly reduced, on account of the yaw imposed on the flying bomb causing rudder drag in the attempt to counteract.

8. The point at which impact took place in relation to the centre of gravity of the bomb was also of great importance when considering the distance which the bomb was likely to travel after impact.

An impact at the wing tip would, if the wire got a grip and did not slide off the wing, certainly cause a crash within a shorter distance than would be the case if the same wire impacted at the point of junction between wing and fuselage. In the first case the drag at the outboard end of the wing has a much greater turning movement than the same drag applied further inboard; to correct this turning drag, the automatic control of the bomb must impose opposite rudder. This adds considerably to the total amount of drag imposed on the flight of the bomb. In the second case the turning movement imposed is almost negligible and the drag which wire and parachutes are capable of imposing is the only hindrance to the machine. On the wires available in sufficient quantity more exhaustive experiments were conducted by Royal Aircraft Establishment, Farnborough, which resulted in the following data being accepted.

(i) 15 Gauge Scheme. Out of 100 impacts on suspended 15 S.W.G. with appropriate parachutes, $33\frac{1}{3}\%$ could be expected to cause the flying bomb to crash within 3/4 miles whilst the balance would be likely to cause the flying bomb to crash within a distance of not less than 9/12 miles - although, for various reasons, a proportion of this balance may be to all intents and purposes totally ineffective.

(ii) KB1A Scheme. Out of 100 impacts, 66.2/3rds% could be expected to crash the flying bomb within 2/3rds miles from impact, whilst the balance could be expected to crash within an acceptable distance, although a proportion for various reasons would be ineffective.

Other things being equal, from the above it would appear that the KB1A Scheme should be the only one to be considered as being sufficiently lethal for use in dealing with Flying Bombs. On the other hand the amount of wire which an LZ Balloon could lift to a reasonable height in addition to its own cable obviously affected the choice of wire in a very material degree.

9. In considering the types of wires available which possessed any acceptable degree of lethality, viz: 15 S.W.G. and KB1A, the fact that 15 S.W.G. weighs 14 lbs. per 1,000 ft. and KB1A 28 lbs. for the same length, had a large bearing.

In fact if it could be arranged for a balloon to lift a suspended assembly of the KB1A Scheme to 4,000 ft. the same balloon would clearly be capable of lifting two such assemblies of the 15 gauge Scheme to the same height.

10. From previously quoted figures two separate chances with the 15 Gauge Scheme would give the same crash probability as one chance with the KB1A Scheme, but in addition to this it was also possible that with two 15 S.W.G. assemblies, double the number of crashes might be obtained within distances of up to 12 miles from point of impact than with one KB1A assembly.

Thus if the twin 15 Gauge Scheme sites were positioned at a sufficient distance from the built up target area to allow the drag imposed by this assembly and its parachutes to take full effect, it should be possible to obtain a larger number of kills before the target is reached than would be the case if these same sites were equipped with Single KB1A Scheme.

11. The problems to be faced are:-

(i) To obtain the maximum impact probability.

(ii) To obtain the maximum percentage of crashes within an acceptable distance (i.e. before the built-up area is reached) from these impacts.

In other words, it is one thing to obtain an impact, but an impact was useless unless it could be converted into a crash before the target was reached.

The solution to (i) was to suspend in the track of the Flying Bomb the maximum number of obstacles in the shape of wires and (ii) to ensure the maximum lethality of these suspended obstacles.

12. Unfortunately, the limiting factor to both these problems was the lift of the balloon. Thus an L.Z. Balloon could in addition to its own mooring cable only carry a limited extra amount of weight to a height which was acceptable when dealing with Flying Bombs.

It was a matter for decision as to which method of using this available extra lift would prove more advantageous and produce the maximum number of crashes.

13. METHODS OF SUPPORTING LETHAL WIRE ASSEMBLIES

Out of a large number of suggestions, three main ideas emerged. Two of these methods were advocated by the Boom Defence Section of the Royal Navy and the third was a product of B.D.E. Cardington.

The two Naval Schemes were as follows:-

(i) The Curtain Scheme. This consisted of attaching between the cables of two adjacent balloons, a wire from which was suspended a number of 1,000 ft. assemblies of 15 S.W.G. each complete with parachutes. These assemblies were controlled at the foot by a second wire also attached between the cables of the two balloons. Considerable trial was made in this scheme, but operational and handling difficulties were very great. Ground obstacles between the two balloons employed for the lifting of the curtain seriously interfered with the raising and lowering and in fact on the great majority of the sites in the area made it quite impossible of operation apart from the operational time factor and the large number of personnel required to handle each curtain.

(ii) The Admiralty Whisker. This consisted of a series of 500 ft. 15 S.W.G. assemblies with parachutes being attached by clips to the flying cable at intervals of 250 ft. The lower ends of these assemblies flew loose. Again operational and handling difficulties were great with this Scheme. In calm weather with no wind, the "Whisker" assembly hung straight down and became twisted around the flying cable. This gave no extra Impact Chance and caused much trouble to disentangle when lowering. The 500 ft. assemblies were not reeled up but allowed to coil down loose. Kinks and entanglements caused a very high percentage of assemblies to be rendered unserviceable on each operation. The operational time taken in raising and lowering a set of "Whiskers" was under the best conditions barely unacceptable and under bad weather conditions the scheme was operationally impracticable. One or two impacts with "Whiskers" were however obtained and one crash substantiated.

100 Sites were set aside for the trial and development of these two Schemes and work was continued until the final deflation of the barrage, but it cannot be said that either scheme ever showed any promise of developing into a practical operational proposition. Statistics of results and experience gained are presumably held by the Admiralty.

(iii) The B.D.E. Suspended Lightwire Lethal Assemblies. The "Crossbow" Scientific Sub-Committee decided to hand the responsibility for development, production and even putting into operation on "Diver" Sites of their suspended light wire schemes in toto to B.D.E. Cardington. This was agreed to by the Ops. Branch, Headquarters, Balloon Command.

Basically, the B.D.E. Scheme consisted of suspending either directly from the balloon or by means of attachments from the balloon flying cable one or more assemblies consisting of 2,500 ft. of KB1A or 15 S.W.G. furnished at each end with weak links of 5 cwt/S.W.R. in parallel with which a paracan containing the appropriate size of parachute was attached.

In order to ensure that each suspended assembly would give an extra impact chance, it was necessary to suspend each assembly at a distance from the main cable, or any other assembly of at least the wing span of the Flying Bomb viz. 16 ft.

In practice, it was found that an L.Z. Balloon of normal weight, purity and gas content would lift one KB1A or two 15 S.W.G. assemblies to a height of 3,500 to 4,000 ft. This height was considered to be the minimum operational height acceptable.

14. Development and Installation of B.D.E. Suspended Light Wire Schemes

The responsibility for the development and operational installation of Light Wire assemblies was given to B.D.E. who were given complete powers to operate and experiment on all sites of F. Flight, 958 Squadron.

B.D.E. established a Field Experimental Headquarters at F. Flight Headquarters, 958 Squadron, Riverhead. The production of Light Wire cable assemblies to designs worked out by B.D.E. and given a first trial at the Experimental Field Headquarters, was carried on at B.D.E. Cardington where special reeving machinery and assembly lines were installed. Any Scheme or modification thought worth while after such trials, was produced by B.D.E. at Cardington and distributed to sites through the Field Headquarters at Riverhead.

The Superintendent, B.D.E., requested the loan of a number of Training Officers and N.C.O's who were required to demonstrate the use and handling of the Light Wire assemblies to crews. The method adopted was that as the equipment was received from Cardington at B.D.E. Field H.Q. Riverhead, the training staff, having assisted with the assembly of the various components, took a set of equipment to each site supervised the installation and gave the crew instruction on the method of handling and maintenance of this equipment. This involved a great amount of work, as eventually 1,450 Sites were equipped with single KB1A assemblies and 200 Sites with 15 S.W.G. twin assemblies.

The main concern of the "Crossbow" Scientific Sub-Committee was to ensure that the maximum number of light wire assemblies were flown and it was, therefore, necessary to proceed without delay with the installation and equipping of as many sites with some form of extra lethal assembly, although experiments to improve the Scheme were by no means completed. In fact experiments involving modifications and improvements continued throughout the whole period of the Anti-Diver barrage operational existence. Each development and improvement was embodied as it was produced. This, of course, led to considerable confusion and difficulty as far as both the production of assemblies, their installation on sites and the training of crews in the manipulation of the assemblies. In fact, it became very difficult to keep pace with the Experimental Branch of B.D.E. in respect of modifications and alterations. This aspect of the problem was, however, inevitable. When development and experimentation have to go hand in hand with the actual operation of a new device, a certain amount of confusion and even exasperation is unavoidable. The problem was a new one and it was vital that each development should be given a chance to prove its efficacy as an Anti-Diver device.

The development of Light Wire assemblies proceeded mainly on two schemes:-

(a) Single Suspended KB1A Scheme.

(b) Twin 15 S.W.G. Scheme.

15. SINGLE SUSPENDED K.B.1A. SCHEME

The simplest method of suspending a single assembly and ensuring a distance of at least 16 ft. between the assembly and the flying cable at all times, was to attach this to the balloon itself at a convenient point astern of the point of attachment. It was found convenient and satisfactory to attach this to a shackle on a No.4 line bight slung between the two stern ballast bag strops by means of a safety hook.

The complete assembly was wound on a drum. Some form of frame and control for the Light Wire Assembly Drum had to be obtained. Army Signals barrows, used for laying field telephone wires, which were in good supply, consisting of a detachable wooden drum controlled by a hand brake and hand winding crank, were found to be suitable for the purpose and a large number were obtained.

The upper end of the cable assembly having been attached to the balloon in the manner described above, the winch was paid out, whilst an operator controlled the speed of pay out of the Light Wire assembly by means of the brake on the barrow. The end of the assembly consisting of a 50 ft. F.S.W.R. strop below the lower parachute was secured to the flying cable by means of a triangular "Bolas" cable grip, after which the Balloon was paid out to operational height. The amount of "spread" or "Bight" on the Light Wire assembly could be adjusted by the brake on the barrow and required to be carefully controlled, in order to avoid fouling local Site obstacles, such as telephone or overhead Electric Power Wires, etc.

Likewise, when hauling down, a drum strop which remained attached to the barrow drum was connected to the end of the Light Wire assembly and as the balloon was hauled in, the Light Wire assembly was wound in manually. Skill was required to co-ordinate the speed of pay out or haul-in of the Light Wire assembly and the balloon. In high wind conditions, the tension on the Light Wire assembly due to wind drag was very considerable and manual hauling a heavy job.

It is to the great credit of the men concerned that upwards of 1,400 sites operated Single Light Wire assemblies in this manner with very few accidents during the latter period of the "Diver" barrage's existence.

This system was by no means ideal and is capable of further improvement, but it was operated and successful results were obtained.

The number of impacts obtained on Suspended K.B.1A. assemblies was 47 and the number of confirmed and credited crashes 38.

In fact, from the statistics, it appears that suspended assemblies of KB1A possess at least equal lethality to the main balloon flying cable armed with DP/R and D.P.L. when subject to the tension imposed by the balloon.

16. Twin 15 S.W.G. Assemblies

The problem of suspending and operating more than one assembly presents considerably greater difficulty than the single suspended assembly, for the following reasons:-

(a) A "spread" of at least 16 ft. (i.e. the wing span of the flying bomb) must be obtained at the point of suspension, between the two or more light wire assemblies and the main flying cable, in order to ensure the full benefit of the "extra" impact chances.

(b) The synchronisation of paying out and hauling in a single assembly with the speed of pay out or haul in of the balloon by the main winch was sufficiently difficult with the manually operated barrow; with a twin scheme it was virtually impossible to synchronise the control of the cable assemblies and the balloon. Unless some mechanical form of hauling could be introduced, which would deal with both assemblies at a speed regulated to that of the main flying cable, the system was operationally impossible.

(c) The man power for manual manipulation of more than one barrow was not available.

(d) The single scheme with the assembly attached to the balloon was liable to serious handling difficulties when the balloon was close to the ground in gusty weather conditions. The twin scheme with two assemblies attached to the balloon doubled this disadvantage.

(e) The tendency of the balloon to rotate in calm weather when paying out or hauling in and so twisting the light wire around the main cable, could in some measure be checked when operating the Single Wire Scheme, by moving the mobile barrow around the Central Anchorage to conform to the movement of the balloon. With a twin assembly, this twisting was infinitely more difficult to avoid. A Light Wire assembly twisted around the flying cable was for obvious reasons worse than useless and might just as well not be flown at all.

To overcome these difficulties took some time and much hard experimental work under difficult conditions. The Training Branch at Headquarters, Balloon Command gave valuable assistance to B.D.E. in the development work required to arrive at a method of flying a twin suspended assembly which could be considered to be capable of operation.

17. The final Scheme as developed, is described at Appendix II.

Briefly the problem was solved by -

(a) Using the main flying cable to drive the drum barrow both when hauling down and paying out. This was done by passing the flying cable over a driving pulley secured to the axle shaft of the drum. The barrow was fixed in position on adjustable legs immediately behind the winch. The amount of "drive" given to the pulley on the drum could be controlled by a lever which operated a jockey pulley running on the top of the flying cable. The same lever also controlled, when operated in the opposite direction, a band brake bearing on a channel on the surface of the drum. By operating this lever, the barrow operator could very simply control the speed of hauling in or paying out and so synchronise accurately with the speed of the balloon. The amount of "bight" on the suspended assemblies in this manner was capable of being satisfactorily controlled.

(b) By increasing the diameter of the barrow drum to 20 inches, it was both possible to wind a twin assembly on to the one drum and also ensure that the necessary amount of "overdrive" was provided. Overdrive was obtained by designing the diameter of the barrow drum and the driving pulley operating this drum in such a manner that the speed of wind on the barrow drum was slightly greater than the haul in speed of the winch. As the flying cable itself drove the barrow drum, this difference in speed of wind between the light wire assembly and the flying cable remained constant, whatever the hauling speed of the winch.

Conversely, when paying out the difference in speed of pay out of the Light Wire assembly and the flying cable still remained a constant factor.

By this means, when hauling in, the Light Wire assemblies tended to be wound on at a greater rate than the flying cable - this ensuring that the "bight" on the Light Wire assemblies was maintained at a minimum. This was highly desirable in order to avoid slack reeving on the drum. Likewise, when paying out, the Light Wire assemblies tended to pay out at a greater speed than the flying cable, thus producing a "bight" which was desirable in order to give the necessary spread.

When hauling in, if on account of the over-drive, the tension on the light wire assemblies became too great, the flying cable slipped in the groove of the barrow drum driving pulley and so allowed this tension to relax.

It was important to ensure that the flying cable would slip on the driving pulley groove before the tension became too great in the light wire assemblies, as otherwise the weak links were in danger of being fractured. This was adjusted by raising or lowering the barrow on its adjustable legs.

When paying out the amount of bight could be simply controlled by means of the hand brake. Likewise when hauling in the brake could be used to control the tension on light wire assembly caused by overdrive; but in this case it was desirable to ensure a correct adjustment of the barrow for "slip" on the driving pulley so that the operator had his hands free for reeving.

(c) Suspending the light wire cable assemblies from either end of a trapeze boom which in turn was suspended from a "Bolas" grip fitted to the flying cable at approximately 206 ft. below the balloon. The suspension between the bolas grip and the trapeze boom consisted of a suitable length of wire which bifurcated to support the two ends of the boom. Any tendency for the balloon to revolve in most cases resulted in the twists being taken on this boom suspension wire and not on the light wire assemblies themselves.

By attaching the assemblies at a point 200 ft. below the balloon the whole system could be removed before turbulent ground wind currents caused the balloon to plunge and yaw.

By providing a compensatory pulley at the point of bifurcation of the trapeze suspension over which the wire supporting either end of the trapeze could run, any difference in tension between the two light wire assemblies could be taken up and automatically adjusted.

(d) Providing a pair of bellmouth fairleads positioned one on either side of the central anchorage and slightly nearer the winch.

When flying, the lower ends of the two light wire assemblies were in turn secured to bracket grips attached to the flying cable. In order to ensure "spread" and prevent the light assemblies twisting around each other, it was necessary to introduce an extra strop 40 ft. in length below the lower parachute can on one of the assemblies. The assembly having this extra strop was always attached to the lower of the two bolas clips.

When hauling down and paying out the assemblies were each led through one of the fiarleads on to the bed and thence to a drum strop on the barrow drum. These fair-leads ensured that the barrow could at all times remain in its fixed position behind the winch which was, of course, essential if the mechanical driving power was to be obtained from the balloon flying cable.

It will be seen that the arrangement described above answered all the requirements and enabled the twin wire assembly scheme to be operated by a normal Diver Crew of 3 men with reasonable operational efficiency.

18. Towards the end of the active "Diver" period B.D.E. made some experiments with triple 15 S.W.G. assemblies. These assemblies had to be somewhat shortened if the required operational height was to be reached. It was, however, proved that the manipulation of 3 such assemblies by means of mechanical hauling on to one drum as described for the twin assembly scheme, was not an operational impossibility, and in fact, offered distinctly promising possibilities. The cessation of the Flying Bomb attacks prevented the operational development of the Triple Suspension Scheme from being completed, although experimental trials were continued by B.D.E. at Cardington.

19. NICOPRESS

No record of the light wire auto-dive schemes would be complete without reference to the "Nicopress" method of swaging wire eyes.

For some years the American Balloon Barrage had employed "Nicopress" ferrules for producing eyes in wire in preference to the laborious method of splicing in the case of flexible wire, or soldering in the case of solid drawn or piano wire, which were employed in the British barrages.

The priority attached to the Diver Barrage enabled B.D.E. to obtain a sufficient supply of nicoprers ferrules and swaging tools. It will be appreciated that the number of wire eyes required in the manufacture of some thousands of light wire assemblies was astronomic. The old splicing and soldering methods were hopelessly slow and would have been entirely unable to cope with the demand. "Nicopress" provided the answer and it is safe to say that had this method of making wire eyes not been available the light wire assemblies which accounted for a number of the Flying Bombs could not have been operated on the scale called for.

20. Details of impacts on 15 S.W.G. Scheme are somewhat confused on account of the single and twin schemes, both being employed in the Anti-Diver Barrage, but the following figures can be taken as an approximation of the results obtained:-

Total impacts on 15 S.W.G. Scheme 40
Total confirmed and credited crashes 23.

APPENDIX "K"

The following remarks were made by the Balloon Command Armament Officer when summarising the analysis of results obtained for the first 300 impacts between Flying Bombs and Balloon Cables.

> "15 S.W.G. Auxiliary Parachute armed wires have not provided sufficient experience upon which to base any reasonable conclusions, but examination of detailed incidents indicate that even when the apparatus functions correctly, the Flying Bomb tends to proceed for long distances before crashing, and in consequence, it can probably be most effectively employed on the Southern Perimeter of the Barrage."

21. Crashes caused by impacting KB1A Scheme assemblies, on the average occurred much nearer to the point of impact, than was the case with the 15 S.W.G. Scheme, and results in this case followed very closely the calculations made by R.A.E. Farnborough referred to in Para. 7.

APPENDIX "K"

FLYING BOMBS CLAIMED AS DESTROYED BY ANTI-DIVER BARRAGE

Results obtained from flying from 480 Balloons to 1,000 Balloons

	Flying Bombs			Percentage of Collisions claimed as Destroyed	Final assessment of claims (A.W.A.S.)
	Through Barrage When Balloons Operational	Collisions	Claims		
June 17/23	406?	39	31	79%	2
24		2	1	50%	1
25		4	4	100%	4
26		-	-	-	-
27		-	-	-	-
28		-	-	-	-
29		3	1	33.3%	1
30		5	4	80%	1
July 1		21	15½	74%	12
	406	74	56½	76.3%	21

Results obtained from flying from 1,000 Balloons to 1,750 Balloons
plus 265 Mark VI Balloons

July 2	35	10	5	50%	9
3	73	1	1	100%	4
4	29	7	5	71.4%	3
5	70	5	1	20%	1½
6	22	6	1	16.6%	1
7	45	2	-	-	-
8	26	1	1	100%	-
9	27	2	2	100%	1
10	19	2	2	100%	3
11	36	6	6	100%	6
12	45	8	6½	81.2%	6
13	17	1	1	100%	1
14	12	1	1	100%	-
15	27	5	4½	90%	1
16	27	4	1	25%	3
17	17	6	3	50%	4
18	32	10	6	60%	3
19	33	4	3	75%	5
20	45	8	4	50%	1
21	62	14	13	92.8%	17
22	40	8	8	100%	2
23	19	4	2	50%	6½
24	17	5	3	60%	2
25	11	4	3	75%	2
26	11	6	5	83.3%	5
27	37	5	3	60%	2
28	42	6	5	83.3%	2
29	23	1	1	100%	4
30	24	4	3	75%	1
31	16	3	2	66.6%	4
	939	149	102	68.4%	100

APPENDIX "K"

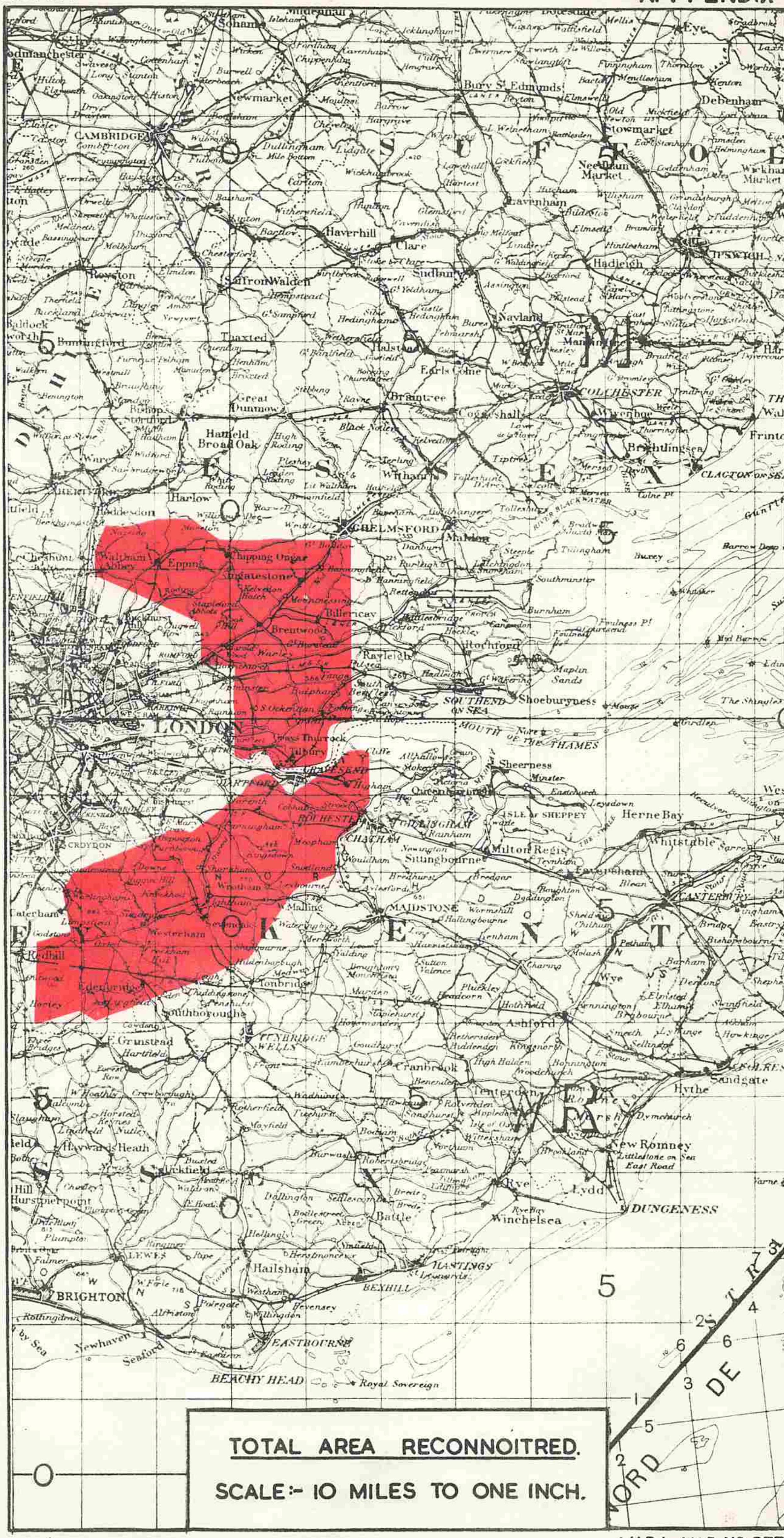
Results obtained from flying 1,750 Balloons

	Flying Bombs				
	Through Barrage When Balloons Operational	Collisions	Claims	Percentage Collisions claimed as Destroyed	Final assessment of claims (A.W.A.S.)
August 1	34	9	5	55.5%	3
2	95	8	5	62.5%	7
3	58	31	26	83.8%	24½
4	39	10	6	60%	6
5	26	7	4	57.1%	3
6	33	19	14½	76.3%	14½
7	20	4	2	50%	2
8	21	7	4	57.1%	3
9	7	2	2	100%	2
10	13	5	2	40%	1
11	7	2	-	-	-
12	22	10	8	80%	6½
13	16	6	2	33.3%	2
14	12	6	4	66.6%	3
15	21	4	3	75%	3
16	28	8	6	75%	6
17	15	2	2	100%	1½
18	1	1	-	-	-
19	7	4	4	100%	4
20	7	-	-	-	-
21	37	14	9	64.3%	9
22	27	7	3	42.9%	2
23	10	7	1	14.3%	1
24	-	-	-	-	-
25	-	-	-	-	-
26	-	-	-	-	-
27	8	1	1	100%	1
28	7	2	2	100%	2
29	28	5	4	80%	4
30	3	3	1	33.3%	1
31	-	-	-	-	-
	602	184	120½	65.5%	112

Results obtained from flying an average of 1,354 Balloons Daily for 81 days

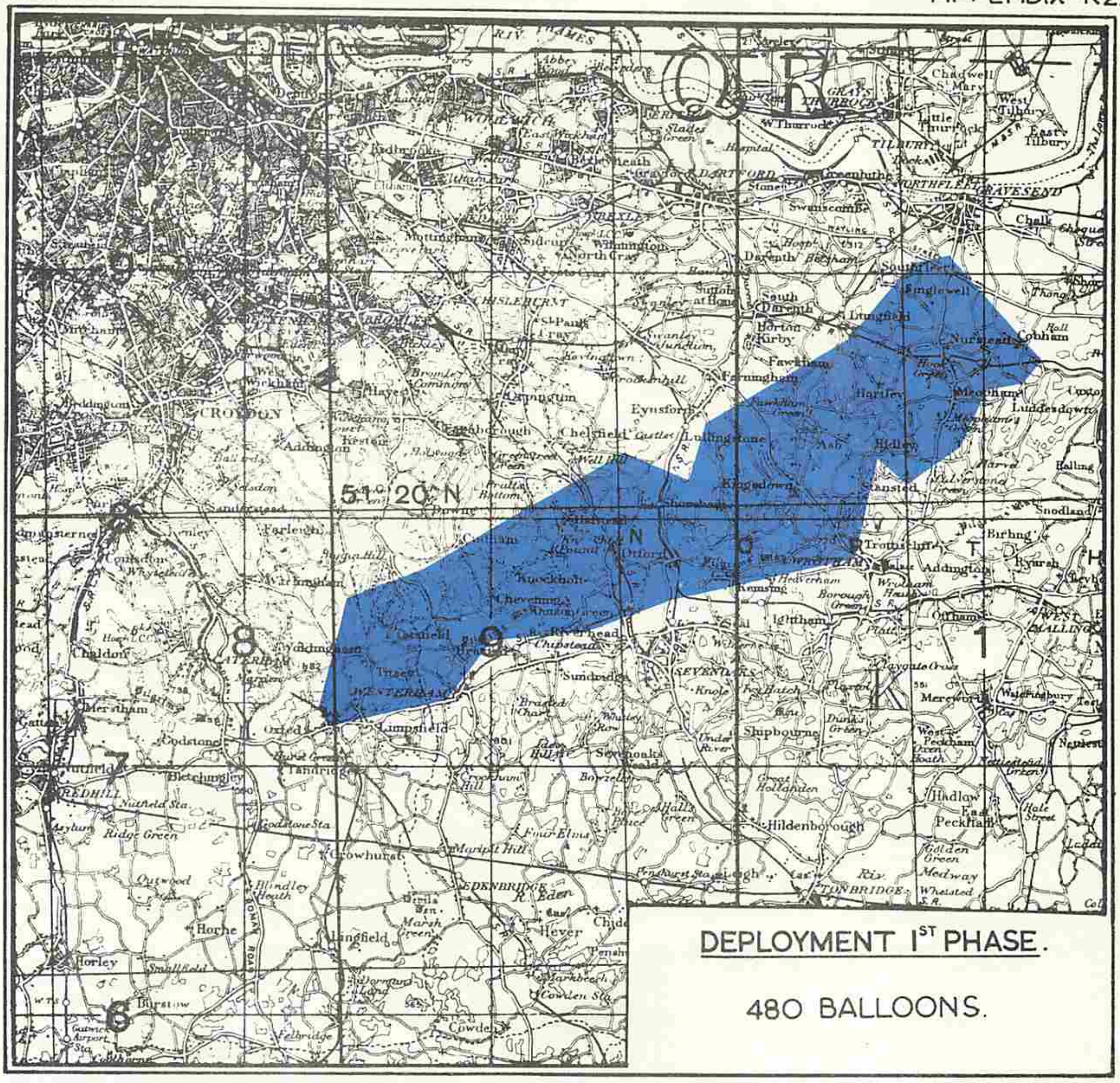
June 17/30	406	74	56½	76.3%	21
July	939	149	102	68.4%	100
August	602	184	120½	65.5%	112
Sept. 1/6	-	-	-	-	-
	1,947	417	279	64.5%	233

<u>NOTE</u>. It will be noted that, apart from the first two weeks of the anti-Diver Barrage, the claims made for flying bombs destroyed varied little from the final assessment. It was from the "Claimed Destroyed" totals that the value of the balloon barrage was estimated at the time. The final assessment of flying bombs destroyed is for comparison only.



TOTAL AREA RECONNOITRED.

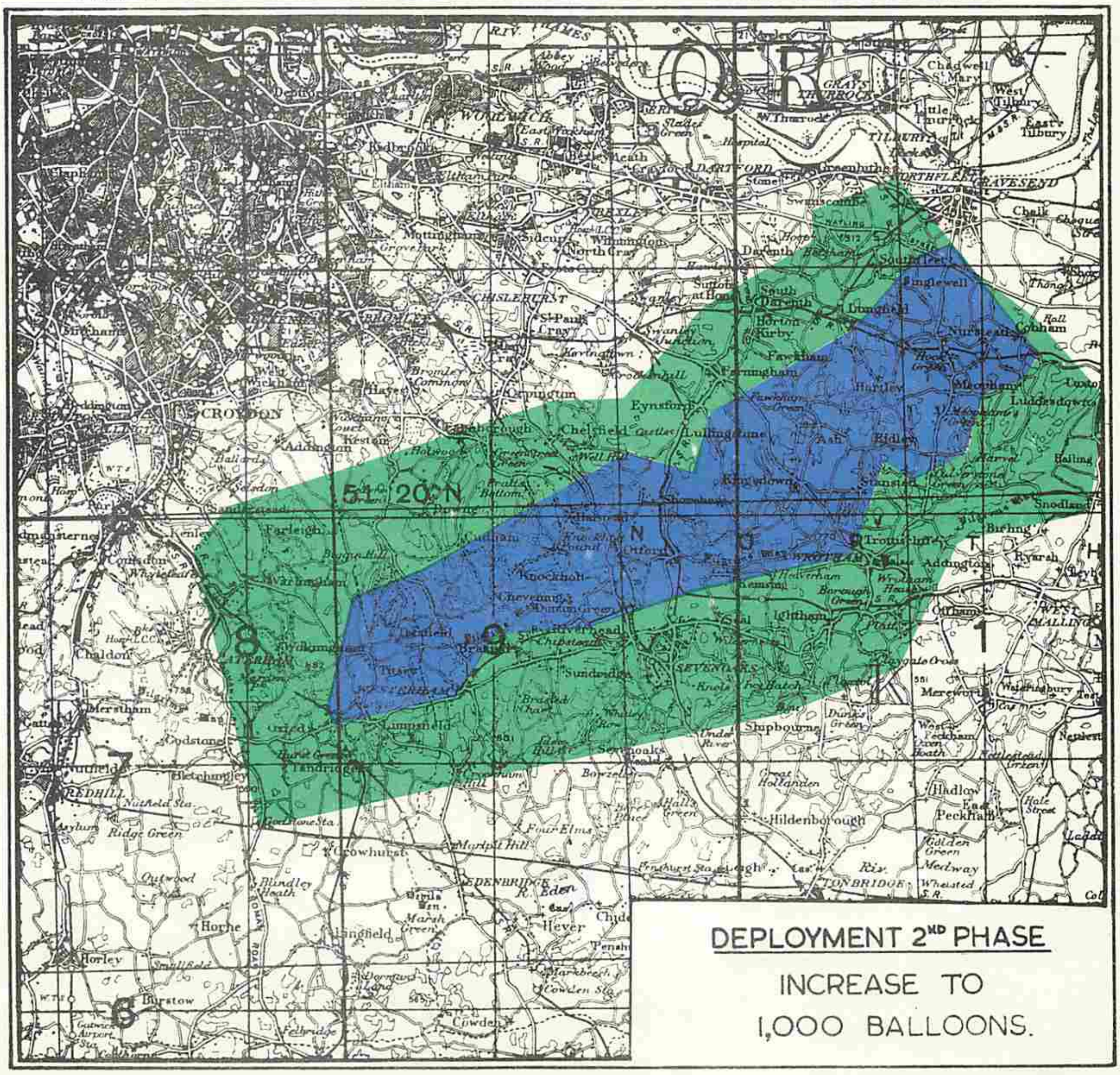
SCALE:- 10 MILES TO ONE INCH.



DEPLOYMENT 1ST PHASE.

480 BALLOONS.

SCALE. 5 4 3 2 1 0 5 10 15 MLS.



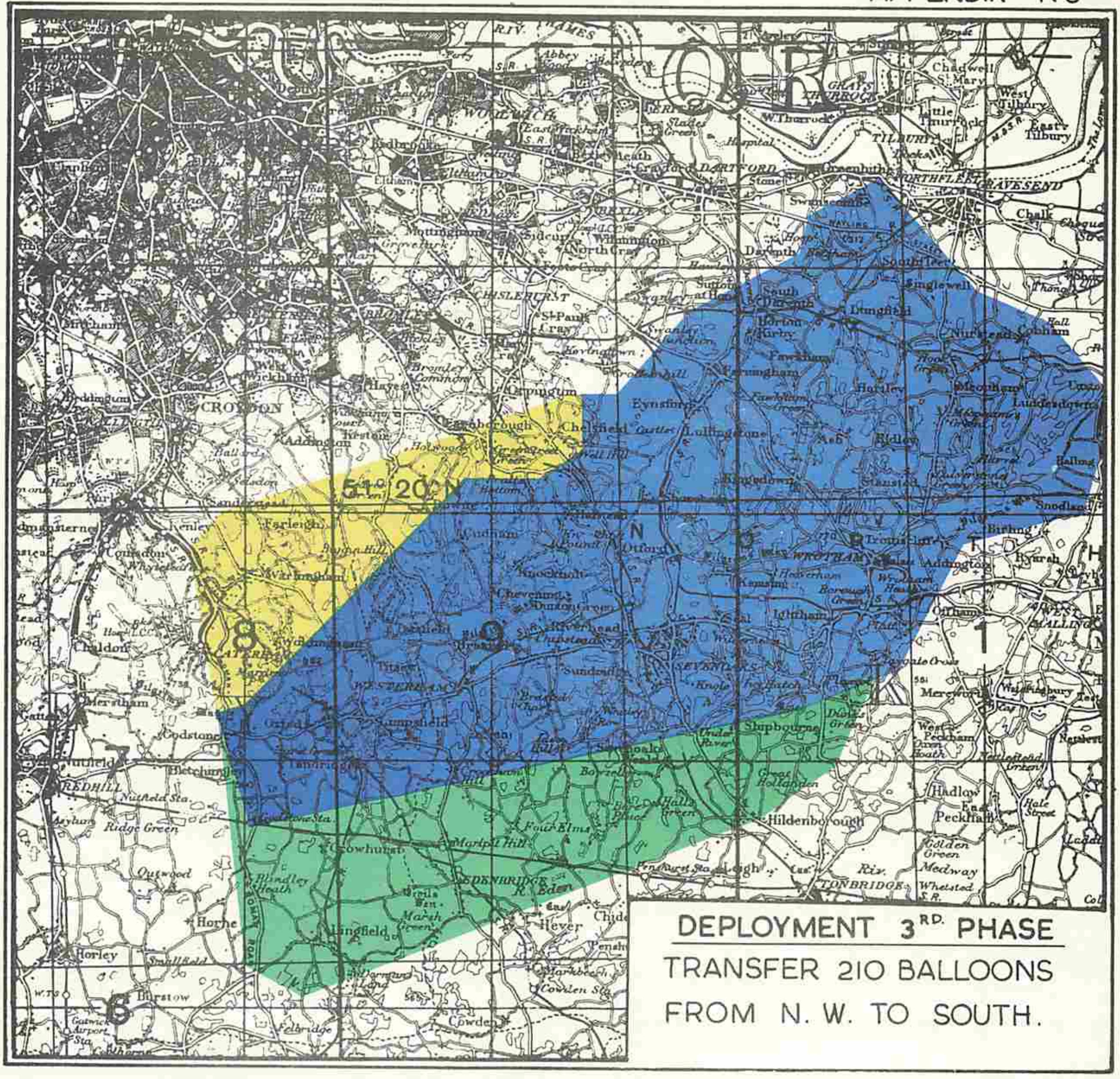
DEPLOYMENT 2ND PHASE

INCREASE TO

1,000 BALLOONS.

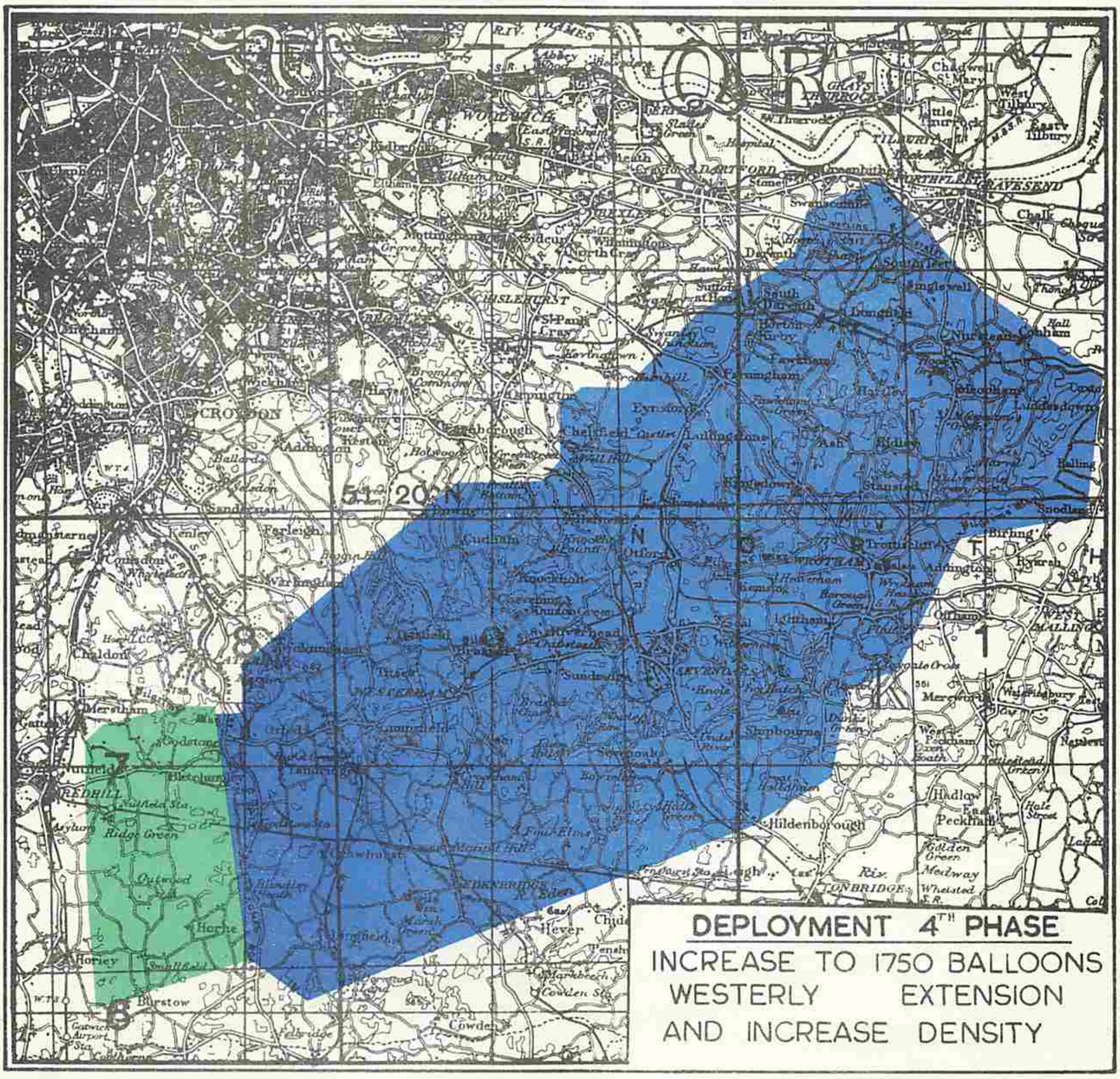
SECRET

APPENDIX K 3



DEPLOYMENT 3RD. PHASE
TRANSFER 210 BALLOONS FROM N. W. TO SOUTH.

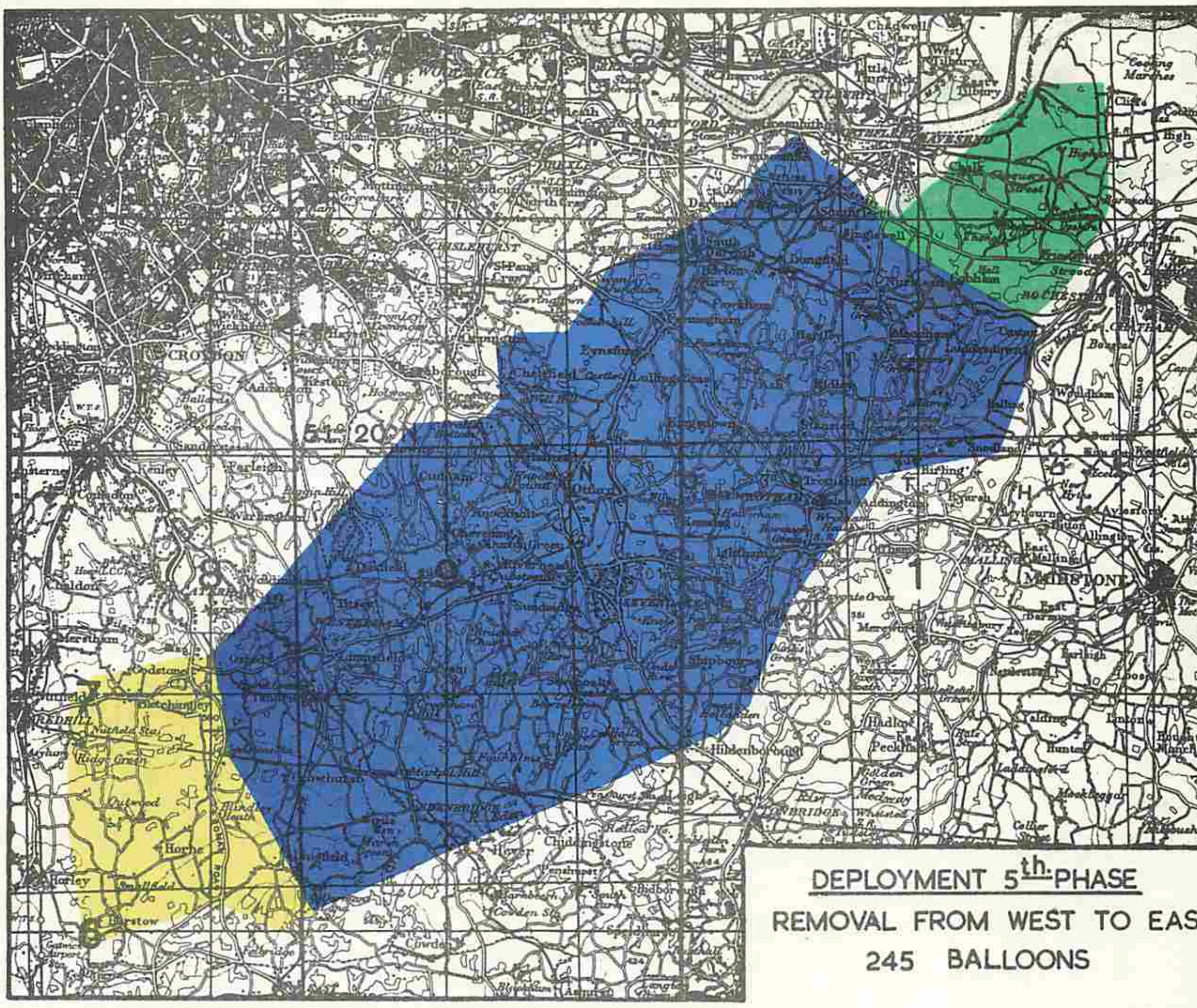
SCALE 5 4 3 2 1 0 5 10 15 MLS.



DEPLOYMENT 4TH PHASE
INCREASE TO 1750 BALLOONS WESTERLY EXTENSION AND INCREASE DENSITY

A.H.B.1. MAP. Nº 385.

APPEND. 'K.4'.

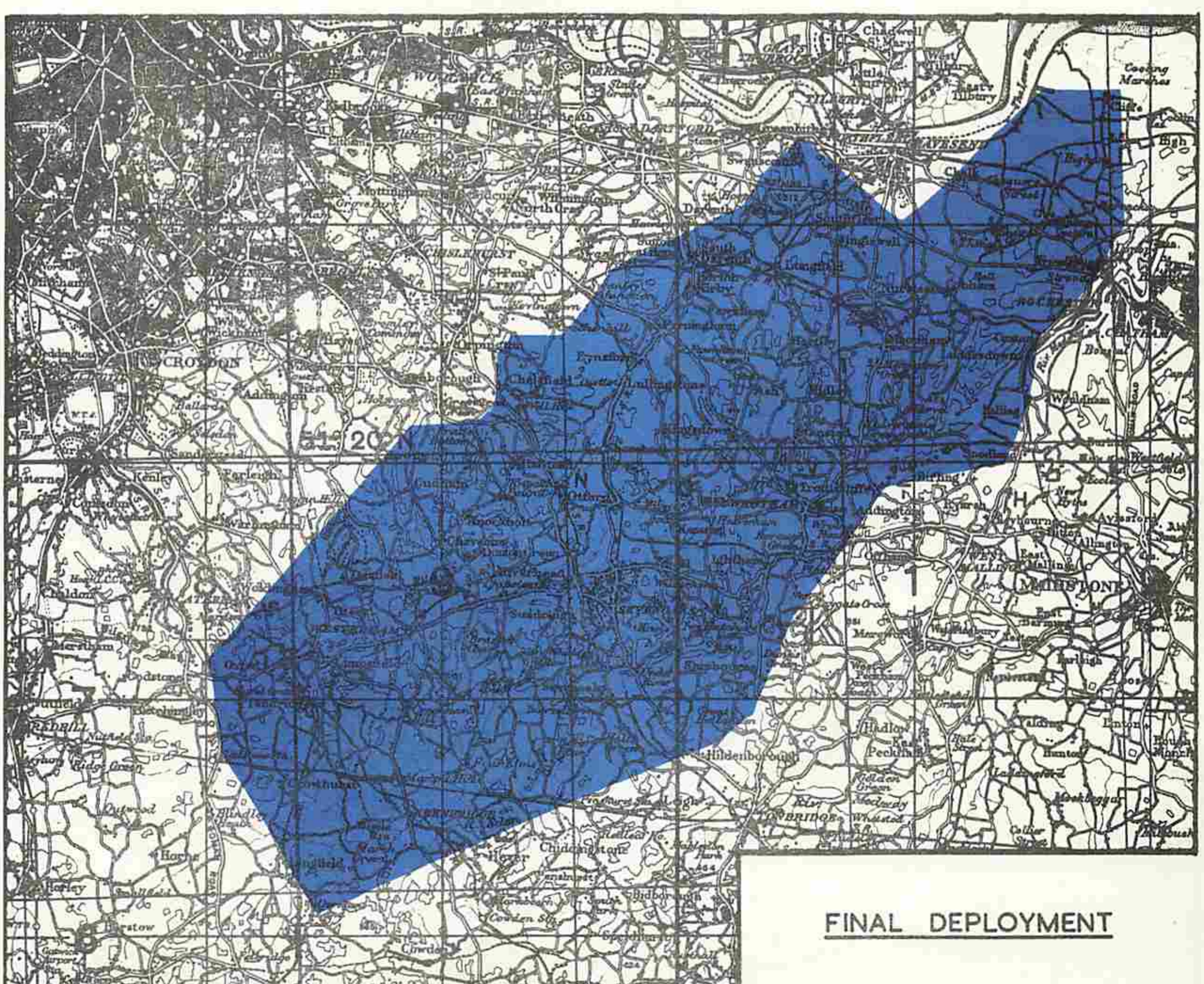


DEPLOYMENT 5th. PHASE

REMOVAL FROM WEST TO EAST.

245 BALLOONS

Scale 5 4 3 2 1 0 5 10 15 Miles.



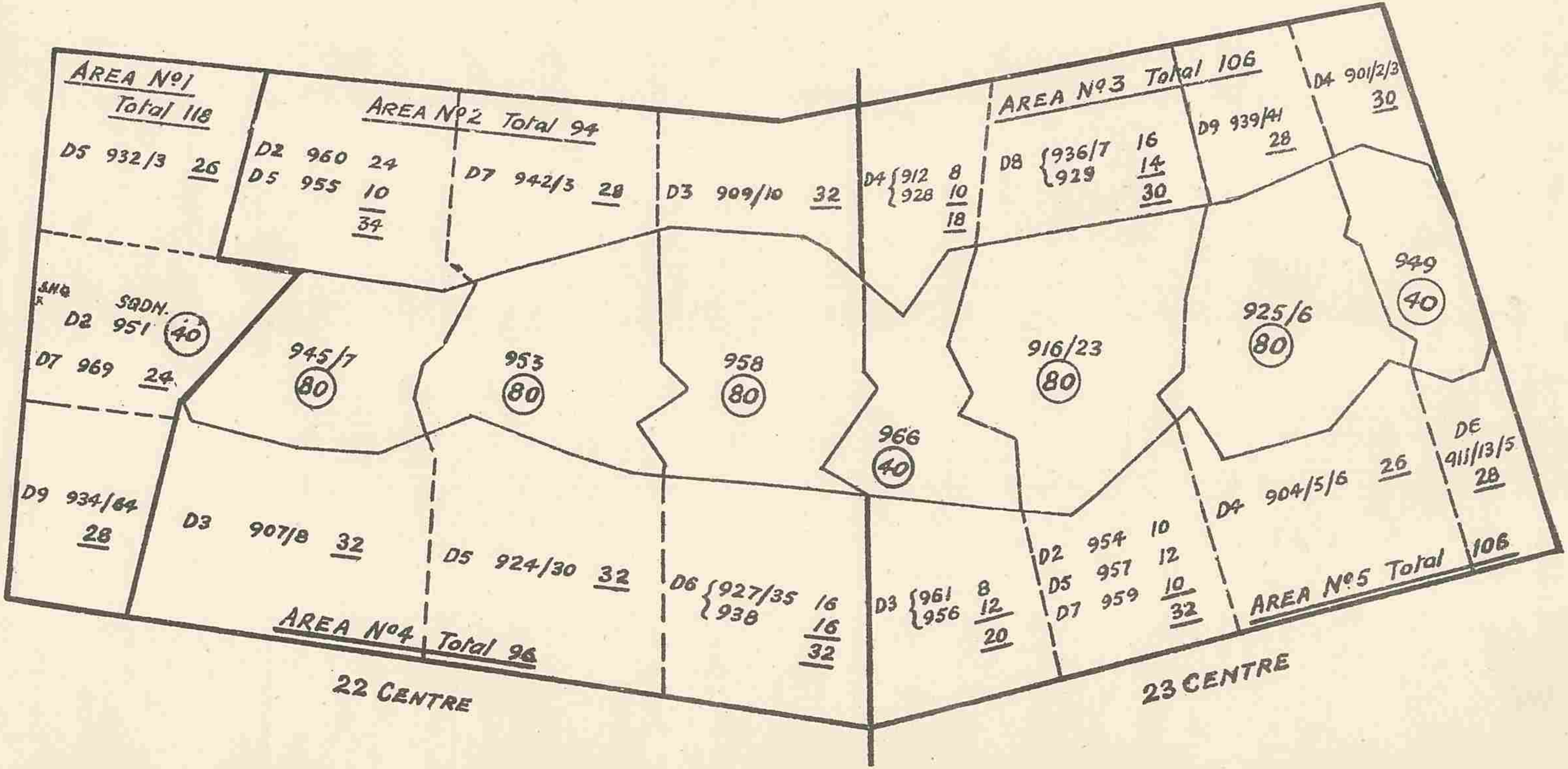
FINAL DEPLOYMENT

A.H.B.I. MAP No. 387.

SECRET

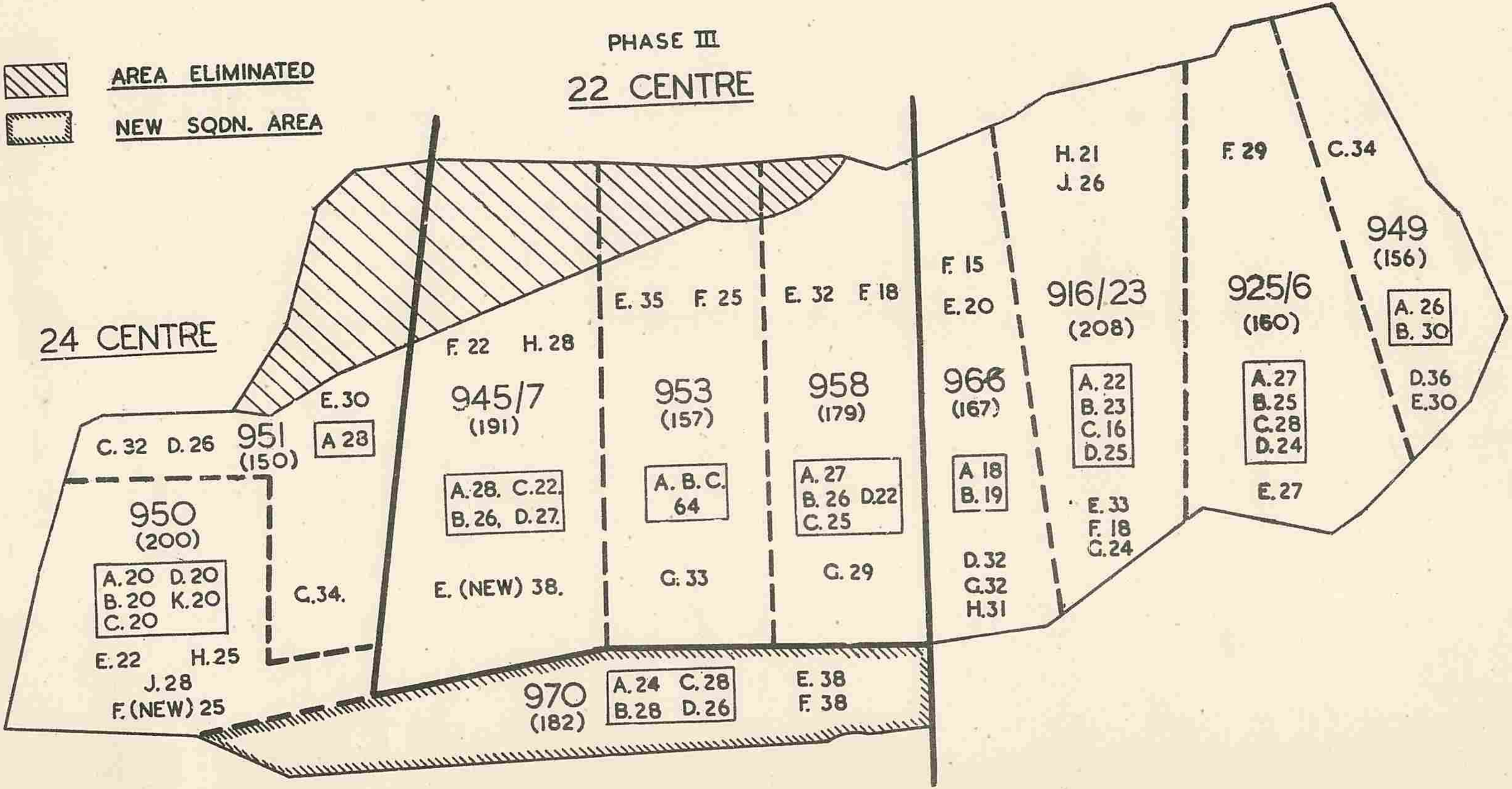
PHASE I & II

SCHEDULE OF DEPLOYMENT



APPENDIX K5.

AHB 1 DIA. 160.

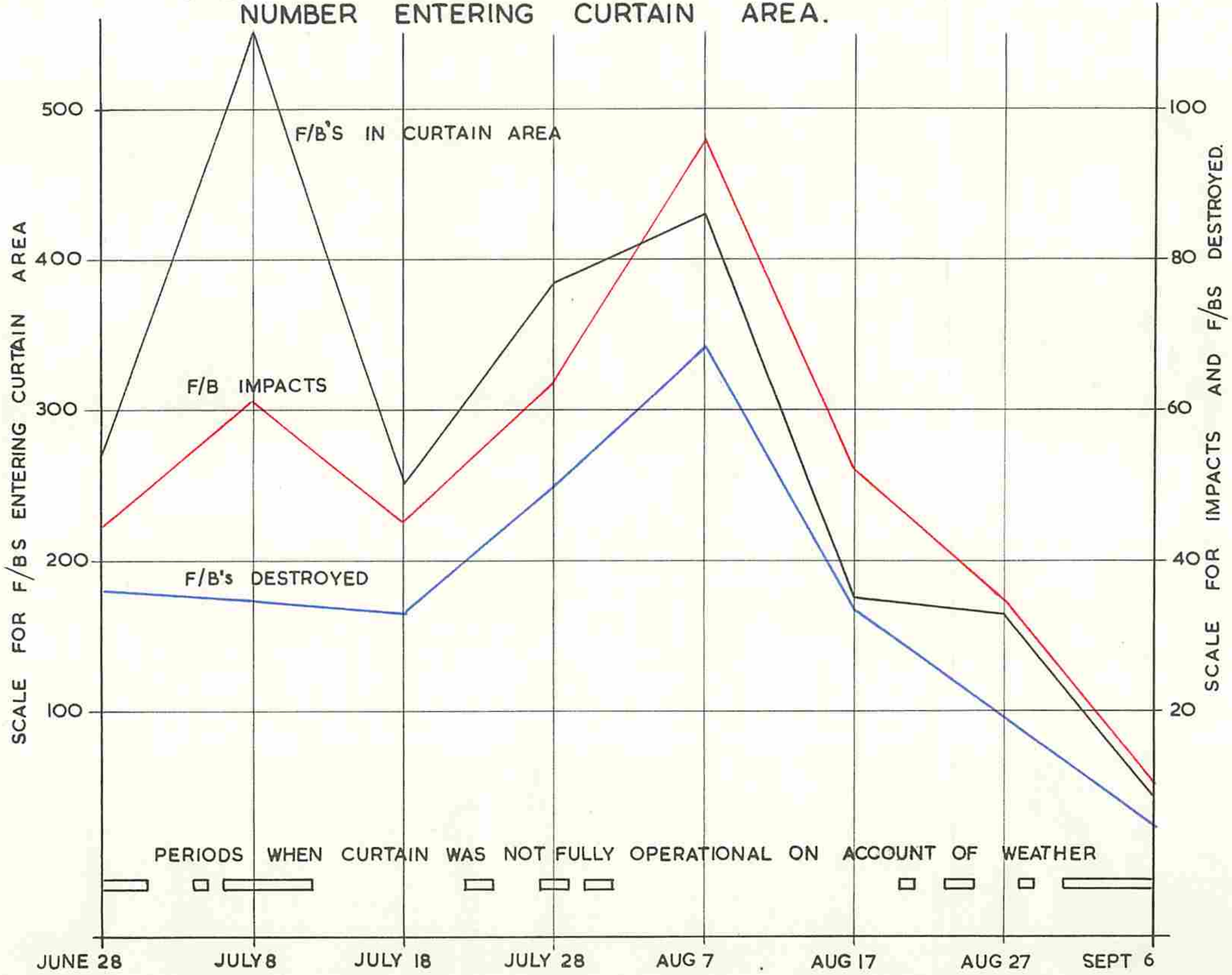


AREA ELIMINATED
NEW SQDN. AREA
PHASE III
22 CENTRE
24 CENTRE
951
(150)
C. 32 D. 26
E. 30
A 28
950
(200)
A. 20 D. 20
B. 20 K. 20
C. 20
E. 22 H. 25
J. 28
F. (NEW) 25
C. 34.
945/7
(191)
F. 22 H. 28
A. 28. C. 22.
B. 26, D. 27.
E. (NEW) 38.
953
(157)
E. 35 F. 25
A. B. C.
64
G. 33
958
(179)
E. 32 F. 18
A. 27
B. 26 D. 22
C. 25
G. 29
970
(182)
A. 24 C. 28
B. 28 D. 26
E. 38
F. 38
966
(167)
F. 15
E. 20
A 18
B. 19
D. 32
G. 32
H. 31
916/23
(208)
H. 21
J. 26
A. 22
B. 23
C. 16
D. 25
E. 33
F. 18
G. 24
925/6
(160)
F. 29
A. 27
B. 25
C. 28
D. 24
E. 27
949
(156)
C. 34
A. 26
B. 30
D. 36
E. 30

APPENDIX. K6.

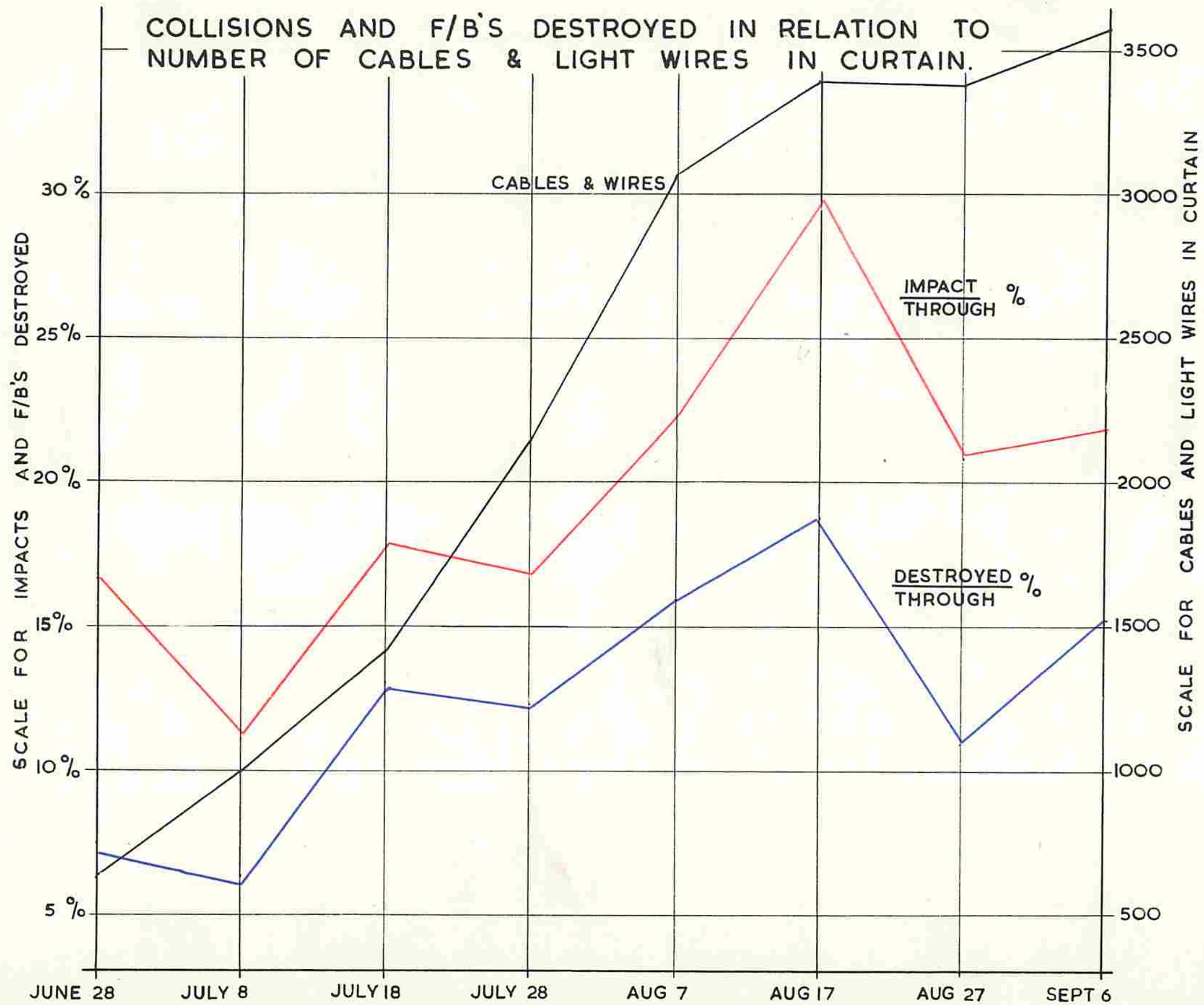
SECRET

COLLISIONS AND F/B'S DESTROYED IN RELATION TO NUMBER ENTERING CURTAIN AREA.



APPENDIX K7.

A.H.B.1. DIA. No.158.


COLLISIONS AND F/B'S DESTROYED IN RELATION TO NUMBER OF CABLES & LIGHT WIRES IN CURTAIN.
CABLES & WIRES
IMPACT / THROUGH %
DESTROYED / THROUGH %
SCALE FOR IMPACTS AND F/B'S DESTROYED
SCALE FOR CABLES AND LIGHT WIRES IN CURTAIN
30 %
25 %
20 %
15 %
10 %
5 %
3500
3000
2500
2000
1500
1000
500
JUNE 28
JULY 8
JULY 18
JULY 28
AUG 7
AUG 17
AUG 27
SEPT 6

APPENDIX K8.

SECRET

APPENDIX "L"

CENTRAL ELECTRICITY BOARD

Notes on the Construction of the Board's Overhead Lines and the effects thereon of the Balloon Barrage

The following describes briefly the salient features of the Board's main and secondary overhead transmission lines and reviews the effects of damage to these lines resulting from the operation of the balloon barrage during the war.

(1) Constructional Details

The Board's overhead lines are normally of single or double circuit construction and are carried on steel latticework towers, the single circuit comprising three conductors and an earthwire, and the double circuit six conductors and an earthwire common to both circuits. The earthwire carries no current and is strung above the conductors, being clamped at each tower at or near its apex.

The normal operating voltage of the primary lines is 132,000 between any two conductors and 76,000 between any one conductor and earth. The secondary lines operate for the most part at 33,000 volts between conductors (19,000 volts between conductors and earth) but other voltages ranging from 66,000 to 6,600 are also in use.

The construction of the primary lines is fairly closely standardised and the technical details of the normal construction are shown in the second column of Table I below. More varied types of construction are adopted for the secondary lines, concrete and wooden poles being used in addition to steel towers, but the predominating type is the 33,000 volt line on steel towers, and particulars of this construction are shown in the third column of Table I. It should be noted that the height of tower and length of span is liable to considerable variation to meet local conditions, contour difficulties and special crossings.

TABLE I

	Primary Lines	Secondary Lines
Normal operating voltage:-		
between any two conductors	132,000	33,000
between any conductor and earth	76,000	19,000
Type of conductor normally employed (a)	Steel-cored Aluminium	Steel-cored Aluminium
Comprising core of steel wires and outer aluminium wires	7-0.110" dia. 30-0.110" dia.	1-0.161" dia. 6-0.161" dia. (b)
Diameter of complete conductor	0.77"	0.483"
Ultimate strength of complete conductor	17,700 lbs. (8 tons)	5,870 lbs. (2.1 tons)

Notes: (a) The earthwire is normally of somewhat smaller section than the conductors, and may be of galvanised steelwire only.
(b) Larger conductors (up to the 132 kV. size) are also employed on secondary circuits.

TABLE I (Contd.)

	Primary Lines	Secondary Lines
Max. Working tension	8,000 lbs. (3.5 tons)	2,900 lbs. (1.3 tons)
Normal span length	900 feet	5-700 feet
Maximum span length employed	3,060 feet	1,830 feet
Maximum tower height employed	487 feet	362 feet
Minimum clearance to ground (Height of lowest conductor in mid-span)	22 feet	20 feet
Outline of normal type of straight-line tower		
Single circuit. Dwg. No.	1.354A and B	1,348D
Double " " "	1.352A	1.350J
Route miles of overhead lines in service at end of 1944	3,581	1,295 } various voltages

(2) Nature of Overhead Line Faults

If, by any means, metallic contact is made between any two conductors or between the conductors and the earthwire or the ground, abnormally high currents flow in the path thus provided which, if not promptly cut off, would cause serious damage to the lines and to the generators and transformers supplying them. This constitutes a "fault" on the line, and protective equipment is provided at each end of the line which detects the abnormal currents and switches out or "trips" the affected line, normally within less than a second. It is not necessary for complete metallic contact to be made as, on high voltage lines, a wire in contact with one conductor coming within, say, 18" or less of another conductor or the earthwire may allow an arc to strike over the intervening space and cause a fault.

It is readily seen that the wire cable trailing from a breakaway barrage balloon can cause a fault when it fouls the overhead line; faults may also occur when balloons flown in proximity to the line are brought down by lightning, gunfire, etc., so that the trailing cable falls across the conductors. Instances have occurred of the balloons themselves colliding with overhead lines and forcing conductors into contact, and of the various devices such as piano wires trailing from certain types of balloon fouling the lines. A few cases have occurred of balloons towed by ships fouling lines at river crossings; this is usually a serious matter, since repairs are very difficult at these crossings on account of the height of tower and length of span employed and the interference with traffic on the river when conductors have to be lowered.

(3) Damage resulting from Barrage Balloons

The damage usually resulting from the contact of a balloon cable with the line took the form of burning at the points of contact by the heavy fault currents. Such damage varied in extent from the burning through of a few strands of the aluminium to complete severance of the conductors or the earthwire. Unless severe burning took place, it was found difficult in many cases to detect the damage from ground level, unless the point of damage was known from other evidence and the conductors lowered for close inspection. Hence the damage to lines from many known balloon faults has not been discovered and it is quite possible that many faults during the war classified as "cause unknown" were actually due to balloon cables, the damage being too slight to be detected by a ground patrol.

Apart from burning, severe mechanical damage was occasionally caused by the trailing cable becoming entangled with the conductors and even, on occasion, anchoring the balloon thereto. In other cases, the cable has been dragged along the conductors, severing the aluminium wires and drawing them into a tangled bunch, or "bird-caging" them.

In the event of a conductor being severed or the earth-wire being severed and fouling the conductors, or of the trailing cable itself remaining lying across the line, the circuit was out of commission until the damage could be located and repaired. Where, however, no major damage was caused and the trailing cable was clear of the conductors, the circuit could usually be put back into service forthwith. In the latter case, it was, however, still necessary to patrol the line at the first opportunity to ensure that there were no conductors in a dangerously weakened condition.

(4) Repair of the Damage

Minor burns to the aluminium only were normally dealt with by taping with aluminium tape or inserting a joint or repair sleeve at the point of damage. Broken conductors or conductors in which the steel core itself was exposed necessitated the jointing in of a length of new conductor to replace the damaged portion. In some cases, insulators and vibration dampers would also be damaged and these would require replacement.

The time necessary for repairs varied considerably with the magnitude and ease of location of the damage and also with the accessibility of the site. A broken conductor usually entailed a loss of use of the line for at least six hours and often for as much as twenty-four hours.

(5) Other Effects of Barrage Balloon Faults

Apart from the actual damage to the lines and any loss of supplies occasioned directly or indirectly by the tripping of lines due to balloon faults, there are two further aspects in which the indirect effect of barrage balloon damage was very noticeable.

The first was the consequential damage to Grid equipment by the passage of frequent heavy currents resulting from faults, of which some 75% were attributable to balloons. Conductor joints in the overhead lines of certain types were often so damaged by the repeated passage of fault currents that they subsequently failed in service. In certain cases, major damage to transformer windings occurred which were attributed to the repeated overstressing by fault conditions. The latter was a particularly serious matter since transformers weighing up to 100 tons are in use and to remove these to the Maker's Works for repair and replace them with spares (if available) was a considerable undertaking. The additional duty on the switches (or oil circuit-breakers) also necessitated considerable increase in maintenance work on them since it is desirable to overhaul an oil circuit-breaker whenever it has had to operate to clear a fault.

The second aspect was the effect on the protective gear employed to detect and isolate faults. In normal times, faults between one conductor and earth (earth faults) predominate and faults between conductors (phase faults) or between more than one conductor and earth are relatively infrequent. Certain of the various types of protective gear used by the Board are designed to take advantage of this fact and are arranged for separate detection of earth and phase faults, with provision for making the earth fault equipment more elaborate and sensitive in action. Balloon faults, however, not only presented the protective gear with every possible type of fault, including an unusually high proportion of phase faults, but the type of fault often varied as the cable was dragged across the conductors. In these circumstances, the accuracy and speed of the protective gear were often affected with the result that in some cases, not only the faulty line, but other lines also would be unnecessarily tripped, making the effects of the fault more widespread than they should have been.

15th January, 1946
DMC/OT

APPENDIX "L"

CENTRAL ELECTRICITY BOARD

South West England Area

Damage due to Breakaway Barrage Balloons
24th/25th April, 1943

The following sets out the sequence and effects of damage to the Board's overhead lines in the South West England Area by escaped barrage balloons which occurred during a gale on the night of 24th/25th April, 1943. This particular series of incidents is described rather than others much more widespread and disasterous in result as being a case in which the source and number of breakaway balloons may be most easily ascertained and in which the whole of the incidents occurring were attributable to these balloons.

The effect on continuity of supplies was much less serious in this particular case than might have been, as the whole of the incidents took place during an Easter weekend when the demand for electricity was at a minimum. Had the incidents occurred during a normal weekday, the loss of supply would have been four or five times greater and the effects on the operation of the Grid system very much more serious.

Description of Faults

The incidents began at 22.45 hours on the 24th April, 1943, after a report had been received of breakaway balloons from the Plymouth region. At the time a southerly gale with gusts up to Strength 9 was blowing, and shortly before the breakaways were reported, air-raid warnings had been given in the Plymouth district.

The faults which occurred subsequently are tabulated in chronological order in Table O.D.2/1039 which shows the lines affected, the damage thereto and the loss of supplies resulting. It will be noted that, in all, seventeen faults occurred in a twelve-hour period and that the total estimated loss of units supplied amounted to 8,048.

It will be observed that loss of lines occurred due to maloperation of the protective equipment simultaneously with the loss of lines affected by balloon faults. This is due in part to the nature of the faults caused by the balloon cables for which the protective equipments were not primarily designed to cater, and in part due to the small amount of generating plant running at the time, which reduces the fault currents; under these circumstances, the protective gear is liable to be less accurate in operation and lines which were not actually affected by balloon cables were incorrectly disconnected.

Diagrams

The attached drawing Appendix L 1 ~~No. 10.961/1~~ shows the geographical layout of the Board's transmission lines in the South West England Area. The approximate areas which were affected by interruptions of supply during the incident are shown washed yellow on the drawing, while those of the Board's lines which actually suffered damage from balloon cables are marked in blue.

The attached diagram ~~No. 10.961/1A~~ Appendix L 2 shows the main 132 kV. connections in diagrammatic form in the condition existing prior to the incidents on the evening of 24th April, 1943. Diagrams Appendix L3-L6 show these connections at four stages during the following twelve hours. In these five diagrams, the stations generating to supply the Grid system at the time are shown in red, the other points not coloured drawing their supplies from these stations over the Grid lines shown red, being those which were "alive" and in commission at the various stages.

The lines which tripped out, or were laid dead by the tripping of other lines are shown in green, the solid colour indicating that the line in question was reclosed before the end of the period shown on the diagram; the broken colour indicates that as a result of damage or for operating reasons, the line in question was not recommissioned at the end of the period to which the diagram relates.

The number shown in ~~yellow~~ blue against a line denotes the fault number under which the tripping of the line is described in Table O.D.2/1039.

It will be noted that where the tripping of any line or lines isolates a supply point on the Grid from all running generating stations, the supply at that point is interrupted until a connection with a generating station can be restored. The points at which interruptions of supply occurred are shown green on the diagrams, and the duration of the interruption at that point is also shown in green.

It is normally the Board's practice to arrange for each point at which they give supply to have at least two alternative lines of supply over the Grid system, and the diagrams show that with a number of faults in quick succession, as many as three lines are inadequate, and interruptions follow if the faulty lines cannot be reclosed very promptly.

It will also be observed that the Grid in South West England was on this occasion broken up by the faults into several independent sections, on which the local generating plant was sufficient to cover local demands, and interruption of supply did not therefore ensue. During normal working hours, however, several of the sections would not have had sufficient generating plant available for the local demand (inflated as a result of migration of war loads to the West country) and severe restriction if not complete failure of supply would have resulted in some sections had the incidents occurred on a normal weekday.

1.1.46
DMC/NP

SECRET

CENTRAL ELECTRICITY BOARD

Table O.D.2/1039

Sheet 1

APPENDIX "L"

Sequence of Barrage Balloon Faults in South West England

24th/25th April, 1943

Fault No.	Time	Lines put out of service	Damage	Time of Reclosures	Supplies Interrupted				Notes
					At:-	Load kW	Duration Minutes	Units Lost	
48	22.45	Plymouth - Fraddon	Not located	23.08	-	-	-	-	Hayle and Fraddon isolated.
49	23.29	Exeter - Newton Abbot	Not located	04.06	-	-	-	-	Newton Abbot, Plymouth, Fraddon and Hayle isolated.
50	23.30	Exeter - Dorchester	Balloon Cable hanging on line	After repair	-	-	-	-	-
51	23.31	Exeter - Bridgwater Bridgwater - Portishead	Not located " "	23.37 23.45	Exeter Bridgwater Main (all)	2300 4740	14 m. 6 m.	536 474	Tripping of Bridgwater-Portishead suspected to be due to maloperation of protective equipment.
52	23.48	Plymouth - Newton Abbot	Slight to earth wire	23.50	Newton Abbot (Torquay)	5500	2 m.	183	-
53	23.59	Portishead - Melksham	Earth wire and top conductor severed	After repair	Wapley	1500	75 m.	1875	Supplies restored via. non C.E.B. standby connection.
54	00.03	Portishead - Lydney	At two points. At one, the earth wire and two conductors tangled together in mid-span	After repair	Lydney	5000	6 m.	500	Portishead, Bridgwater and Exeter isolated. Interruption of supplies at Lydney due to a switching instruction being misheard, and the wrong switch being closed in an attempt to reclose the line.
55	00.08	Ebbw Vale - Oxford Gloucester - Watford Ebbw Vale - Gloucester	Both lines, all conductors burned None	07.26 03.39 07.26	-	-	-	-	Owing to arrangements during construction work at Ebbw Vale, loss of the Oxford line entailed also the loss of the Gloucester line. Reclosure of these lines was delayed by a circuit breaker defect.
56	00.20	Portsmouth - Nursling	Slight	01.12	-	-	-	-	-
57	01.00	Bridgwater Local - Weston Bridgwater Main - Weston	Slight "	01.40 02.05	Bridgwater Local Weston	600 310	2 m. 40 m.	20 206	Interruption at Bridgwater Local due to maloperation of protective equipment.
58	01.21	Bridgwater - Portishead	Earth wire severed and conductors burned	01.27	Exeter Bridgwater	2300 3140	7 m. 6 m.	268 642	Portishead isolated.
59	01.40	Melksham-Andover-Nursling Portsmouth - Nursling	Not located None	01.57 01.46	Andover Winchester Salisbury Whaddon Cowes Southampton Bournemouth Dorchester (all)	500 200 230 200 2000 4400 5000 1740	5 m. 6 m. 6 m. 6 m. 1 m. 8 m. 7 m. 7 m.	42 20 23 20 33 587 583 203	Cowes plant overloaded, and temporarily shut down, after which they isolated themselves from the system and carried their own load. Tripping of the Portsmouth - Nursling line is suspected to be due to a defect in the protective equipment.

Fault No.	Time	Lines put out of service	Damage	Time of Reclosures	Supplies Interrupted				Notes
					At:-	Load kW.	Duration Minutes	Units Lost	
60	02.40	Melksham-Andover-Nursling Portsmouth - Nursling	Not located None	02.46 02.56	Andover Winchester Salisbury Whaddon Southampton Bournemouth Dorchester (all)	500 200 230 200 3600 4000 1200	4 m. 9 m. 9 m. 9 m. 8 m. 6 m. 5-8 m.	33 30 36 30 480 400 144	The tripping of the Portsmouth - Nursling line is suspected to be due to a defect in the protective equipment.
61	03.27	Reading - Oxford	Not located	03.35	-	-	-	-	
62	05.10	Cardiff - Gloucester	Slight	05.43	-	-	-	-	Cardiff, Newport, Lydney, Upper Boat, Tir John and Ebbw Vale isolated as a group.
63	05.18	Newport - Lydney Newport - Cardiff	Slight None	05.27 05.55	-	-	-	-	Lydney and Newport isolated but both by this time had generating plant running. The tripping of Newport - Cardiff was due to maloperation of the protective equipment.
64	10.13	Plymouth - Fraddon Fraddon - Hayle	Not located None	20.58 10.20	Fraddon	6000	7 m.	700	Hayle isolated. Tripping of Fraddon - Hayle line due to maloperation of the protective equipment.
					Total Units Lost			8068	

3.1.46
DMC/NP

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TABLE O.D.2/1041

Sheet 1

APPENDIX "L"

CENTRAL ELECTRICITY BOARD

Incidence of Barrage Balloon Faults on the Board's System

Column a = No. of lines affected (excluding those which also tripped due to maloperation of protective equipment)

Column b = No. of faults recorded.

Column c = No. of faults causing interruption of supplies to consumers.

Column d = No. of interruptions included in Col. c which exceeded an hour in duration.

Year	District	January				February				March				April				May				June			
		a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
1939	Central Scotland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	South Scotland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North East England	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North West England	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mid-East England	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Central England	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	South East England	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	South West England	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	All Areas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1940	Central Scotland	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	South Scotland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North East England	-	-	-	-	3	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-
	North West England	1	1	1	-	-	-	-	-	1	1	-	-	8	4	4	3	-	-	-	-	1	1	-	-
	Mid-East England	-	-	-	-	-	-	-	-	5	4	2	-	-	-	-	-	4	4	1	-	2	2	-	-
	Central England	4	3	1	-	1	1	-	-	3	1	1	-	1	1	-	-	-	-	-	-	2	1	1	-
	South East England	3	2	1	-	1	1	1	-	1	1	-	-	3	3	1	-	2	2	-	-	3	3	1	-
	South West England	-	-	-	-	-	-	-	-	4	3	1	1	-	-	-	-	5	4	2	-	-	-	-	-
	All Areas	9	7	3	-	5	4	2	-	14	10	4	1	12	8	5	3	11	10	3	-	9	8	2	-
1941	Central Scotland	15	9	4	1	20	14	4	-	5	4	1	-	4	4	-	-	2	1	1	-	-	-	-	-
	South Scotland	1	1	1	1	7	5	4	3	7	4	3	-	2	2	1	-	-	-	-	-	-	-	-	-
	North East England	8	6	2	-	21	12	5	2	1	1	1	-	4	4	1	-	-	-	-	-	-	-	-	-
	North West England	9	6	2	-	35	30	7	-	5	3	2	1	2	1	-	-	9	7	3	-	1	1	1	-
	Mid-East England	8	7	-	-	12	12	1	1	1	1	1	-	9	5	1	-	-	-	-	-	-	-	-	-
	Central England	3	3	1	-	7	7	1	-	6	6	1	-	3	2	-	-	2	1	-	-	3	2	-	-
	South East England	14	9	4	-	50	35	8	-	24	19	5	1	10	5	-	-	9	8	1	-	1	1	-	-
	South West England	24	14	6	2	43	23	11	3	28	21	6	-	16	8	5	2	3	2	-	-	11	5	2	1
	All Areas	82	55	20	4	195	138	41	9	77	59	20	2	50	31	8	2	25	19	5	-	16	9	3	1
1942	Central Scotland	5	3	1	-	-	-	-	-	-	-	-	-	4	2	1	-	-	-	-	-	-	-	-	-
	South Scotland	4	4	3	-	-	-	-	-	2	2	2	1	2	2	2	-	1	1	1	-	-	-	-	-
	North East England	14	6	2	-	-	-	-	-	5	3	1	1	6	5	2	-	1	1	-	-	1	1	-	-
	North West England	4	2	-	-	3	1	1	-	-	-	-	-	7	6	2	-	-	-	-	-	-	-	-	-
	Mid-East England	1	1	-	-	-	-	-	-	1	1	-	-	3	3	-	-	6	5	3	-	-	-	-	-
	Central England	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-	5	3	-	-	-	-	-	-
	South East England	2	2	-	-	4	3	1	-	-	-	-	-	6	4	1	-	3	2	1	-	2	2	-	-
	South West England	8	5	4	-	1	1	1	-	1	1	-	-	11	8	4	-	10	9	-	-	-	-	-	-
	All Areas	38	23	10	-	8	5	3	-	9	7	3	2	41	32	12	-	26	21	5	-	3	3	-	-
1943	Central Scotland	1	1	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	South Scotland	4	4	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North East England	1	1	-	-	1	1	-	-	1	1	-	-	5	5	-	-	3	2	2	-	-	-	-	-
	North West England	4	4	-	-	2	2	-	-	2	1	-	-	-	-	-	-	2	2	1	-	1	1	-	-
	Mid-East England	3	3	-	-	1	1	-	-	-	-	-	-	3	3	-	-	-	-	-	-	1	1	-	-
	Central England	7	4	2	-	3	3	1	-	1	1	1	-	-	-	-	-	7	4	-	-	1	1	-	-
	South East England	26	22	4	-	6	5	-	-	9	6	2	-	12	10	3	-	12	7	2	1	-	-	-	-
	South West England	19	15	4	-	7	6	1	-	-	-	-	-	21	17	8	1	10	8	3	-	8	3	1	1
	All Areas	65	54	14	-	20	18	2	-	14	10	3	-	41	35	11	1	34	23	8	1	11	6	1	1

Year	District	July				August				September				October				November				December				Total			
		a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
1939	Central Scotland	-	-	-	-	-	-	-	-	-	-	-	-	3	2	1	-	-	-	-	-	-	-	-	-	3	2	1	-
	South Scotland	-	-	-	-	-	-	-	-	-	-	-	-	3	2	2	-	2	2	2	1	-	-	-	-	5	4	4	1
	North East England	-	-	-	-	-	-	-	-	2	1	1	-	5	3	1	1	-	-	-	-	2	1	-	-	9	5	2	1
	North West England	-	-	-	-	-	-	-	-	1	1	-	-	1	1	-	-	2	2	-	-	-	-	-	-	4	4	-	-
	Mid-East England	3	3	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-	-	-	-	-	5	5	1	-
	Central England	-	-	-	-	-	-	-	-	5	3	1	1	-	-	-	-	6	4	-	-	-	-	-	-	11	7	1	1
	South East England	1	1	-	-	-	-	-	-	15	6	4	-	5	4	1	1	48	32	18	9	1	1	-	-	70	44	23	10
	South West England	-	-	-	-	-	-	-	-	-	-	-	-	3	3	-	-	4	2	2	2	6	4	1	1	13	9	3	3
	All Areas	4	4	1	-	-	-	-	-	23	11	6	1	20	15	5	2	64	44	22	12	9	6	1	1	120	80	35	16
1940	Central Scotland	-	-	-	-	1	1	-	-	9	5	-	-	6	5	2	-	4	2	1	-	3	3	2	1	24	17	5	1
	South Scotland	-	-	-	-	-	-	-	-	6	5	2	1	-	-	-	-	9	9	9	5	1	1	1	1	16	15	12	7
	North East England	7	4	1	-	9	6	3	-	6	3	1	-	6	4	3	-	7	5	2	-	2	2	1	-	41	27	12	-
	North West England	4	1	1	-	23	16	6	2	31	20	9	1	3	3	2	-	24	17	10	3	4	3	2	-	100	67	35	9
	Mid-East England	4	3	1	1	18	13	3	1	41	27	9	2	6	5	1	-	27	22	7	-	11	9	-	-	118	89	24	4
	Central England	-	-	-	-	12	8	1	-	29	22	6	3	17	12	4	-	35	26	1	-	7	6	-	-	111	81	15	3
	South East England	1	1	-	-	18	16	-	-	97	65	23	9	55	43	12	2	77	53	20	4	29	20	4	-	290	210	63	15
	South West England	4	3	-	-	8	5	1	1	37	30	16	6	9	7	2	1	22	16	9	3	3	3	-	-	92	71	31	12
	All Areas	20	12	3	1	89	65	14	4	256	177	66	22	102	79	26	3	205	150	59	15	60	47	10	2	792	577	197	51
1941	Central Scotland	-	-	-	-	1	1	-	-	-	-	-	-	2	2	-	-	1	1	-	-	-	-	-	-	50	36	10	1
	South Scotland	3	2	1	-	-	-	-	-	-	-	-	-	1	1	-	-	4	3	3	2	-	-	-	-	25	18	13	6
	North East England	-	-	-	-	4	3	-	-	1	1	-	-	4	4	3	2	8	5	4	-	3	3	-	-	54	39	16	4
	North West England	3	2	2	-	18	12	3	1	3	1	1	-	17	11	4	-	3	3	1	-	5	4	1	-	110	81	27	2
	Mid-East England	3	3	2	-	13	11	3	-	-	-	-	-	3	3	1	-	6	5	1	-	3	2	1	-	58	49	11	1
	Central England	-	-	-	-	4	2	2	-	-	-	-	-	1	1	-	-	1	1	1	-	-	-	-	-	30	25	6	-
	South East England	3	3	3	-	13	11	1	-	-	-	-	-	2	1	1	-	5	3	2	1	10	8	4	2	141	103	29	4
	South West England	4	3	1	-	13	8	4	1	6	5	3	1	10	5	5	1	3	3	-	-	10	8	5	-	171	105	48	11
	All Areas	16	13	9	-	66	48	13	2	10	7	4	1	40	28	14	3	31	24	12	3	31	25	11	2	639	456	160	29
1942	Central Scotland	-	-	-	-	3	3	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	13	9	2	-
	South Scotland	-	-	-	-	-	-	-	-	-	-	-	-	2	2	2	1	-	-	-	-	1	1	-	-	12	12	10	2
	North East England	2	1	-	-	1	1	-	-	-	-	-	-	3	3	1	1	-	-	-	-	7	6	3	1	40	27	9	3
	North West England	3	1	1	-	-	-	-	-	-	-	-	-	2	1	1	-	-	-	-	-	-	-	-	-	19	11	5	-
	Mid-East England	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	14	12	3	-
	Central England	3	2	1	-	-	-	-	-	1	1	-	-	1	1	-	-	-	-	-	-	5	3	-	-	17	12	1	-
	South East England	2	2	-	-	-	-	-	-	-	-	-	-	11	6	3	1	-	-	-	-	3	3	-	-	33	24	6	1
	South West England	5	2	2	-	2	2	1	-	2	2	-	-	1	1	1	-	3	3	1	-	6	3	2	1	50	37	16	1
	All Areas	17	9	4	-	6	6	1	-	3	3	-	-	21	15	8	3	3	3	1	-	23	17	5	2	198	144	52	7
1943	Central Scotland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-
	South Scotland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4	4	-
	North East England	-	-	-	-	-	-	-	-	6	4	4	1	-	-	-	-	-	-	-	-	-	-	-	-	17	14	6	1
	North West England	-	-	-	-	-	-	-	-	-	-	-	-	4	3	1	1	-	-	-	-	-	-	-	-	15	13	2	1
	Mid-East England	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-	-	-	-	-	-	-	-	-	10	10	-	-
	Central England	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	1	1	-	-	-	-	-	-	21	15	5	-
	South East England	4	3	1	1	6	4	2	-	3	2	1	-	-	-	-	-	4	3	1	-	4	4	-	-	86	66	16	2
	South West England	1	1	1	-	5	4	1	-	-	-	-	-	3	3	1	-	4	3	1	1	-	-	-	-	78	60	21	3
	All Areas	5	4	2	1	11	8	3	-	9	6	5	1	10	9	3	1	9	7	2	1	4	4	-	-	233	184	54	7

1944/

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SECRET

Sheet 2

Year	District	January a	b	c	d	February a	b	c	d	March a	b	c	d	April a	b	c	d
1944	Central Scotland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	South Scotland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North East England	3	2	-	-	2	1	-	-	-	-	-	-	-	-	-	-
	North West England	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mid-East England	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-
	Central England	8	4	1	-	-	-	-	-	3	3	1	-	1	1	-	-
	South East England	5	3	1	-	2	2	-	-	11	4	2	1	-	-	-	-
	South West England	11	8	1	-	3	2	1	1	-	-	-	-	4	3	1	-
	All Areas	29	18	3	-	7	5	1	1	15	8	3	1	5	4	1	-
1945	South East England	-	-	-	-	-	-	-	-	2	2	1	-	-	-	-	-

Year	District	May a	b	c	d	June a	b	c	d	July a	b	c	d	August a	b	c	d
1944	Central Scotland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	South Scotland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North East England	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North West England	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-
	Mid-East England	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-
	Central England	2	1	1	-	-	-	-	-	-	-	-	-	1	1	-	-
	South East England	7	6	-	-	14	12	3	-	43	40	14	1	49	37	7	-
	South West England	1	1	1	1	4	4	2	1	3	5	2	-	12	9	4	1
	All Areas	10	8	2	1	18	16	5	1	46	45	16	1	66	51	11	1
1945	South East England	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Year	District	September a	b	c	d	October a	b	c	d	November a	b	c	d	December a	b	c	d	Total a	b	c	d
1944	Central Scotland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	South Scotland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North East England	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	3	-	-
	North West England	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	3	-	-
	Mid-East England	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3	-	-
	Central England	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	16	11	3	-
	South East England	18	16	3	1	1	1	-	-	1	1	-	-	3	3	-	-	154	125	30	3
	South West England	2	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	40	34	13	4
	All Areas	20	18	4	1	2	2	-	-	1	1	-	-	3	3	-	-	222	179	46	7
1945	South East England	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	1	-

SUMMARY

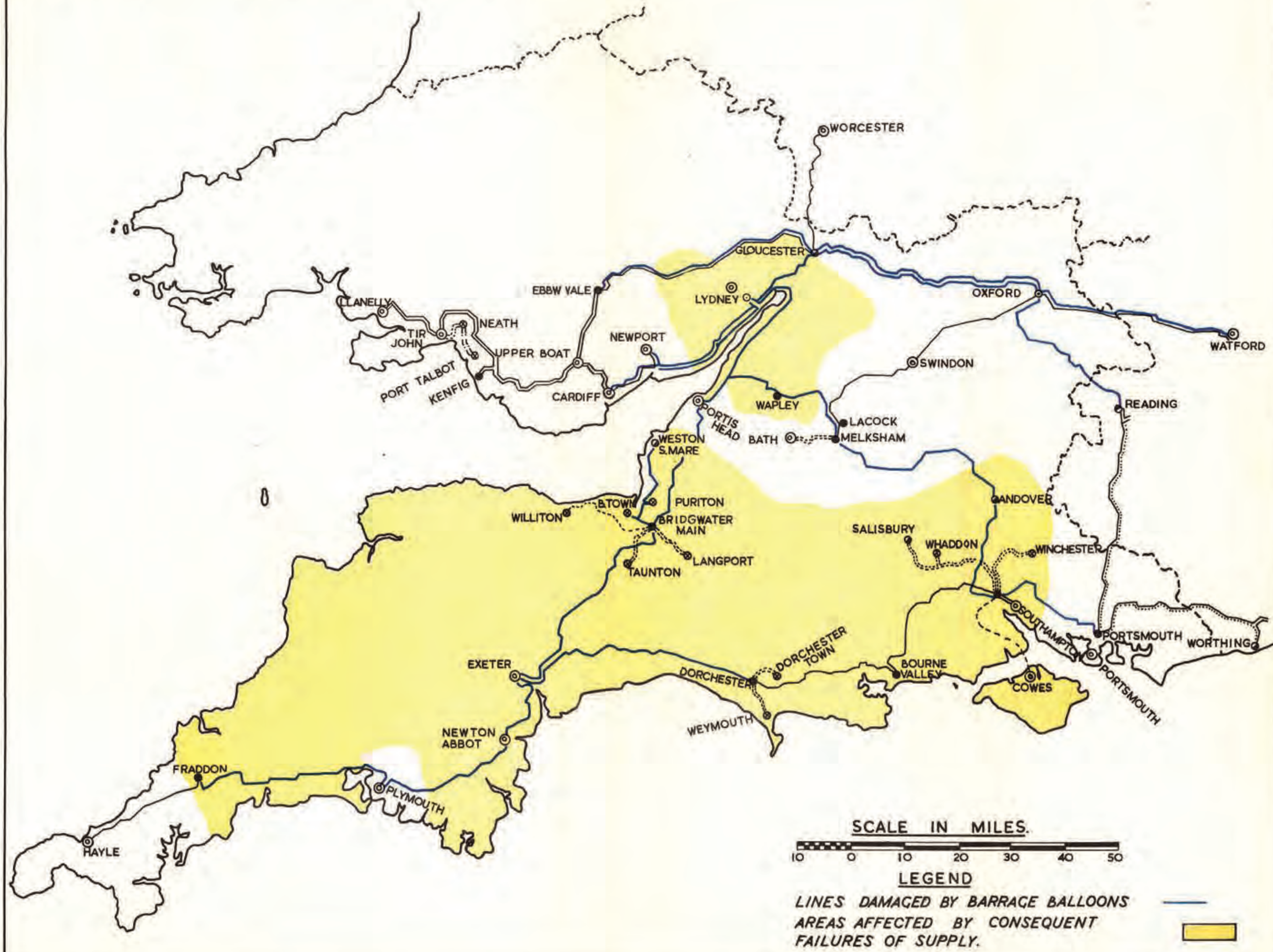
TOTAL ALL AREAS	a	b	c	d	Estimated kWh cost due to faults	TOTAL 1939-1945	a	b	c	d
1939	120	80	35	16	Not available	Central Scotland	92	66	18	2
1940	792	577	197	51	" "	South Scotland	62	53	43	16
Worst day (17th September, 1940)	(123)	(83)	(38)	(19)	(937,000 approx.)	North East England	166	115	45	9
1941	639	456	160	29	Not available	North West England	252	179	69	12
1942	198	144	52	7	" "	Mid-East England	208	168	39	5
1943	233	184	54	7	131,412	Central England	206	151	31	4
1944	222	179	46	7	296,396	South East England	776	574	168	35
1945	2	2	1	-	720	South West England	444	316	132	34
1939-1945	2,206	1,622	545	117		All Areas	2,206	1,622	545	117

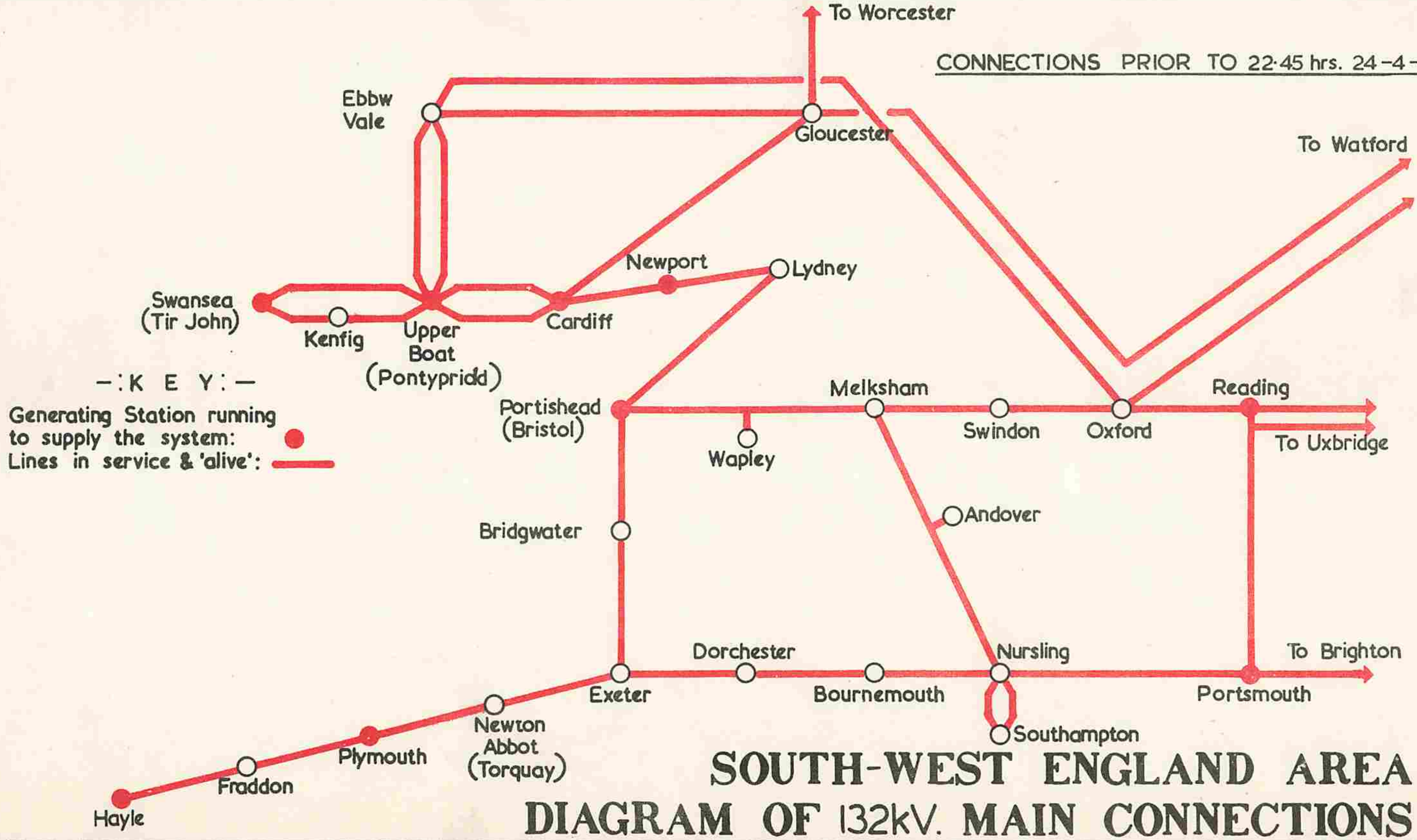
14.2.46
DMC/GT
DM 12471/1(142)

CENTRAL ELECTRICITY BOARD

SOUTH WEST ENGLAND & SOUTH WALES

EFFECTS OF BALLOON BARRAGE TO LINES APRIL 24TH/25TH 1943



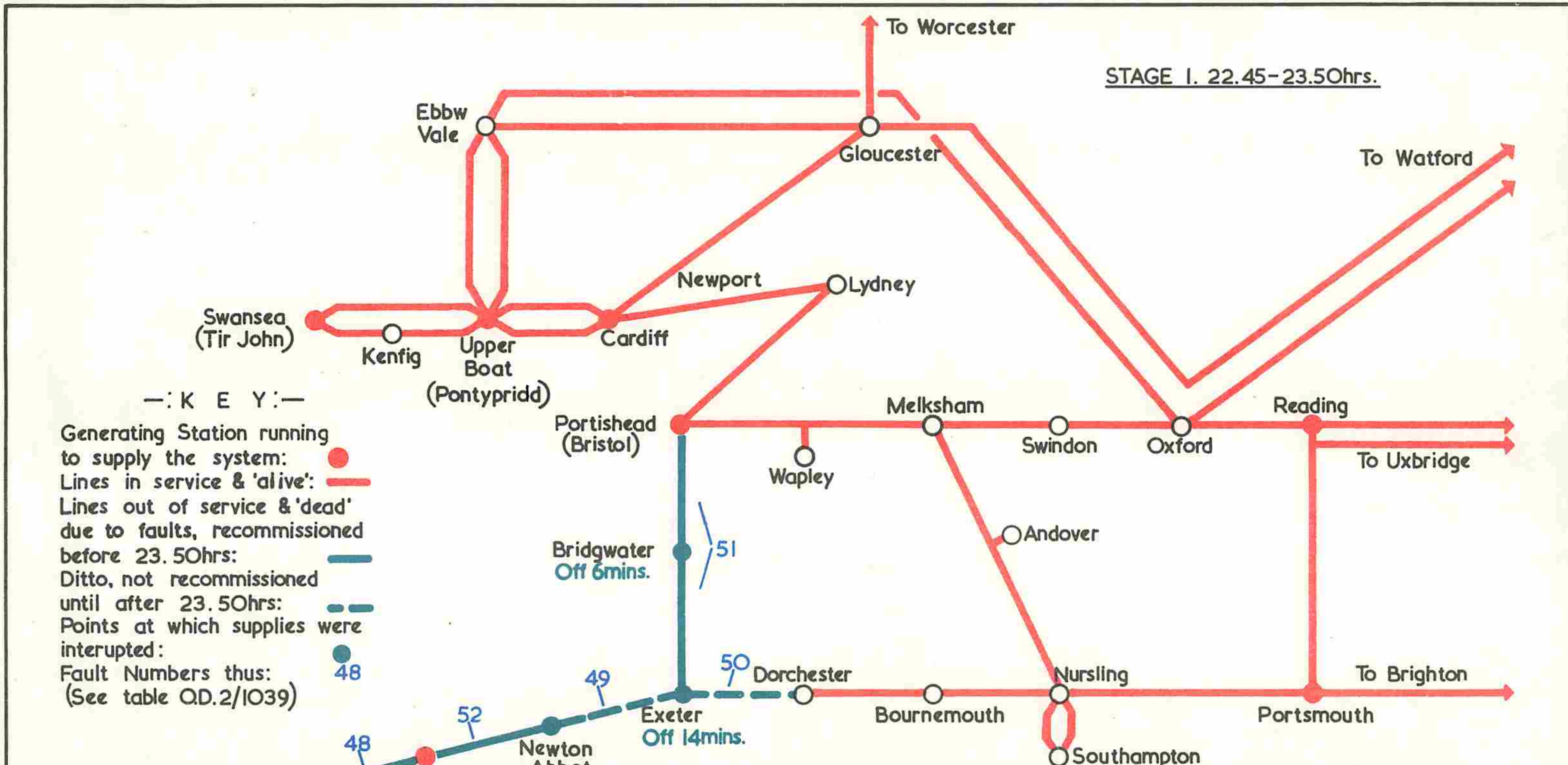


SOUTH-WEST ENGLAND AREA
DIAGRAM OF 132kV. MAIN CONNECTIONS

CENTRAL ELECTRICITY BOARD

APPENDIX L2.

A.H.B.I. DIAG. No. 156.



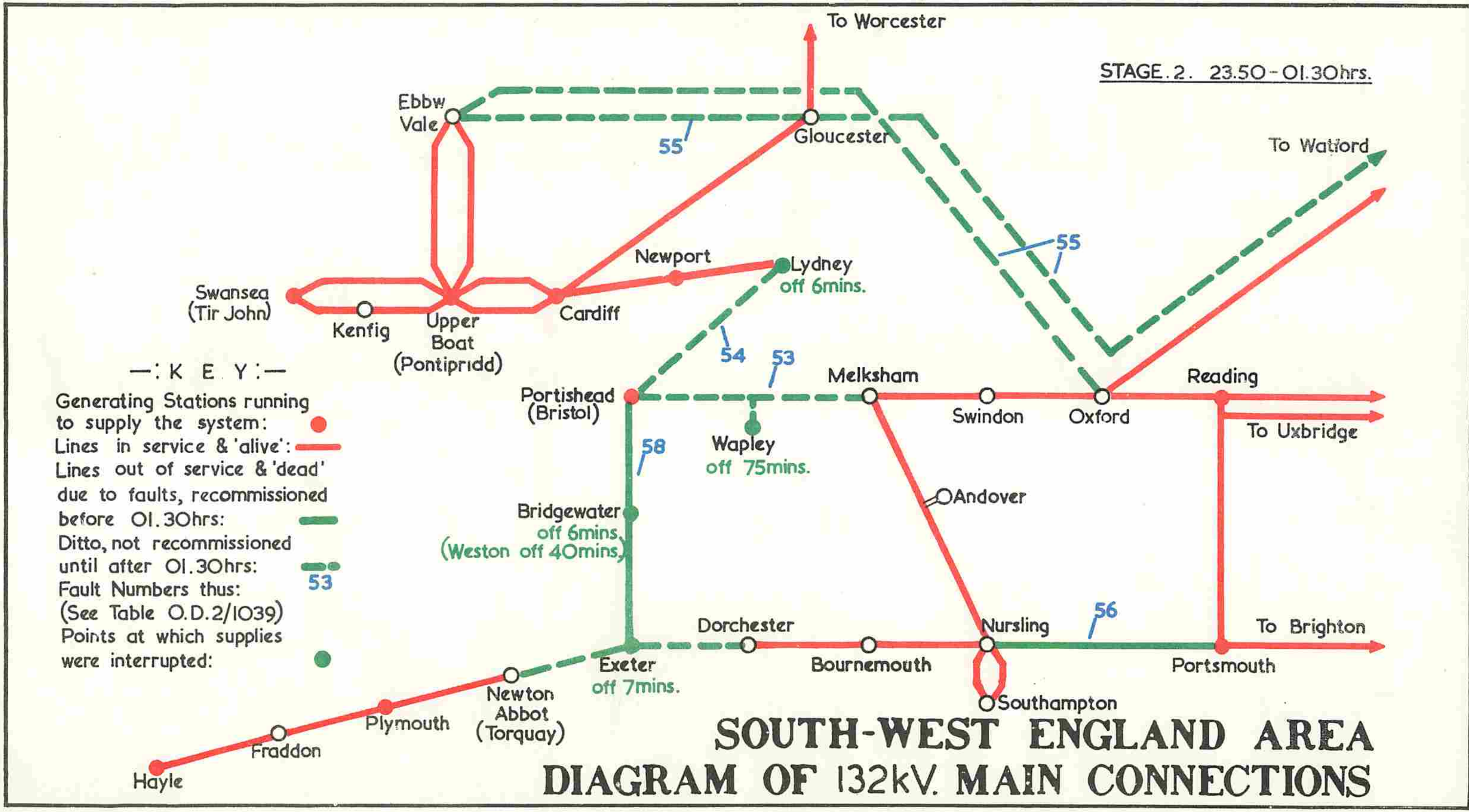
SOUTH-WEST ENGLAND AREA
DIAGRAM OF 132kV. MAIN CONNECTIONS

CENTRAL ELECTRICITY BOARD

SECRET

APPENDIX 13.

A.H.B.I. DIAG. No.159



SOUTH-WEST ENGLAND AREA
DIAGRAM OF 132kV. MAIN CONNECTIONS

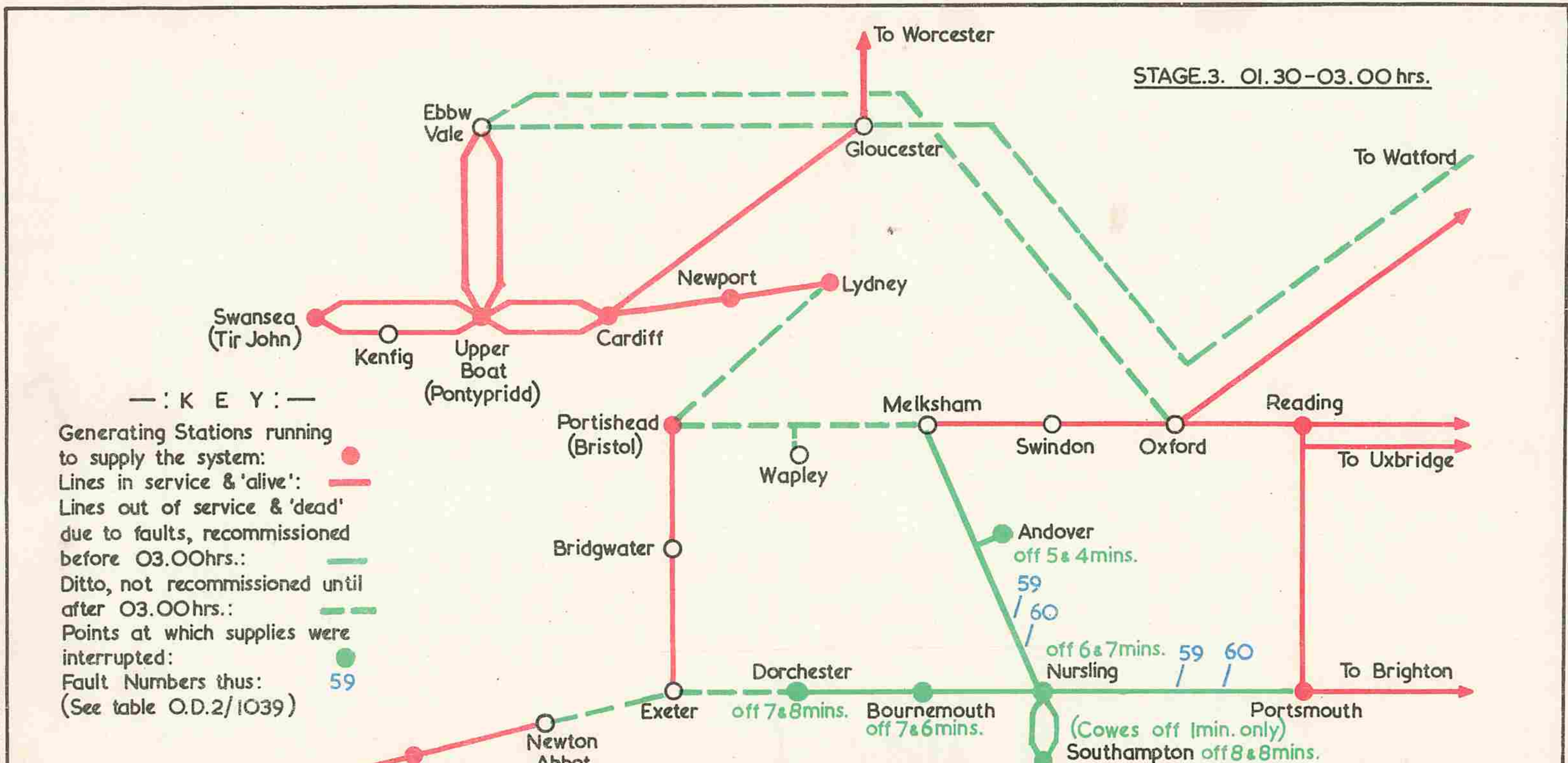
CENTRAL ELECTRICITY BOARD

SECRET

APPENDIX L4.

A.H.B.I. DIAG. No. 169.

CENTRAL ELECTRICITY BOARD

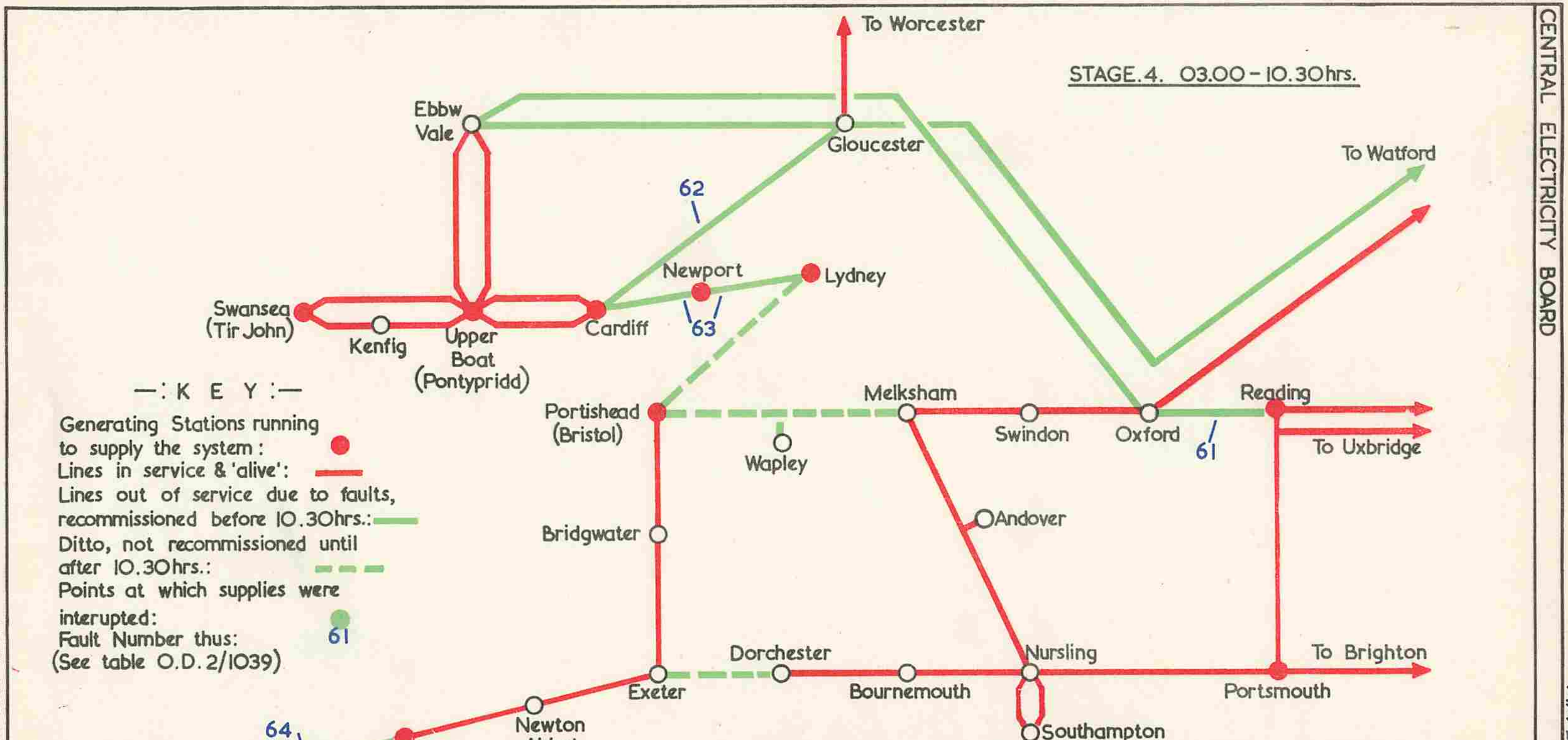


SOUTH-WEST ENGLAND AREA
DIAGRAM OF 132kV. MAIN CONNECTIONS

A.H.B.I. DIAG. No.171.

SECRET

APPENDIX 15



SOUTH-WEST ENGLAND AREA
DIAGRAM OF 132kV. MAIN CONNECTIONS

A.H.B.I. DIAG. No.172.

SECRET

APPENDIX L6.

APPENDIX "M"

A.M. PAMPHLET 64
4th Edition, February, 1939

BALLOON SQUADRONS OF THE AUXILIARY AIR FORCE

Notes for the Information of Candidates

1. Balloon squadrons are organised to provide a defence against attack by hostile aircraft in a defined area.

They form part of the Auxiliary Air Force and are recruited and administered by the Territorial Army and Air Force Association responsible for the county or area in which the unit is located.

Conditions of Entry and Service

2. Applicants for appointment to commissions or for enlistment in the ranks will apply to the commanding officer of the unit they wish to join (see para.19).

3. Age Limits

(i) Officers. Candidates must have attained their 32nd birthday but must not have passed the age of 50, but special consideration may be given to the application of any candidate who is over the age limit at the time of application.

(ii) Men. Candidates must have attained their 25th birthday but must not normally have passed the age of 50, except that men under the age of 25 may be accepted provided they are not physically fit for ordinary enlistment in the Auxiliary Air Force but otherwise attain the medical standard laid down.

4. Nationality

All candidates must be British subjects and of pure European descent. They must also be the sons of parents both of whom are (or, if deceased, were at the time of death) British subjects and a departure from this rule will only be made on the authority of the Secretary of State for Air. (Candidates who possess foreign, as well as British nationality may, in certain cases, be regarded as ineligible for entry). Where there is doubt of nationality or descent, the burden of proof will rest upon the candidate.

5. Medical Standard

A candidate for appointment to a commission or for enlistment will be required to undergo a medical examination, and must attain the following general standards of physical fitness:-

(i) He must be of a fair muscular development and able to undergo a considerable degree of physical exertion of a nature not involving severe strain.

(ii) He must not be suffering from any progressive organic disease or from any disability liable to aggravation on exposure,

(iii) Eyesight. The wearing of glasses will not necessarily debar a candidate, but he will be required to reach the standard set by the medical board.

A candidate for enlistment who is under 25 years of age will not be accepted for service in a balloon squadron if he is physically fit for ordinary enlistment in the Auxiliary Air Force.

6. Classes Ineligible for Entry

(i) Registered medical practitioners (except for medical duties), dental surgeons, medical students, dental students and members of police forces, prison services and fire brigades.

(ii) Candidates who have been discharged from any of the regular or reserve forces of the Crown or the Royal Irish Constabulary:-

(a) for misconduct or inefficiency; or

(b) with a character of "fair" or below.

(iii) Candidates who have been convicted of a serious offence by the civil power.

(iv) Candidates in receipt of disability retired pay or disability pension.

7. Period of Engagement

(i) Officers will be appointed for an initial period of five years to be followed by five years in the Auxiliary Air Force Reserve of Officers. Extension of Service on the active list may be granted for periods not exceeding five years at any one time.

(ii) Men will be engaged for a period of four years, re-engagements being allowed for 1, 2, 3, or 4 years at a time.

8. Rank on Entry and Promotion

(i) Officers will normally be entered in the rank of acting pilot officer, and they will be confirmed in the rank of pilot officer after twelve months' satisfactory service and on the recommendation of the commanding officer. A pilot officer is eligible for promotion to the rank of flying officer at any time after completing 18 months' satisfactory service from the date of confirmation as pilot officer. Promotion to ranks above flying officer will be made within establishment from among officers who have passed the appropriate tests.

(ii) Men will be entered in the rank of aircraftman, 2nd class, and will be promoted, when qualified, as vacancies arise.

9. Obligations

(i) Officers and men on appointment or enlistment accept the following obligations:-

(a) To be called out and to serve within the British

Islands against actual or apprehended attack, or on embodiment of the Auxiliary Air Force when the Air Force Reserve has been called out by Royal Proclamation in a time of national danger or great emergency.

(b) Not to leave Great Britain or Northern Ireland without first obtaining the written permission of the group commander.

(c) To attend for training.

(d) To attend for medical examination when so required.

(ii) Officers of the Auxiliary Air Force are subject to the Air Force Act at all times, and men are so subject when called out for training or service.

(iii) If at any time when the period of service of an officer or man in the Auxiliary Air Force would normally expire, a national emergency exists or appears to be imminent and he has been called out for service, he may be retained, if an officer, until the emergency has passed, or if a man, for a further period not exceeding twelve months.

10. Service with a Foreign Power

An officer or man of the Auxiliary Air Force may not enter the service of a foreign power during his period of service or for five years after his service expires, without the consent of the Air Ministry.

11. Termination of Appointment or Discharge

(i) Candidates for service in the Auxiliary Air Force should be prepared to serve for the full period for which they engage.

(ii) The services of an officer or man of the Auxiliary Air Force may be terminated at any time:

(a) on account of medical unfitness,

(b) on account of unsatisfactory conduct,

(c) if it appears unlikely that he will become efficient in his duties, or

(d) if his services are no longer required.

(iii) A man serving in the ranks may obtain his discharge on giving three months' notice, on delivering up in good order all public property in his possession and on paying such sum, not exceeding £5, as may be required.

Training

12. (i) Officers and men are required to carry out annually 30 hours' training and attendance at annual camp for 15 days.

(ii) The performance of obligatory training set out above is not sufficient to attain the standard required to enable Auxiliary Air Force squadrons to function as designed in war, and the training of personnel is laid down in a progressive syllabus involving, apart from the

15 days' continuous training in camp, regular attendance throughout the year for two hours on one evening a week and for one weekend in three (Saturday and Sunday).

13. Failure to carry out Training

A man of the Auxiliary Air Force who, except with leave from his commanding officer or on account of sickness duly certified, or other reasonable cause, fails to carry out the training prescribed in para.12(i) will be liable to a financial penalty.

Financial Provisions

14. Pay and Allowances

(i) Officers. Subject to the conditions laid down in the regulations for the Auxiliary Air Force, officers, when carrying out annual training, courses of instruction or other training necessitating continuous attendance, receive pay at the rates set out below, and allowances at the current rates laid down for officers of the same rank in the Royal Air Force.

For the purpose of allowances officers are regarded as unmarried:-

	Daily Rate of Pay		
	£	s.	d.
Acting pilot officer		10	0
Pilot officer		10	0
Flying officer		11	10
Flight lieutenant		19	0
Squadron leader	1	8	6
Wing Commander	1	13	6

(ii) (a) Men. Subject to the conditions laid down in the regulations for the Auxiliary Air Force, men, when carrying out annual training, courses of instruction or other training necessitating continuous attendance, receive pay at the rates set out below, and allowances at the current rates laid down for airmen of the same rank in the Royal Air Force.

Men under training will receive group V, R.A.F., rates of pay. When trained, drivers petrol and winch, will continue on Group V rates, plus drivers' bonus of 3d. per day, and balloon riggers and balloon fabric workers will receive group III rates of pay. A man who qualifies in all four trades will be eligible for Group II rates. Skilled men classed as hydrogen workers will, on trade qualification, become entitled to group III rates for hydrogen workers (2nd class).

APPENDIX "M"

Daily Rates of Pay of Airmen of the Royal Air Force

Rank	Group II	Group III	Group V
	s. d.	s. d.	s. d.
Aircraftman, 2nd class	3 6	3 0	2 0
Aircraftman, 1st class	4 3	3 9	3 6
Leading aircraftman	5 0	4 3	4 0
Corporal	6 6	5 0	4 6
Sergeant	8 6	6 6	6 0
Flight sergeant	10 0	8 0	7 9
Warrant officer	12 6	11 6	11 6

(b) Family allowance at the rates and under the conditions laid down for the regular Air Force is issued for the benefit of the wives and children of married men of the Auxiliary Air Force who have attained 21 years of age, for the period of annual training, and for approved whole-time courses of instruction, if these are instituted, subject in each case to the completion of a minimum period of attendance and the satisfaction of other conditions prescribed by regulations.

(c) Good conduct pay in respect of badges awarded under the regulations is issued under the same rules as for the Royal Air Force, for periods of service for which ordinary pay is issued.

(d) Bounties are payable to men for each training year at the following rates and under the conditions specified in detail in the regulations:-

(1) Compulsory training bounty of £3 a year will be paid to all airmen, whether recruits or trained men, subject to the completion of 30 hours' training (outside the 10 specified week-end camps mentioned in (3) below) and in addition 15 days' attendance at annual camp.

(2) Recruits will, in addition, be eligible for an efficiency grant of 10s. on passing the prescribed tests within the first year of service.

(3) Trained men will, in addition to the compulsory training bounty, be paid a voluntary training bounty of £2, subject to attendance at 10 week-ends (Saturday and Sunday) to be specified by the C.O.

(iii) Time increased of pay are governed by R.A.F. rules, but only service given in the regular Air Force or in the Air Force Reserve when mobilised or Auxiliary Air Force when embodied is allowed to reckon as qualifying service for such increases.

(iv) Training allowance will be paid for attendances for non-continuous training, such as evening, weekday and week-end training, at the following rates:-

Officers	1s. per hour
Sergeants and above	9d. " "
Corporals	7d. " "
Aircraftmen	6d. " "

Payment will be made in respect of each hour of useful attendance devoted to training (excluding travelling time but including meal times) subject to a maximum payment in respect of 8 hours on any one day.

(v) On embodiment, the rules for issue of emoluments will follow generally those for the regular Air Force, subject to whatever regulations may be in force at the time.

(vi) A gratuity of £5 will be issued to each officer and man of the Auxiliary Air Force at that time serving on the strength of a unit of the Auxiliary Air Force who is called up under the obligation referred to in para.9(i)(a) provided he is then fit, and is actually retained, for service.

15. Travelling Expenses

Actual and necessary travelling expenses from the place of residence or business, if within the County (or Riding) to which the squadron belongs, to the place of training (or assembly for training) will be allowed for all attendances for training, subject normally to a limitation of 50 miles in respect of journeys extending beyond the County (or Riding) boundary.

16. Uniform

(i) Officers

(a) The only obligatory uniform for officers is the regulation R.A.F. service dress, and the items of uniform which they are required to provide are as follows:-

Cap, field service	1
Cap, service dress	1
Jackets, service dress	2
Trousers	2 pairs
Boots, ankle	1 pair
Gaiters	1 "
Shirts, blue	4
Collars	12
Gloves, leather	1 pair
Ties, black	1
Haversack	1
Water bottle	1
Greatcoat	1

(b) A grant of £40 for the provision of the articles of uniform referred to above is made to an officer who has not previously held a commission in the Royal Air Force, or its reserves or auxiliaries, and to officers whose previous service in any of these forces was terminated at least three years before the date of appointment to the Auxiliary Air Force. Officers whose previous service in any of the above forces was terminated within three years of appointment to the Auxiliary Air Force, and retired R.A.F. officers with a recall liability, are not eligible for the above-mentioned outfit grant. A modified grant may in certain circumstances be issued in these cases. Officers attending for training or other duty will be allowed a deduction of £7.10s. on account of upkeep of uniform, in the assessment of their pay to income tax for any one year.

An officer may be required to refund the above grant if he fails to complete satisfactorily his initial period of service retaining, however, 1/3rd of the total grant for each completed year of satisfactory service on the active list of the Auxiliary Air Force.

(ii) Men are supplied with uniform free of charge.

17. Medical benefits

Subject to the conditions laid down in the regulations for the Auxiliary Air Force, officers and men when present for training are eligible for treatment by a R.A.F. medical officer or by a civilian medical practitioner engaged for attendance on Air Force personnel. In certain circumstances they are also eligible for pay for a limited period, if the disability is attributable to Air Force service.

18. Compensation for disability or death

Provision is made for the award, subject to certain conditions, of disability retired pay to officers and pensions and gratuities to men invalided in consequence of wound, injury or disease directly attributable to the conditions of service and of pensions or allowances to the widows and children or other dependent relatives of officers and men who die as a result of wound, injury or disease directly attributable to the conditions of service. The rates and conditions are laid down in the regulations for the Auxiliary Air Force.

19. Location of Squadrons

The location of squadrons and of the respective County Associations are shown in the subjoined table.

Balloon Squadron	Centre	Name and Address of County Association concerned
Nos.901, 902 and 903	No. 1 Balloon Centre, Kidbrooke, London, S.E.3.	County of London Territorial Army and Air Force Assoc., Duke of York's Headquarters, Chelsea, London, S.W.3.
Nos.904 and 905	No. 2 Balloon Centre, Mansfield Road, Hook, Surrey.	County of Surrey Territorial Army and Air Force Assoc., Burwood House, 16, Caxton Street, London, S.W.1.
Nos.906 and 907	No. 3 Balloon Centre, Stanmore Park, Middlesex.	County of Middlesex Territorial Army and Air Force Assoc., 20, Grosvenor Gardens, London, S.W.1.
Nos.908, 909 and 910	No. 4 Balloon Centre, Chigwell, Essex.	County of Essex Territorial Army and Air Force Assoc., Market Road, Chelmsford.
Nos.911, 912 and 913	No. 5 Balloon Centre, Sutton Coldfield, Birmingham.	County of Warwick Territorial Army and Air Force Assoc., 46, High Street, Warwick.
Nos.914, 915, 916, and 917	No. 6 Balloon Centre, Wythall, Birmingham.	
No. 918	No. 7 Balloon Centre, Crewton, Derby.	County of Derby Territorial Army and Air Force Assoc., 1, Uttoxeter Road, Derby.
Nos.919, 920 and 921	No. 8 Balloon Centre, Lime Tree Farm, Liverpool.	West Lancashire Territorial Army and Air Force Assoc., St. George Building, Lime Street, Liverpool, 1.
Nos.922 and 923	No. 9 Balloon Centre, Houghton Green, Warrington.	
Nos.924, 925 and 926	No. 10 Balloon Centre, Bowlee, Manchester.	East Lancashire Territorial Army and Air Force Assoc., Blackfriars House, The Parsonage, Manchester, 3.
Nos.927, 928 and 929	No. 11 Balloon Centre, Pucklechurch, Bristol.	County of Gloucester Territorial Army and Air Force Assoc., 17, Whiteladies Road, Bristol, 8.
Nos.930, 931, 932 and 933	No. 12 Balloon Centre, Titchfield, Fareham, Hants.	Hampshire I.O.W. Territorial Army and Air Force Assoc., 30, Carlton Place, Southampton.

APPENDIX "M"

Balloon Squadron	Centre	Name and Address of County Association concerned
No. 934	No. 13 Balloon Centre, Collaton Cross, Yealmpton, Plymouth, Devon.	County of Devon Territorial Army and Air Force Assoc., 23, Longbrook Street, Exeter.
No. 935	No. 14 Balloon Centre, Caerau, Cardiff.	County of Glamorgan Territorial Army and Air Force Assoc., 6, St. Andrews Crescent, Cardiff.
Nos.936, 937 and 938	No. 15 Balloon Centre, Long Benton, Newcastle.	County of Northumberland Territorial Army and Air Force Assoc., Drill Hall, Hutton Terrace, Newcastle-on-Tyne.
Nos.939, 940 and 941	No. 16 Balloon Centre, Hensworth, Sheffield.	West Riding of the County of York Territorial Army and Air Force Assoc., 9, St. Leonards, York.
Nos.942, 943 and 944	No. 17 Balloon Centre, Wawne Road, Hull.	East Riding of the County of York Territorial Army and Air Force Assoc., Mail Buildings, Jameson Street, Hull.
Nos.945, 946 and 947	No. 18 Balloon Centre, Easter Cross Hill, Glasgow.	City of Glasgow Territorial Army and Air Force Assoc., 201, West George Street, Glasgow, C.2.

General Note

20. The information contained in this pamphlet has been prepared to provide prospective candidates with a summary of the emoluments and conditions of entry and service current at the date of issue. Changes are liable to occur in these and it must be understood that they are subject in all respects to the detailed regulations which have been, or may be, issued from time to time by the Air Council; in particular, nothing in this summary may be used to support a claim to any rate of pay, etc.

AIR MINISTRY
Issued February, 1939.

APPENDIX "N"

AIR STAFF INSTRUCTIONS PART I (OPERATIONS) NOS.111-113, 115-129

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123	16. 7.43	OPERATIONAL HEIGHT OF BALLOONS	
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125	23. 8.43	CHANGES IN OPERATIONAL POSITION	
126	29.10.43	ARMING OF BALLOON CABLES	
127	29.10.43	COLLISION WITH BALLOON CABLES BY AIRCRAFT	
128	3. 6.44	A.A.DEFENCE - MACHINE GUNS	

SECRET

APPENDIX "N"

Part 1. Serial No. 111
Page 1
Date of Issue 1.4.41

BALLOON COMMAND

AIR STAFF INSTRUCTIONS

Reconnaissances for New Barrages or additions to Barrages

In future, when new barrages, or additions to existing barrages are required, the Group in whose area they are to be established will make the necessary reconnaissance.

1(a) Prior to this reconnaissance, in order to economise in time and man power, a preliminary survey is to be carried out by an Air Staff Officer detailed by Group Headquarters. This survey will show the proposed layout of the balloon defence and is to be submitted to Balloon Command. The siting in this survey (which may require considerable minor alterations when the reconnaissance is carried out) will be approved or amended by Balloon Command and will form the basis on which the reconnaissance is made.

2. A full report and appreciation, both from an operational and administrative aspect, is required and is to be forwarded in quintuplicate to this Headquarters, which will be responsible for the distribution of the report.

3. In order to ensure uniformity and ease of reference, the report is to be rendered in the form set out below. It will be divided into two parts, i.e. Part I, Air Staff, Part II, Administrative. Part I, Air Staff report dealing with siting and communications will form the basis on which is built Part II Administrative Report dealing with housing, supplying, equipping. The reconnaissance is to be done jointly.

4. It should be borne in mind when making the reconnaissance and compiling the report that the object of a reconnaissance is to obtain the maximum amount of information from a personal visit to the location where the barrage is to be flown. The information obtained should be set out in precis form in such a way that easy reference can be made to any desired part. It should be realised that the report is not only necessary as a basis for the planning of the barrage and its initial establishment, but will also be extremely valuable to the Barrage Commander as a basis of operation when the barrage is deployed. It will therefore be appreciated that a satisfactory and complete report is of great value from the operational and administrative point of view.

Composition of Reconnaissance Party

5. The reconnaissance party is to consist of an Air Staff Officer, an Administrative Staff Officer and the appropriate Centre Commander or his representative. Balloon Command Headquarters is to be informed of the date when the reconnaissance will be carried out in order that the Chief Engineer may detail a Lands Officer to join the reconnaissance party. This Lands Officer will, inter alia, contact the War Agricultural Executive Committee.

A Signals Officer need not be present at this stage as the general information of existing circuits and outstanding signals problems should be obtained by the Group Signals Officer beforehand.

6. The report is to be compiled under the following headings:-

Part I Air Staff Report

1. Policy

This should state the authority for the reconnaissance and the reason for the establishment for the barrage if it is known.

2. Objective

This should comprise a list of the vulnerable points to be protected, if possible giving 1-inch map co-ordinates.

3. Scale of Defence

The number of balloons to be sited and, if the proposed number is inadequate, the number required and reasons should be stated.

4. Organisation

A brief statement of the Squadron or Squadrons which will provide the protection and their present location, and the date at which the barrage is to be established, are to be given if known.

5. Reconnaissance

Under this heading should be given details of the reconnaissance party, and the date the reconnaissance was carried out, with a brief summary of the activities of the party carrying out the reconnaissance.

6. Communications

A brief statement of communication requirements is to be given, supplemented by an appendix giving precise details of any existing facilities, telephone and teleprinter lines, accompanied by a diagrammatic plan of requirements.

6(a)(i) The Group Signals Officer is to include in the statement his suggestions for suitable sites at which a Squeaker could be installed to give ample warning to friendly aircraft of their proximity to the Barrage.

(ii) When a resiting, involving an alteration in the perimeter of an existing Barrage already equipped with Squeakers is required, the statement will indicate whether any change of Squeaker Siting is necessary, and if so include details of sites recommended as suitable to give adequate warning of the new Barrage area.

7. Siting of Balloons

A general survey of the barrage area from the siting aspect, giving in general terms the type of country and type of site that can be found, and the general principle which guided the choice of sites by the reconnaissance party. Such details as possible lines of attack might usefully be included. Sites should be co-ordinated with the Army Officers responsible for A.A. defences, and a statement to that effect given, supplemented by a tracing of the proposed siting for the 1-inch ordnance survey made in quadruplicate and one tracing for the 6-inch map should be attached; also an appendix in which each site should be separately detailed with the address of the site or some means of enabling the site to be quickly located by the Squadron when deployed. If possible, alternatives for the proposed sites should be given.

8. Control

The proposed arrangements for barrage control should be stated and the address of the headquarters of barrage control. In the event of any of the proposed sites being within 4 miles of Fighter Aerodromes or 3 miles of any other aerodromes, details of such sites should be given, in order that arrangements may be made for "Operational" "Fighter" or "Emergency" control of the sites affected by the aerodrome authorities.

9. Contacts with Representatives of other Services

10. A further appendix is required giving details of Meteorological services required and of any existing facilities near the proposed barrage area.

7. Part II. Administrative Report

The following headings and notes are intended as a guide to the officer making the reconnaissance. This pro-forma is not applicable in every case as each situation is to be considered on its merits.

Part II. Administrative Report

1. Location

A brief summary of the Air Staff report: the Squadron and Flight Headquarters.

2. Establishment

i. Number of squadrons, flights and balloons.

ii. Landborne or waterborne (Barge
(Drifter.

iii. Additional vehicles required above normal establishment.

3. Method of Approach to Area

Road, rail, sea, air.

4. Lines of Communication

i. From higher formation to barrage.

ii. From Squadron Headquarters to Flight Headquarters.

iii. From Flight Headquarters to sites.

5. Equipment (Abnormal requirements).

6. Hydrogen

i. Method of Supply.

ii. Method of unloading for distribution to Barrage Hydrogen parks.

iii. Total quantity needed for initial inflation and immediate reserve.

7. Accommodation

Summary of where Headquarters personnel will sleep and eat; lighting and heating requirements. (This information should be set out in full in an Appendix (Appendix 'A') showing the actual location for sleeping and eating of all Headquarters personnel. The report will require to be comprehensive).

8. Works Services

i. Summary of outstanding requirements. (Details to be given in an appendix (Appendix 'B') showing what each Headquarters and site will require).

ii. In the appendix, details are required under the following headings:-

(a) Position and address if known.

(b) Names and address of owner and occupier.

(c) Surface of ground.

(d) Obstructions.

(e) Accommodation.

(f) Water supply and sanitation.

(g) Hardstanding.

(h) Whether coal gas main is in the vicinity.

Note 1. In drawing up this summary of information, it should be remembered that the water supply and drainage which will be sufficient for a house occupied under civil conditions, may not be adequate when occupation is made in numbers by a deployed unit.

9. Balloon Repairs

Facilities for local repairs if necessary.

10. M.T. Repairs

Facilities for local repairs if necessary.

11. Rations

Number of cooking centres required and whether the whole barrage can be fed from flight cooking centres. Location of cooking centres. Method of supply of rations. Method of distribution to and from cooking centres. N.A.A.F.I. facilities.

12. Petrol

Source of supply and method of storage recommended.

13. Battery Charging

Where facilities can be obtained.

14. Boot Repairs

Local contract, or R.A.F. shoemaker.

15. Laundry

16. Clothing and repairs

17. Medical requirements

i. Existing facilities. R.N., Army or R.A.F. Hospitals.

ii. Medical inspection room.

iii. Suitable premises.

18. Decontamination

19. A.R.P.

20. Branch of Nearest Local Bank and Early Closing Day

21. Facilities for recreation

Note 2. If R.N. or Army are associated with the barrage, close contact should be made with the Services and possibilities of joint supply, and requirements should be considered and discussed.

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BALLOON COMMAND

AIR STAFF INSTRUCTIONS.

Reconnaissances for new barrages which will be required to fly at immediate notice

Air Staff Instructions Part I, Serial No.111, laid down a form of appreciation to be adopted when making a reconnaissance for a new barrage or an addition to an existing barrage.

2. Cases will arise when the deployment of the barrage will take place at very short notice. On these occasions it is probable that the initial deployment will be made by a Rover squadron specially earmarked and equipped for immediate mobility. These specially organised Squadrons will be replaced by a permanent unit when the full requirements of the particular barrage are known and arrangements have been made to meet them.

3. Under such conditions it will be obvious that a reconnaissance of the type previously demanded would be inapplicable and not available in time. Consequently, when a reconnaissance for an immediate barrage is required a modification of the existing pro forma on the lines detailed below will be adopted.

Part 1. Air Staff Report

The Policy, Objective, Scale of Defence and Organisation will be very briefly summarised. It is still important that the one-inch map co-ordinates of the vulnerable points should be supplied if possible. Details of Organisation and of the formation of the reconnaissance party need not be included. Communications will in the first place be carried out by the Signals Pool, who will be ordered to deploy at the same time as the Rover squadron, but if waterborne sites are included in the barrage some estimate of the distances which the R/T will need to cover and a location for their shore bases should be indicated. Siting of balloons should again be set out briefly, but with sufficient accuracy to enable the Rover squadron to deploy without confusion. The forwarding of tracings will be limited in the first instance to a tracing of whatever map the reconnaissance party have with them. It will still be necessary to detail any controls which will be imposed. Liaison with other Services concerned is essential.

Part 2. Administrative Report

(a)(i) This should be drawn up on a basis of providing immediate facilities of any kind to enable the personnel to operate and be accommodated. For this purpose billeting will obviously have to be resorted to for personnel so far as is possible, and unless suitable empty premises which Headquarters can occupy immediately are available, tentage should be demanded for this purpose.

(a)(ii) Where suitable empty premises are available details of black-out requirements and essential works services in these properties are to be included in the report.

(b) Works Services, Balloon Repairs and M.T. Repairs will not be included.

(c) Information on rations and petrol should be detailed as far as is possible.

(d) The remaining items of the Administrative reconnaissance, on page 5 of Serial No.111 will be omitted.

BALLOON COMMAND

AIR STAFF INSTRUCTIONS - PART 1

Breakaway Balloons

1. Whenever a balloon breaks away the following action is to be taken.

2. The nearest Fighter Group Controller and the nearest Control Centre of the Central Electricity Board will be informed by telephone, stating the approximate length of cable, the height and direction of travel and the time and place of the breakaway. A list of addresses and telephone numbers of Control Centres of the Central Electricity Board is attached in Appendix "A".

3. Balloons breaking away in England, Scotland or Wales and likely to drift over Ireland will, in addition, be reported to Headquarters, Balloon Command.

4. Balloons breaking away in Northern Ireland will only be reported by the Unit concerned by telephone direct to No.82 Group, Northern Ireland (Telephone No. Belfast 28171).

5. Whenever a breakaway balloon is reported as grounded or stationary the following action is to be taken:-

(a) If it is grounded within 15 miles of a Balloon Centre, the Balloon Centre will collect the balloon.

(b) If it is grounded more than 15 miles from a Balloon Centre, the nearest R.A.F. Station is to be asked to collect and despatch to the nearest Balloon Centre. If the nearest R.A.F. Station is R.A.F. Station, Cardington they will collect but will retain the balloon.

(c) If the balloon is flying, the nearest Balloon Centre or R.A.F. Station, Cardington, will send out to collect the balloon immediately. Balloon Command is to be informed by telephone with operational priority of the 1" map co-ordinates and the height of the balloon.

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APPENDIX "A"

TO AIR STAFF INSTRUCTIONS - PART I
SERIAL NO.113

DISTRICT	CONTROL CENTRE
South-east England and East England National Control	95-103, Park Street, Southwark, S.E.1. Telephone No.Waterloo 6202
South-west England	Grid House, 26, Oakfield Road, Clifton, Bristol 8. Telephone No.Bristol 35055
Central England	Grid House, 53-55, Wake Green Road, Moseley, Birmingham 13. Telephone No.Birmingham South 2872
Mid-east England	Grid House, St. Mary's Road, Leeds, 7. Telephone No.Leeds Chapeltown 40185
North-west England	Grid House, Wilmslow Road, East Didsbury, Manchester. Telephone No.Manchester Didsbury 2424
North-east England	Carliol House, Newcastle-on-Tyne. Telephone No.Newcastle 27520
Central and South Scotland	Grid House, 168, Broomhill Drive, Glasgow, W.1. Telephone No.Glasgow Western 3769

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AIR STAFF INSTRUCTIONS PART I

Operational Chain of Command of Balloon Barrages

1. The co-ordination of the A.A. defences of this country is vested in the Air Officer Commanding-in-Chief, Fighter Command.

2. The balloon defences of this country are under the Command of the Air Officer Commanding, Balloon Command, who applies to the balloon defences the policy laid down by the Air Officer Commanding-in-Chief, Fighter Command.

3. Operational policy within Balloon Command

The operational policy of Balloon Command is directed by the Air Officer Commanding, Balloon Command, through the Air Officers Commanding Balloon Groups and through Balloon Barrage Commanders.

4. Delegation of Operational Control to A.O.C. Fighter Groups

The Air Officer Commanding-in-Chief, Fighter Command delegates the operational control of all balloons located within the Fighter Group area to the Air Officer Commanding that Fighter Group, who operates the balloons through the Balloon Barrage Commanders.

5. Barrage Commanders

The Balloon Barrage Commander may be either the Centre Command (if the Centre is within 5 miles of the Barrage), or else the Officer Commanding one of the Squadrons comprising the Barrage.

6. Responsibilities of Centre Commanders

A Centre Commander (who is a Unit Commander in the normal chain of Command) even when he is not the Barrage Commander, is nevertheless responsible for exercising a general supervision over the subordinate Barrage Commander, in order to ensure that the operational policy has been carried out efficiently.

7. Executive Authority of Barrage Commanders

Full executive authority is delegated to the Barrage Commander to operate the Barrage in accordance with the policy laid down by the Air Officer Commanding Balloon Command on receipt of operational orders from the Air Officer Commanding the Fighter Group in which the Barrage is located.

8. Delegation of Authority to Units

Authority is also delegated to any Squadron Commander, Flight Commander or i/c crew, over their particular Unit, to take the necessary action in exceptional circumstances which may arise from the failure of the balloon or its equipment, in order to minimize the damage to adjacent property or to avoid the loss of the balloon or injuries to personnel.

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BALLOON COMMAND

AIR STAFF INSTRUCTION - PART I

Operation of Balloon Barrages

Appendix A - First Line Barrages
" B - Second Line Barrages
" C - Duties of Balloon Officer at Fighter Group Headquarters

Information

The primary object of Balloon Barrages is to provide protection for vulnerable points and areas against low flying attacks by enemy aircraft. This is accomplished by raising a lethal cable barrage into the air around the target, thus denying the area to the enemy and compelling him to fly above the barrage at heights at which other Anti-Aircraft weapons can be used against him most effectively.

Policy

2. The policy governing the general operation of Balloon Barrages is to provide the maximum balloon protection possible commensurate with the prevalent weather conditions immediately but not until an air attack threatens a barrage area.

3. When a barrage is not directly threatened, balloons are grounded or kept at a reduced height where they will provide as little potential danger as possible to friendly aircraft.

4. In certain areas the amount of warning of enemy attack which can be expected, is insufficient to permit the balloons to be raised from the grounded position by the time the attack develops. These barrages are normally flown operationally, fully armed, and at an intermediate height to counter such low flying surprise attacks.

Operational Control

5. The operational control of all balloons in his area, is vested in the Air Officer Commanding the Fighter Group in whose area they are located, with the exception of the barrage at Scapa Flow which is under the operational control of the Admiral Commanding, Orkneys and Shetlands.

6. Officers known as Balloon Officers are located at Fighter Group Headquarters to maintain a 24 hour watch in the Operations Room. These officers, acting under the authority of the Fighter Group Controller, control and operate barrages as required by the tactical situation.
Note I. The balloon barrage at Scapa is not controlled by a Balloon Officer at Fighter Group Headquarters, but is operated by the Barrage Commander on plots received at Barrage Control.

7. At each Barrage Headquarters, the Barrage Commander is responsible for taking action on the instructions received from the Balloon Officer at Fighter Group

Headquarters, or on his own initiative if necessary; in accordance with the principles laid down in Headquarters Balloon Command Air Staff Instructions.

8. Barrage Controllers are provided to assist the Barrage Commander, to maintain liaison with local flying and anti-aircraft authorities, and to decide the extent and height to which balloons are flown when required.

Classification of Balloon Barrages

9. Balloon Barrages are classified into two types.

(a) First Line Barrages

Protecting areas which are liable to surprise attack (Appendix A).

(b) Second Line Barrages

Protecting areas remote from surprise attack (Appendix B).

Method of Operation

10. (a) Operation of Barrages when attack threatens barrage area

First and Second Line Barrages are flown (as provided below) to R.O.H. immediately the area is threatened by attack from enemy aircraft.

(b) Operation of barrages when barrage area is not known to be threatened

(i) First Line Barrages are flown operationally by day and night at 1500' to guard against surprise attack by low flying enemy aircraft. This height is known as the "normal height".

(ii) Second Line Barrages are grounded or flown non-operationally up to 500' at the discretion of the Barrage Commander.

Note II. Certain First Line Barrages fly at R.O.H. all the time. These are indicated at Appendix A.

Air Raid Warnings

11. Warning of impending attack on a barrage area may be received by the Barrage Commander:-

(a) From an order given by Balloon Officer at Fighter Group Headquarters.

(b) By plots received from Gun Operations Room.

(c) By the sounding of local sirens.

Action by Barrage Commander when Attack Develops or Threatens a Barrage Area

12. Subject to any control requiring balloons to remain grounded the Barrage Commander is to act as described below on receipt of warning of an impending attack or when an

attack develops on a barrage area:-

(a) Orders from the Balloon Officer

On receipt of orders from the Balloon Officer (para. 13), the Barrage Commander is to take appropriate action to provide the maximum balloon protection for the target area possible under the circumstances in accordance with Air Staff Instructions.

(b) Plots from G.O.R.

Barrage Commanders should notify the Balloon Officer if he receives an apparently dangerous plot from the G.O.R. without an operational order being received from the Balloon Officer. If he is unable to communicate quickly with the Balloon Officer, the Barrage Commander is to order balloons to be flown if he considers it necessary on the information available to him.

(c) Local Sirens

If local sirens are sounded the Barrage Commander is to order balloons to be flown.

(d) Hostile Acts

If a hostile act is committed by aircraft without warning in the barrage area, the Barrage Commander is to order balloons to be flown.

(e) Breakdown of Communications

(i) In the event of communications breaking down at any time, the Barrage Commander is to operate his barrage at his own discretion even to the extent of flying the barrage at R.O.H. without any definite indication of an impending attack, should he consider that the tactical situation requires it. In determining his policy, the Barrage Commander should bear in mind the object of balloon barrages as set out in Air Staff Instructions.

(ii) The Barrage Commander has discretion to authorise i/c crews to fly balloons to R.O.H. if the local sirens are sounded or in the event of a hostile act being committed, should communication with sites be known to be interrupted. (Before using this authority i/c crews are first to attempt to contact Barrage Control through Flight Headquarters, while the remainder of the crew are taking preparatory action).

Note III. Balloons raised without instructions from the Balloon Officer will nevertheless only be lowered on receipt of orders from him provided of course that communication is possible.

Operational Orders

13. The Operational Orders to be used and action to be taken on them are set out below:-

(a) Stand-by - implying that a dangerous plot is approaching the barrage area but is not yet sufficiently close or dangerous to justify balloons being flown at R.O.H.: all preliminary action to enable balloons to be flown rapidly will be taken; the extent of such action being at the discretion of the Barrage Commander.

(b) Stand-down - implying that the emergency has passed and that "stand-by" precautions may be cancelled.

(c) Shine - implying that the barrage area is threatened by attack; the Barrage Commander will order balloons in the appropriate categories to be flown at R.O.H. with all possible speed.

(d) Dull - implying that an attack has passed or has not materialised; balloons revert to their normal position and crews stand down.

14. If an operational order cannot be executed or the Barrage Commander acts (as provided in these instructions) in a manner contrary to the general policy, he is to notify the Balloon Officer and the Balloon Group Headquarters immediately.

Training and Public Morale

15. (i) For the purpose of training, and to reassure public morale, second-line Barrages are to be flown to R.O.H. or below cloud base, whichever is the lower, at least three times per week, subject to the following provisions:-

(a) Permission is always to be obtained from the appropriate Fighter Group and other controlling authorities.

(b) Two at least of these occasions are to be during the hours of daylight.

(c) If flown during the hours of daylight, visibility must be good.

(d) When flown for these purposes all Balloon cables will be armed in accordance with instructions laid down in A.S.I. Part I. Serial 126 paragraph 6, sub-paragraph (iii).

(ii) In First-line Barrages, the Barrage Commander, in order to facilitate "Site" training, may ground balloons for the purpose, provided that:-

(a) Balloons so grounded, together with those down for daily inspection and topping-up, do not exceed 30 per cent of the Barrage.

(b) Due consideration is given by the Barrage Commander to the tactical situation and the likelihood of current weather conditions permitting surprise attack.

(iii) The provisions of sub-para. (i) (a), (b), (c) and (d) above, may also be applied to first-line Barrages at the discretion of the Barrage Commander.

Communications

16. (i) Private wire circuits are provided within Balloon Command for passing -

(a) Operational messages.

(b) Meteorological information where special Meteorological circuits cannot be provided.

(c) Urgent administrative calls.

(ii) G.P.O. Exchange lines are provided for all normal administrative matters.

(iii) Authorised facilities and routeing to meet Balloon Command operational requirements are fully set out in Balloon Command Signals Instruction, Section I, Serial No. 1, issued 1st June, 1943.

(iv) Arrangements have been made to ensure that operational calls can be passed with a minimum of delay by use of Priority Prefixes. Full instructions for the use of these Priority Prefixes are laid down in Balloon Command Signals Instruction Section I, Serial No. 4 issued 23rd August, 1943.

24th January, 1944.

APPENDIX "A"

TO AIR STAFF INSTRUCTIONS - PART I
SERIAL NO.117

FIRST LINE BARRAGES

Fighter Group	Balloon Group	Barrage
11 12	30	London *Dover Thames *Harwich Portsmouth Southampton Canterbury Chelmsford Yarmouth/Lowestoft Norwich
10	32	*Plymouth Falmouth Dartmouth (Mark VI Balloons)
12	33	Hull Humber Newcastle Billingham Sunderland
13	33	Forth
N/A	33	*Scapa

NOTE I Barrages marked * normally fly at full operational height when weather conditions permit.

NOTE II Humber Barrage - Anti-mine-laying mobile water-borne balloons which fly at R.O.H. at night and are non-operational by day.

NOTE III. Dartmouth Mark VI Barrage is flown from unarmed sites in accordance with Balloon Command Operational Instruction No. 10. It is normally flown during daylight hours only but may be operational day or night up to 2000 feet.

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APPENDIX "B"

TO AIR STAFF INSTRUCTIONS PART I SERIAL 117

SECOND LINE BARRAGES

Fighter Group	Balloon Group	Barrage
10	32	Weston Bristol Brockworth Cardiff/Barry Newport Swansea/Port Talbot Yeovil
11	30	Langley (Al 56) Weybridge

APPENDIX "C"

TO AIR STAFF INSTRUCTIONS PART I SERIAL NO. 117

DUTIES OF BALLOON STAFF OFFICER AT HEADQUARTERS FIGHTER GROUPS

1. The duties of Balloon Officers in connection with the operation of balloons, subject to any over-riding instructions issued by the A.O.C. of the Fighter Group in whose Operations Room they are located, are set out below.

Operational Orders

2. The Balloon Officer issues the operational orders as required by the tactical situation depicted in the Fighter Group Operations Rooms, or as ordered by the controller.

3. As a general rule, unless he has previously imposed an over-riding control, the Balloon Officer will order barrages to be brought to a state of readiness to fly, as follows:-

(a) First Line Barrages. When hostile or unidentified aircraft are plotted within 70 miles of the barrage area.

(b) Second Line Barrages. When hostile or unidentified aircraft are plotted within 85 miles of the barrage area.

4. Orders to fly should be given as follows:-

(a) First Line Barrages. When a hostile or doubtful plot appears within 50 miles of the barrage.

(b) Second Line Barrages. When a hostile or doubtful plot appears within 60 miles of the barrage.

Notification of Changes in the Operational State of Barrages

5. The Balloon Officer is to notify any changes in the operational state of the barrages under his control, to the Operations Room, Headquarters, Fighter Command, and to the Fighter Sector Controllers concerned.

Imposition of Controls

6. The Balloon Officer is responsible for imposing and releasing controls on balloons as directed by the Fighter Group Controller and for notifying the authorities requiring the control when the balloons have been grounded, or the control terminated.

7. In the event of an over-riding control being in operation when a barrage is threatened by attack, it is the responsibility of the Balloon Officer to check up with the authority who required the control, that it is still necessary for the control to operate. In this event the Balloon Officer should draw the attention of the Group Controller to the situation.

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To be read in conjunction with Instructions issued by Met. Office Air Ministry, No.796024/38 dated 20.5.40.

BALLOON COMMAND

AIR STAFF INSTRUCTIONS - PART I

Flying of Balloons in Adverse Weather

RESPONSIBILITY AND DISCRETION OF THE BARRAGE COMMANDER

When balloons are flown operationally it is the responsibility of the Barrage Commander to determine the R.O.H. and the number of balloons in the barrage which are to be flown. In adverse weather less balloons should be hazarded than when the weather is favourable.

2. When an attack threatens or develops on a barrage area the primary consideration governing the action the Barrage Commander must take is the safety of the targets in the barrage area and the loss of balloons is a secondary consideration. Under such circumstances therefore, a considerable risk of balloon casualties both from wind and lightning must be accepted. Less risk should be taken when flying first line barrages at their normal height since, although operational, their purpose at this height is precautionary.

3. Similarly, by day and by night in bright moonlight conditions, a greater risk of balloon casualties must be accepted than on dark nights when the presence of balloons in the air would not be visible to enemy pilots.

4. The Barrage Commander nevertheless has the discretion to retain on the ground the entire barrage if, in his opinion, having duly considered all the circumstances and the tactical situation, the balloon casualties would be so great as to nullify the value of the balloon protection.

DIVISION OF BARRAGES INTO CATEGORIES

5. Balloon Barrages are divided into three categories:-

Category 1. equivalent to 30% of the barrage.

Category 2. equivalent to a further 40% of the Barrage.

Category 3. the remainder of the barrage.

Note. The above is subject to the following qualifications.

(a) The minimum number of balloons in category 1 is never to be less than 16.

(b) When a category is below strength, deficiences are to replaced as far as possible by the temporary allocation of sites from other less important categories to fill their place.

6. The category to which a site belongs is to be made known to the i/c site. He will also be made aware of the R.O.H. and the current category to be flown in execution of operational orders. Variations in either as a result of change in weather conditions are to be advised to him without delay.

VARIATIONS OF METEOROLOGICAL FORECASTS

7. If a Barrage Controller, by observation or from information obtained from audible lightning predictors in the barrage, considers that the weather conditions of the current meteorological forecast do not obtain over the barrage area, he may vary the weather risk imposed as a result of that forecast and alter the categories of balloons to be operational to conform. Before doing so, however, he should whenever possible, consult the parent meteorological station.

FLYING IN LIGHTNING

8. The following minimum categories of balloons should be flown when the barrage is flown operationally:-

Lightning Conditions "A"	- Category 1.
Lightning Conditions "B" and "D"	- Category 1 and 2.
Lightning Conditions "C", "E", "F", "G" and "H"	- Categories 1, 2 and 3.

9. When balloons are being flown in a lightning risk a sharp look-out is to be kept by the balloon watch on sites for the approach of thunderstorm conditions. If they are observed their approach is to be reported immediately to Barrage Control.

10. If a balloon is struck by lightning while an attack is actually in progress, the fact is to be reported to the Barrage Controller who is to upgrade the lightning risk to "A" and order appropriate balloons to be grounded.

11. If a balloon is struck by lightning or if a steady warning from an audible lightning predictor is received when flying operationally but when an attack is not actually taking place over the barrage area at the time, the Barrage Commander may order all balloons to be grounded if it appears likely that the remainder will be lost. This discretion should only be used in extreme emergency.

12. The i/c crew of a site not in category 1, is to order the balloon on his site to be grounded without reference to his Flight Commander or Barrage Controller if another balloon in the vicinity is observed to have been struck by lightning.

13. (a) The degree of risk to be taken when flying balloons in high winds cannot be set out as definitely as in lightning conditions. The Barrage Commander should vary the categories to be flown in accordance with the prevalent winds conditions and the general principles outlined in paras. 1 - 4.

(b) The Barrage Commander is responsible that when surface wind speeds reach Force 6 and over on the Beaufort scale, all sites which are flying, or would fly in raids conditions, have their winch bollards connected and the emergency breaking tackle rigged, as laid down in Balloon Command letter reference KBC/C.21523/9/B.I.O. dated 12th May, 1943.

(c) At the discretion of the Barrage Commander, when a barrage is grounded in gale conditions, balloons on sites which are known to be a high casualty risk in high winds, may be deflated by valve subject to the following conditions:-

(i) The total number of balloons deflated in this manner is not to exceed 30 per cent of the normal flying quota of the barrage.

(ii) Deflations are not to be initiated until the Barrage Commander is reasonably satisfied that weather conditions forecasted are materialising.

(iii) Deflations are to be carried out in strict accordance with A.S.I. Part II Section I, Vol.A, Serial 2 dated 1st July, 1942.

(vi) The Barrage Commander is to be satisfied that the necessary supply of hydrogen is available immediately for re-inflations.

METEOROLOGICAL APPENDIX TO SERIAL NO. 118

File 796024/38.

FORECASTS OF ELECTRICAL RISKS TO KITE BALLOONS

This instruction replaces section (i) Electrical, of the memorandum "The supply of Meteorological Information to the Balloon Barrage".

2. Balloons are extremely liable to be destroyed by electrical action. As a result of research in the past 12 months with current indicators attached to the balloon cables, there is strong reason to believe that lightning is the only form of electrical discharge dangerous to balloons. Balloons have been destroyed in conditions when there would otherwise have been no actual lightning discharge to earth, and by strokes so weak that thunder has not been heard on the ground beneath.

Experience shows that there is great danger of lightning to balloons from all precipitating cumulo-nimbus clouds, whether the precipitation consists of rain, hail or snow. So far as is known, only one case has so far occurred of a lightning stroke to a balloon from a non-precipitating cumulos-cloud. The danger of strokes in such conditions cannot however, be ruled out. The risks of strokes to balloons is great during snow showers and is notably severe during those showers which occur during the period of influx of arctic air from between north and east in winter.

It is essential for Meteorological staff supplying information to balloon barrages to give attention to cumulo-nimbus or cumulus clouds. Some guidance to the dangerous development of this type of cloud, especially when the upper parts of the cloud are screened from view, is afforded by the degree of darkness of the cloud and reports of heavy rain or thunder from other stations. The vertical temperature distribution plotted on the tephigram is a most important aid, but in using it, changes due to diurnal variation must be taken into account, and also changes due to advection of different air; and sometimes changes due to uplift either due to orography or convergence in air flow. It is of the highest importance to make proper allowance for diurnal variation. Clouds which are modest in the forenoon may become rapidly dangerous in the middle of the day or during the afternoon.

Balloons cannot be instantaneously brought down and it is therefore essential not to wait until conditions are actually dangerous but to give notification in advance when conditions are developing towards a dangerous state.

3. It has been decided that forecasts of electrical risks to balloons should in future be expressed in the terms given in para. 4. The use of such terms as "severe static" is to be discontinued.

4.

Term	When used
(a) Lightning expected	This term will only be used when (i) there is practical certainty that there will be cumulo-nimbus clouds over the actual area of the balloon barrage, and (ii) lightning is known to have been observed in the existing meteorological regime in which the barrage is or will be situated. (The cumulo-nimbus clouds may be known by observation to be approaching the barrage or cumulus clouds may have begun to develop which are practically certain from the meteorological conditions to grow into cumulo-nimbus. The case of a definite line-squall approaching the barrage would also be included in this category "Lightning expected". Care must be taken to distinguish between large cumulus and cumulo-nimbus. Cumulo-nimbus generally give precipitation.
(b) Lightning probable	This term will be used when, (i) it is expected that there will be cumulo-nimbus clouds over the actual area of the barrage but, (ii) there has been no actual reports of lightning in the existing meteorological regime in which the barrage is or will be situated.
(c) Risk of lightning	This term will be used when it is expected that, over the actual region of the barrage there will be large cumulus which may develop into cumulo-nimbus.

(d)	Local lightning expected	This term will be used (i) when there is practical certainty that there will be cumulo-nimbus clouds in the district where the barrage is situated (but not necessary over the barrage itself) and (ii) lightning is known to have been observed in the existing meteorological regime in which district the barrage is or will be situated,
(e)	Local lightning probable	This term will be used when it is expected that there will be cumulo-nimbus clouds over the district in which the barrage is situated but there have been no actual reports of lightning in the existing meteorological regime in which the barrage is or will be situated.
(f)	Risk of local lightning	This term will be used when it is expected that in the district in which the barrage is situated there will be large cumulus which may develop into cumulo-nimbus.
(g)	Little likelihood of lightning	This term will be used when none of the previous terms apply and it is not certain that there is no risk of lightning (see (h)).
(h)	No lightning	This term is only to be used when there is certainty that there will be no lightning. This is the case when the air is stable and it is certain that any clouds that form will not grow into large cumulus or cumulo-nimbus. The term "No lightning" should not be used if there are large fronts or occlusions in the regions of the barrage or approaching it.

N.B. In all the forecasts (a) to (f) whenever possible the time at which the risk will begin will be indicated.

5. One of the above terms should be included in the forecasts issued to balloon barrages. In considering when to use a term of the set (a) to (c) or (d) to (e) consideration should be paid to the area covered by the barrage. The London Barrage covers an area of approximately 150 square miles so that on days of local showers they would have to be very thinly scattered to miss it altogether and a forecast of set (a) to (c) would in general be applicable on such days. The area covered by particular barrages can be obtained from the Barrage Commander by the meteorological office responsible for the supply of forecasts.

6. Forecasters at a centre remote from a small barrage can only use terms (a), (b) and (c) in cases of frontal showers or thunderstorms and in instances when the track of a widespread thunderstorm or series of storms is accurately known.

In this connection it may be said that the Birmingham Barrage for which forecasts are supplied by "Eta", covers a square of side 10 miles so that as in the case of London it is unlikely to miss local showers.

Meteorological Office,
Air Ministry.

20th May, 1940.

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BALLOON COMMAND

AIR STAFF INSTRUCTIONS - PART I

Control of Balloons by Authorities other than Barrage Commanders

INFORMATION

For the safety of friendly aircraft and to facilitate the operation and calibration of anti-aircraft gun instruments, the Air Officer Commanding a Fighter Group may, at his discretion, grant controls limiting the height of specified or all balloons in a barrage.

2. These controls may be granted to:-

(a) Certain R.A.F., R.N.A.S., U.S.Army Air Corps and Civil Aerodromes to remove the danger to friendly aircraft.

(b) Local A.A. Defence Commanders to prevent interference with the effective operation or training of A.A. Defences.

(c) Casual Authorities in emergencies or for specified occasions.

TYPES OF CONTROL

3. Two types of control will be imposed.

(a) Standing controls, which are operated between the controlling authority and the Barrage Commander as required, without further reference to the Fighter Group when once the initial authority has been granted.

(b) General Purpose Controls for which application is made to the Fighter Group every time the control is required. This control is imposed and released by the Balloon Officer.

4. Both Standing Control and General Purpose Controls are of two qualities, either "terminable" or "over-riding".

(a) Terminable Controls are to be released by the Barrage Commander on receipt of warning of impending attack on a barrage area.

(b) Over-riding Controls remain operative in spite of enemy activity threatening, or taking place, over the barrage area until released by the controlling authority.

Note 1. Modifications of over-riding controls may sometimes be imposed.

TERMINATION AND RELEASE OF CONTROLS

5. Any control granted may be withdrawn on the special instructions of the Air Officer Commanding the Fighter Group concerned should he consider it operationally necessary.

6. It is the responsibility of the controlling authority to release a control immediately it is no longer required. If the Barrage Commander however, has reason to believe that the balloons are grounded for a longer period than is actually necessary, he is to contact:-

(a) the controlling authority direct, in the case of Standing Controls.

(b) the Balloon Officer, in the case of General Purpose Controls.

7. Terminable Controls unless previously released by the controlling authority are to be terminated by the Barrage Commander when attack developes or threatens the barrage area. (A.S.I. Part I, Serial No. 117, para. 12 (a) - (e)).

8. Over-riding Controls unless previously released by the Controlling Authority can only be terminated by Barrage Commanders if communications with the controlling authority have broken down and a heavy attack develops on the barrage area. (See also notes 1 - 3).

Note 2. Controls terminated by the Barrage Commander are not to be re-imposed automatically when the emergency has passed. A fresh request for the control must be made by the authority concerned.

Note 3. When balloons are controlled by the A.A. Defence Commander under an over-riding control, it is his responsibility to release the control if he becomes aware of the approach of hostile aircraft below 6000 ft. It may occur, however, that the Balloon Officer also, receives information to this effect in which case he is to notify the Barrage Commander who will terminate the control.

Note 4. Standing over-riding controls granted by local A.A. Defence Commanders are to be terminated automatically by the Balloon Officer at Fighter Group when a fighter night is put into force.

NOTIFICATION OF IMPOSITION, EXECUTION AND TERMINATION OF CONTROLS

9. Standing Controls

(a) Notification by the Barrage Commander of the imposition of a Standing Control is to be made to the Balloon Group concerned only if the control is over-riding. The Balloon Group will then notify the Balloon Officer.

(b) The execution of a Standing Control Order is to be notified to the controlling authority by the Barrage Commander immediately the requirements of the control have been completed.

(c) The release of a control by a controlling authority is to be notified to the authorities who were informed of the imposition of the control.

(d) The termination of a control by the Barrage Commander is to be notified:-

(i) to the controlling authority immediately the order is given for the balloons to be flown.

(ii) to the authorities who were informed of the imposition of the control.

10. General Purpose Controls

(a) The imposition of a General Purpose Control is to be notified to the Balloon Group by the Balloon Officer as soon as possible after it has been imposed.

(b) The execution of a General Purpose Control is to be notified by the Barrage Commander, immediately the requirements of the control have been completed, to the Balloon Group concerned for transmission to the Balloon Officer. The Balloon Officer is to inform the controlling authority where necessary and he is not to assume that the order has been complied with until he receives the notification of its completion.

(c) Notification of the release of a control is to be made by the Balloon Officer to the Balloon Group concerned as soon as he has released it.

(d) Notification of the termination of a terminable control by the Barrage Commander without orders to fly being received from the Balloon Officer is to be made by the Barrage Commander to the Balloon Group concerned for transmission to the Balloon Officer.

CHANNELS OF COMMUNICATION

11. Telephone communication between the Barrage Commander and a "Standing Control" authority is by exchange line or private wire. The Barrage Commander is authorised to make use of Priority I where necessary.

NOMAD BALLOONS

12. Nomad balloons are not subject to any of the above controls irrespective of whether they fly in a barrage area or not.

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BALLOON COMMAND

AIR STAFF INSTRUCTIONS - PART I

Report on Active Operations in Time of War

1. A return known as the "Y" return is to be rendered daily by Groups to Headquarters Balloon Command, showing the operational state of the barrages comprising the Group as at 21 hours and the casualties sustained during the previous 24 hours.

2. The return is to be made by teleprinter as SECRET NOT W/T and with an IMMEDIATE priority.

3. The signals will begin with the name of the barrage followed by the prefix letter and the appropriate figures. In the event of a nil return being applicable to any prefix, both the prefix and the word "nil" are to be omitted.

4. The return is to be rendered by barrages in accordance with the following pro-forma:-

PREFIX	CASUALTIES SUSTAINED DURING THE PREVIOUS 24 HOURS
J.	Number of enemy aircraft claimed as casualties.
K. (a)	Number of L.Z. Balloons which have become casualties during the period covered by the return.
(b)	Number of Mark IV Balloons which have become casualties during the period covered by the Return on sites equipped with balloons flown singly.
(c)	Number of Mark IV Balloons which have become casualties during the period covered by the return on sites equipped with balloons flown in tandem.
L.	Classification of L.Z. Balloons under prefix K (a)
(a)	War.
(b)	Breakaway with cable, rip link not fitted.
(c)	Breakaway without cable, rip link having functioned.
(d)	Breakaway, rip link did not function.
(e)	Breakaway, action of rip link not known.
(f)	Miscellaneous, including lightning and deflations replaced by another balloon. The time when each balloon was struck by lightning is to be shown.

M. Classification of Mark VI casualties under Prefixes K(b) and K(c).

(a) War.

(b) Breakaway flying singly.

(c) Breakaway of upper unit flying in tandem.

(d) Breakaway of lower unit flying in tandem.

(e) Breakaway of both units flying in tandem.

(f) Miscellaneous, including lightning or deflations replaced by another balloon. The time when each balloon was struck by lightning is to be shown.

Where Audible Lightning Predictors are installed, it is to be stated whether the instrument functioned or not and if so at what time the warning was received.

OPERATIONAL STATE AS AT 21 HOURS

N. (a) Number of landborne L.Z. Balloons operational.

(b) Number of waterborne L.Z. Balloons operational from vessels.

(c) Number of waterborne L.Z. Balloons operational from buoys.

P. (a) Number of land sites equipped with Mark VI single balloons at which the balloon is operational.

(b) Number of water sites equipped with Mark VI single balloons at which the balloon is operational.

Q. (a) Number of land sites equipped with Mark VI tandem balloons at which the tandem unit is fully operational.

(b) Number of land sites equipped with Mark VI tandem balloons at which only one unit is operational.

(c) Number of water sites equipped with Mark VI tandem balloons at which the tandem unit is fully operational.

(d) Number of water sites equipped with Mark VI tandem balloons at which only one unit is operational.

R. Statement of any unusual occurrence, not included under previous headings, which affected the operational state of the barrages. In the event of casualties in a barrage amounting to 25% or more of the barrage strength, having occurred and these casualties not having been replaced by

21 hours on the day subsequent to the casualty, the number of balloons not replaced is to be stated by Barrages.

ARMAMENT

S. (a) Number of L.Z. Balloons equipped with series arming D.P.L.s.

(b) Number of L.Z. Balloons equipped with single arming D.P.L.s.

(c) Number of L.Z. Balloons flown on single cable unarmed.

(d) Number of L.Z. Balloons equipped with T.C.B. arming.

(e) Number of L.Z. Balloons flown on twin cable unarmed.

T. (a) Number of single Mark VI Balloons armed.

(b) Number of single Mark VI Balloons unarmed.

(c) Number of Tandem Mark VI Balloons fully armed.

(d) Number of Tandem Mark VI Balloons partly armed.

(e) Number of Tandem Mark VI Balloons unarmed.

OCCUPATION OF SITES

V. Additions and deletions of occupied sites flying balloons which have taken place since the previous Return. The sites will be identified by Squadron and Site number wherever:-

(i) A casualty has been sustained during the period but not replaced by the time the Return is made.

(ii) A casualty sustained previous to the period covered by the current Return has been replaced.

(iii) A balloon is made operational during the period.

(iv) A site is vacated during the period.

5. For the purpose of the "Y" Return a balloon is deemed to be a casualty if it has had to be deflated and replaced by another balloon consequent on the failure of or accident to, any part of the balloon, its equipment, or cable during the period covered by the Return. Similarly if the balloon is unable to be flown operationally as a result of an accident to the crew or site, or to the balloon, its equipment, cable or winch at the time the Return is made, it is to be considered a casualty. A balloon flown from a vessel is also to be considered a casualty if for any reason connected with the vessel it cannot be flown from its normal operational position.

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BALLOON COMMAND

AIR STAFF INSTRUCTIONS - PART I

Cloud Indicators

Appendix "A" - Distribution of Cloud Indicators and Communication Channels

Function of Cloud Indicators

1. Cloud Indicators are sited in a barrage for a dual purpose:-

(a) To assist Barrage Commanders in determining the R.O.H. of the barrage.

(b) To provide information for the Meteorological Service for re-transmission to Operational Commands. Barrages required to supply this information are listed at Appendix "A".

Siting of Cloud Indicators

2. The selection of a Cloud Indicator site within a barrage is to be made by the Barrage Commander with the approval of Group Headquarters. The site selected is to be provided with "A.C." Mains electrical supply, 200-250 volts, 50 cycles. It is not to be scheduled as an Audible Lightning Predictor site. Installation of a Cloud Indicator at a barrage, or change of site within a barrage, is to be notified to Balloon Command through the usual channels.

Equipment

3. The site is to be equipped with a Mark X Balloon.

Method of using the Cloud Indicator Apparatus

4. The transmitter section of the apparatus is to be attached with a carpenters stopper to the flying cable 300 feet below the crossover. In order to determine the height of the layers of cloud or fog, the balloon is to be flown so that the cloud indicator transmitter passes through the cloud layer two or three times. The readings obtained from the receiver section of the apparatus on the ground are to be recorded and telephoned from the site to Barrage Control and thence to the Meteorological Officer at the Headquarters or Station by routing shown at APPENDIX "A". The information required is:-

(a) The height (in terms of paid out cable less 300 feet) at which the transmitter reached the base and top of the layer or layers of cloud.

(b) The height (in terms of paid out cable less 300 feet) at which the transmitter passed through the top of the fog.

Operational Use of Cloud Indicator to determine R.O.H.

5. (a) An ascent is to be made to determine the height of the layers of cloud or fog at frequent intervals whenever fog or cloud conditions, of 6/10 or more, are prevalent in the barrage area below maximum operational height.

(b) When a control over the cloud indicator balloon is operative the control is not to be broken without permission of the controlling authority.

(c) When no control is operative the cloud indicator balloon may be flown up to M.O.H. for this purpose without prior authority.

(d) The cloud indicator apparatus is not to be hazarded in adverse weather conditions.

(e) The information obtained from the Cloud indicator readings can be accepted by the Barrage Commander as providing an accurate indication of the cloud layer and, after making any necessary corrections for cable sag and the difference in altitude of the cloud indicator site in relation to the remainder of the barrage, is to be used for determining the R.O.H.

(f) When the barrage is flown at R.O.H. the Cloud Indicator balloon will conform to the remainder of the barrage. If the transmitter is attached the cloud indicator balloon is to be flown below cloud base, except when readings are being taken as continuous flying into cloud is liable to seriously damage the instrument.

Use of Cloud Indicator for Meteorological Ascents

6. (a) Cloud Indicator Balloons when making "Sounding Ascents" are subject to the conditions laid down in paragraphs 5(b) and (d). "Soundings" are to be made so that a reading is obtained at about 10 minutes before 0400, 0700, 1000, 1300, 1600, 1800, 2200 hours G.M.T. and at other times if required.

(b) Soundings are not to be made when cloud conditions are less than 3/10ths, or when the cloud base is unquestionably in excess of 6000 feet.

(c) In barrages where more than one balloon is equipped with a Cloud Indicator, "soundings" for meteorological purposes are only to be made by one balloon.

Arming

7. (a) When the Cloud Indicator Balloon is flown for meteorological purposes the balloon is to be fitted with DP/R.Link Mark II only, set at live, and the parachute strop is to be unshackled from the crossover and suitably secured.

(b) When the Cloud Indicator Balloon is flown operationally, without the transmitter attached, it is to be armed to conform to the remainder of the barrage.

(c) If the balloon is being flown for meteorological purposes when a "shine" order is received the balloon will be flown in accordance with the instructions in para. 5 sub-para. (f) but will remain unarmed.

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APPENDIX "N"

11th May, 1943.

APPENDIX "A"

To AIR STAFF INSTRUCTIONS PART I SERIAL NO. 121

Distribution of Cloud Indicators and Communication Channels

Index No.	Barrage	Barrage Control Station	Location of C.I. Lat.	Location of C.I. Long.	Communication Channel
052	Scapa	950	59. 00'	3. 00'W	R.N.A.S. Hatson.
056	Forth	929	56. 00'	3. 23'W	H.Q. No.18 Group.
057	Glasgow	945/6	55. 51'	4. 16'W	R.A.F. Station, Abbotsinch.
060	Newcastle	936/7	54. 58'	1. 37'W	H.Q. No.13 Group.
062	Billingham	938	54. 36'	1. 17'W	R.A.F. Station, Thornaby.
065	Hull	942/3	53. 45'	0. 20'W	H.Q. No.4 Group via. R.A.F. Station, Church Fenton.
067	Manchester	925/6	53. 29'	2. 14'W	H.Q. No.9 Group via. No.10 Balloon Centre
068	Sheffield	939/40	53. 29'	1. 28'W	H.Q. No.12 Group via H.Q. No.33 Group
069	Liverpool	919/23	53. 24'	3. 04'W	H.Q. No.9 Group via No.10 Balloon Centre
071	Crewe	949	53. 07'	2. 27'W	H.Q. No.9 Group via No.10 Balloon Centre
072	Derby	918	52. 56"	1. 29'W	H,Q. No.12 Group
074	Birmingham	No.63.C	52. 28'	1. 55'W	H.Q. No.12 Group via 918 Sqn. H.Q. Derby
077	Harwich	928	51. 56'	1. 17'W	H.Q. No.3 Group via R.A.F. Station, Felixstowe.
078	Brockworth	912	51. 51'	2. 09'W	H.Q. No.10 Group via No.11 Balloon Centre
080	Swansea	958	51. 37'	3. 57'W	R.A.F. Station, Pembroke Dock.
082	London	906	51. 32'	0. 05'W	H.Q. No.11 Group
083	Langley	956	51. 31'	0. 32'W	H.Q. No.11 Group
084	Bristol	927/35	51. 31'	2. 34'W	H.Q. No.10 Group via No.11 Balloon Centre
085	Cardiff	953	51. 28'	3. 10'W	H.Q. No.10 Group via No.11 Balloon Centre
087	Weybridge	954	51. 22'	0. 27'W	H.Q. No.11 Group
089	Dover	961	51. 7'	1. 18'E	H.Q. No.16 Group via R.A.F. Station, Manston.
090	Yeovil	957	50. 57'	2. 37'W	R.N.A.S. Yeovilton.
091	Southampton	924/930	50. 51'	1. 23'W	R.A.F. Station, Thorney Island, via 932/3 Sqn. H.Q.
092	Portsmouth	932/3	50. 48'	1. 05'W	R.A.F. Station, Thorney Island.
093	Plymouth	934	50. 21'	4. 09'W	H.Q.19 Group
094	Falmouth	959	50. 07'	5. 03'W	H.Q. No.19 Group via No.13 Balloon Centre.

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BALLOON COMMAND

AIR STAFF INSTRUCTIONS PART I

Manning of Sites

1. Squadron Commanders are to be responsible that there are at all times sufficient personnel on each site to ensure the safe and speedy operation of the balloons.

2. The minimum number to be maintained on sites, and then only in the most favourable weather conditions, is, R.A.F. 1 Corporal, 3 A.Cs; W.A.A.F. 1 Corporal, 5 A.C.Ws. Under no circumstances is this number to be reduced.

3. When any less favourable weather conditions are existent or forecast, crews are to be maintained at a suitably increased strength. The precise increase in relation to the existing weather conditions is for decision by the Squadron Commander, having regard to the handling instructions laid down in Air Staff Instructions Part II, and bearing in mind that all other conditions must be subordinated to the maintenance of the barrage.

4. Where the barrage consists of more than one squadron, it is the responsibility of the Barrage Control Officer to keep the Commanding Officers of the associate squadrons constantly informed as to weather conditions and forecasts.

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Date 16.7.43
Cancelling No.105 dated 23.3.41

BALLOON COMMAND

AIR STAFF INSTRUCTIONS - PART I

Operational Height of Balloons

Ruling Operational Height

The R.O.H. is the height at which balloons are to be flown in Air Raid conditions. It is to be selected by the Barrage Commander and is to be known at all times by the N.C.O. or airman i/c of every site, irrespective of whether the balloons are flying or not.

2. When selecting a Ruling Operational Height, the Barrage Commander is to observe the following principles:-

(a) By Day

(i) When the sky is obscured by less than six tenths cloud, the R.O.H. should be as near to the maximum permitted height of the balloons as the Barrage Commander considers safe. No attempt is to be made to force balloons to the maximum permitted height in cases where the Hydrogen purity or weather conditions render such height difficult to reach. Such a course only results in sagging cables and their attendant troubles.

(ii) When cloud conditions are six tenths or more and the lowest cloud layer is below M.O.H. advantage is to be taken of the concealment it provides. In such conditions, with the assistance of readings from cloud indicators, balloons are to be flown into cloud and maintained as high as possible without protruding above. Should cloud indicator readings not be available, balloons are to be flown into cloud base.

(b) By Night

(i) During hours of darkness, cloud conditions may be ignored, except between moon-rise and moon-set, and balloons are to be flown to as great a height as other considerations of weather may permit.

(ii) Between the hours of moon-rise and moon-set the same considerations apply as during the hours of daylight.

(c) In Lightning Conditions

When flying the appropriate category in high lightning risks, the choice of R.O.H. is to be dictated by the considerations set out in sub-paras. (a) and (b) above. No effort should be made to avoid flying balloons into cloud as it has been established that such a course does not minimise the risk of losses from lightning.

(d) When under Over-riding Control

When any balloons in the barrage are under Over-riding Control, the R.O.H. of the balloons concerned will not exceed the controlled height.

(e) In Series Armed Barrages

In Series Armed Barrages in order to minimise the length of the unarmed cable between the No.2 D.P.L. Unit and the central anchorage or winch lead-off, the selection of an R.O.H. between 1600 feet and 2300 feet should be avoided.

Maximum Height of Balloons

3. The following are the maximum heights to which balloons may be flown:-

(a) L.Z. Balloons (all "Marks")

(i) Manned sites 6,500 feet paid cable.

(ii) Unmanned or buoy sites 2,500 feet paid cable.

(iii) T.C.B. sites 3,000 feet altitude.

(b) Mark VI Balloons

(i) R.A.F. armed on piano wire 2,000 paid cable.

(ii) Admiralty armed "A" or "B" rig on K.B.I. cable, 1,000 feet paid cable.

(iii) Flown in tandem R.A.F. armed on piano wire 4,500 feet paid cable.

(c) Mark XIII Balloons

As for Mark VI Balloons.

Waterborne (manned sites close-haul)

4. Waterborne manned sites are considered as close-hauled when flying at any height below 1,000 feet paid cable.

Target Indication

5. When low cloud, fog, ground mist or industrial haze is sufficiently dense, balloons can act as target indicators to enemy aircraft, more especially over isolated V.Ps. In such conditions the following considerations are to be borne in mind by Barrage Commanders

(a) If the Barrage Commander is satisfied that the ground is completely obscured from aerial observation, he may keep his balloons grounded in spite of having received a "shine" order from Fighter Group Headquarters. In arriving at such a decision, he should have obtained corroborative evidence from the Meteorological Officer and/or duty pilots at nearby flying stations.

(b) If the ground is not completely obscured, he should fly his balloons into the fog or haze, provided that this height is a safe one. If it is impossible to maintain balloons at this height the R.O.H. may be fixed up to the maximum laid down in para. 3(a) above.

Special Considerations

6. From the 1st May to the 30th September, in conditions when the direct rays of the sun on balloons are likely to cause super-heating, balloons are not to be flown above 4,000 feet paid cable, except when the barrage area is threatened by hostile attack. This instruction is to apply to the period commencing four hours after sunrise and ending one hour after sunset.

BALLOON COMMAND

AIR STAFF INSTRUCTIONS PART I

Audible Lightning Predictors

Function of Audible Lightning Predictors (A.L.P.)

1. Audible Lightning Predictors have been installed at various barrages for the purpose of providing an automatic warning at the appropriate Flight Headquarters of the approach of dangerous lightning conditions.

Allocation and Siting of A.L.P.

2. (a) Allocation of A.L.P.s to barrages will be made by Balloon Command.

(b) The selection of A.L.P. sites within a barrage is to be made by the Barrage Commander with the approval of Group Headquarters. The Barrage Commander will be governed by the following considerations when selecting suitable sites:-

(i) A.L.P. should be located on perimeter sites and as widely dispersed as possible in order that the maximum warning of lightning conditions can be obtained.

(ii) A.L.P. should always be installed on Category 1 sites.

(iii) The selected site must be one provided with a direct private wire telephone circuit.

(iv) Not more than one A.L.P. warning apparatus is to be installed at any Flight Headquarters.

(v) The selected site is not to be a "Cloud Indicator Site".

(vi) Siting should take into account the prevalent wind conditions and the direction from which storms normally approach the barrage area.

(vii) For reasons of insulation it is necessary that a mobile winch be used.

(c) (i) The sites selected for A.L.P. are to be notified to Group Headquarters, who in turn will notify Balloon Command.

(ii) Any change in A.L.P. siting is also to be notified to Group Headquarters, who will notify Balloon Command.

Method of Using A.L.P.

3. Method of operation of A.L.P. apparatus is fully described in A.P.1634E, Volume 1, Section 1, Chapter 8.

Operational Use of A.L.P.

4. Flight Headquarters are to advise the Barrage Controller forthwith of any warnings received from the A.L.P. apparatus, stating whether they are "steady" or "transient" and giving the time of the occurrence. The Barrage Controller is to take the following action:

(a) "Steady Warning"

(i) Immediately impose the highest lightning risk over the area in which the warning has been received and take all necessary action to safeguard his balloons in accordance with the provisions of Air Staff Instructions Part I, Serial No.118, dated 16th December, 1942.

(ii) Advise the local Meteorological Service of the warning.

(b) "Transient Warning"

(i) Advise the local Meteorological Service of the warning who may or may not decide to impose a lightning risk or upgrade the existing one, depending on the other information available to them.

Recording of A.L.P. Warnings

5. (a) In order that the information required by Operations and Engineering Branches at Headquarters, Balloon Command may be readily available, a log is to be kept of all A.L.P. warnings received at Barrage Control.

(b) The log will record the following information:-

(i) Date and time of warning.

(ii) Site number.

(iii) Type of warning received (steady or transient).

(iv) Category of existing risk.

(v) Estimated direction and speed of movement of the storm, if this can be ascertained.

(vi) The height at which the A.L.P. balloon was flying and the average height at which the other balloons in the barrage were flying.

(vii) A remarks column in which will be recorded the times and site numbers of any balloon struck by lightning shortly before or after the warning, or any other information of a useful character.

Balloons Struck by Lightning

6. Whenever balloons are struck by lightning notification of the performance of the A.L.P. apparatus is to be added to the "Y" Return as instructed in Air Staff Instructions, Part I, Serial No.120, para. 4.

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Date 23.8.43
Cancelling No.110 dated
1.4.41

BALLOON COMMAND

AIR STAFF INSTRUCTIONS PART I

Changing in Operational Position

Notifiable Changes

1. A "Dull" and "Shining" report, showing the operational state will be sent immediately:-

(a) An alteration in the altitude of the whole or part of the Barrage of 500 feet or more takes place except:-

(i) Variations in altitude as the result of the imposition or release of standing terminable controls.

(ii) Variations in altitude or second line barrages between ground and 500 feet.

(b) On the imposition or release of the following controls:-

(i) Standing Over-riding.

(ii) General Purpose terminable and over-riding.

(c) The R.O.H. of a barrage has been altered by 1,000 feet or more.

(d) The number of balloons flying, or which will fly on a "shine" order, has been altered.

Method of Communication

2. (a) Changes are to be notified by telephone message originated at Barrage Control to:-

(i) Balloon Group Operations Room.

(ii) Balloon Command Operations Room.

(b) Messages will be routed in accordance with instructions issued by Group Headquarters and will be given "Ops" Priority II or III prefix depending on the urgency of the message.

(c) The Balloon Officer at the appropriate Fighter Group is to be notified of such changes in the operational position as he may from time to time require. Fullest use will be made of Priority prefixes as laid down in Balloon Command Signals Instruction, Section 1, Serial No.4, dated 1st June, 1943, to ensure rapid transmission of these messages.

Time when Message Originated

3. (a) When balloons are grounded or lowered in height, the message will be sent as soon as the last balloon has reached "Point of Attachment" or the reduced height ordered.

(b) When balloons are ordered upward the message will be sent as soon as the order has been received by Barrage Control.

Form of Message

4. (a) The message is to refer to the Barrage by its code name.

(b) The time when the change was ordered will be given.

(c) Balloons flying will be referred to as "Shining" and balloons close-hauled or bedded down as "Dull". The term "Dull" will also be used in the following circumstances.

(i) All sites in a first line barrage when flying up to a height of 1500 feet, except when barrage receives an operational "shine" and remains at 1500 feet or less.

(ii) Land sites in a second line barrage when flying up to a height of 500 feet, except when barrage receives an operational "shine" and remains at 500 feet or less.

(iii) Waterborne balloons when flying at 1,000 feet or less (height is always to be stated).

(d) The number of balloons "shining" or "dull" is always to be given and a distinction drawn between land sites and waterborne sites (the number of vessels and buoy balloons are to be given separately).

5. The reason for the grounding or alteration in altitude is to be stated according to the following key:-

1. Lightning.
2. Wind.
3. Snow or Ice.
4. Target Indication.
5. Control, type of control to be stated.

6. In addition to routine "dull" and "shining" messages, Barrages are to make a "Dull/Shining" report daily at 0700 hours.

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BALLOON COMMAND

AIR STAFF INSTRUCTIONS PART I

Arming of Balloon Cables

Appendix "A" List of Series Armed Barrages

Intention

All cables of balloons flying at R.O.H. for any purpose, subject to the subsequent provisions of this instruction, will be so armed as to render the maximum length of the cable lethal.

2. In order to avoid:-

(i) Delay in completing the operation.

(ii) Unsatisfactory cable angles, discretions as laid down in A.S.I. Part II, Vol. I, Section B, Ser. 5, Page 7, is to be granted to the N.C.O. in charge of the crew in regard to length of the cable to be paid out before fitting lower D.P.L. Unit.

3. The first line barrages listed at Appendix "A" are to be Series Armed. Future amendments to this appendix will constitute the authority to Series Arm or to discontinue Series Arming Barrages, as may be necessary.

Fitting of D.P/R. Links Mark II

4. The D.P/R. Link, Mark II is permanently positioned between the triangular link and the crossover.

5. D.P/R. Links will be set at "SAFE" when the balloons are bedded. Unless ordered otherwise by Balloon Control, they will be maintained at "LIVE" on all other occasions.

Fitting of D.P.L. Links

6. (i) A minimum distance of 800 feet is to be maintained between the D.P/R. Link Mark II and the DP/L. Unit, or between any two D.P.L. Units arming a section of cable.

(ii) The normal position of a lower D.P/L. Unit is 100 feet above the central anchorage snatchblock or winch leadoff, but an increase in this height is permissable on certain sites to guard against the parachute fouling local obstructions in the event of an impact or during operations.

(iii) Except in barrages which are Series Armed D.P.L. Units will only be fitted when balloons are flown at R.O.H., or for training purposes as laid down in A.S.I. Part I, Serial No.117, para.15.

Series Arming, General Principles

7. The Series Arming of balloon cables is subject to the following qualifications:-

(i) When winds of gale force are expected, category 2 and category 3 balloons will be single armed.

(ii) When prevailing lightning risk is B or D category 2 and category 3 balloons will be single armed.

(iii) When weather conditions are such that all categories of land balloons would be grounded or only category 1 flown, waterborne balloons will be single armed.

(iv) When a balloon in a Series Armed Barrage is raised to R.O.H. from a height below 900 feet, the cable will be single armed.

Series Armed Barrages - Fitting of D.P.L. Units

8. When Series Arming a balloon cable a D.P/R. Link Mark II is fitted in the usual manner, and three D.P.L. Units are to be used as follows:-

(i) D.P.L. Unit No.1, will be fitted to function as a "Lower Unit" wherever the balloon is flown at normal height or any height which will allow of the minimum distance of 800 feet between the D.P/R. Link Mark II and the D.P.L. Unit being maintained.

(ii) D.P.L. Unit No.2, will be fitted at the same time as D.P.L. Unit No.1, but to function as an Upper Unit with its parachute bag 5 feet below the parachute bag of D.P.L. Unit No.1.

(iii) Subject to 6(ii) above, D.P.L. Unit No.3 will be fitted to function as a "Lower Unit" whenever a Series Armed Balloon is raised to M.O.H., provided that the minimum distance of 800 feet between it and D.P.L. Unit No.2 can be maintained.

(iv) In view of the tactics likely to be adopted by the enemy in first line barrage areas, it is desirable that, subject to para. 6(ii) above, the position of number 3 D.P.L. Unit should be such as will afford the maximum length of armed cable.

Setting of D.P.L. Units

9. All D.P.L. Units will normally be flown at "LIVE". The Safety Pins, after removal, are to be hung in the winch cage.

APPENDIX "A"

TO AIR STAFF INSTRUCTIONS PART I SERIAL No.126

List of Series Armed Barrages

30 Group	Southampton Portsmouth Weybridge Langley Chelmsford Canterbury Norwich Gt.Yarmouth and Lowestoft London Dover
32 Group	Yeovil Falmouth
33 Group	Newcastle Billingham Hull Sunderland

SECRET

APPENDIX "N"

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BALLOON COMMAND

AIR STAFF INSTRUCTIONS PART I

Collisions with Barrage Balloon Cables by Aircraft

1. In the event of a collision occurring between a balloon and an aircraft, whether friendly or hostile, the following action is to be taken:-

Signal giving details of the accident to be dispatched immediately by the Barrage Commander to Headquarters, Balloon Command, repeated to the Group.

The signal is to be sent by teleprinter "SECRET not W/T" with priority of "Immediate".

The signal is to give the following information:-

(i) Hostile or friendly aircraft, state type if known, giving such information as the Unit or Station to which the aircraft belongs, which will enable identification to be made.

Raid number, if hostile.

Name of Barrage and Site Number.

Time and Date.

Height of Balloon.

Type of Cable.

Whether section of cable impacted was fully armed.

Height of impact.

Effect on aircraft if known.

Present location of aircraft and crew; distance of crashed aircraft from site.

Whether "Squeekers" were operational, specify type.

This signal is not to be delayed if the information required under (i), (ii) or (x) is not immediately available.

2. If the aircraft is hostile, a second signal is to be sent with "IMMEDIATE" priority, addressed to Headquarters, Balloon Command, repeated to Group, giving the following additional information as soon as it is available:-

(i) 1" co-ordinate of the crash.

(ii) Whether aircraft was engaged by A.A. fire before or after impact.

(iii) Whether aircraft is claimed exclusively by Balloon Barrage.

(iv) Brief resume of events immediately prior to, and after impact.

(v) Any details omitted in previous signal.

3. A report is to be submitted in quintuplicate by Group Headquarters to Headquarters, Balloon Command, and is to be prepared by the Group Armament Officer, if available, otherwise by an officer selected by Group Headquarters for his knowledge and experience in Balloon Armament.

The purpose of this report is to present a picture of the events leading up to the impact, consequent results and evidence from which further knowledge may be gained of the effectiveness of balloon cables whether armed or unarmed.

Narrative

This should give a general description of the impact, eye witness accounts, if available, should be attached in the form of appendices.

Technical Report

This report is to provide an answer to the following questions. As the pro-forma may not be available to all recipients both question and answer are to be set down together:-

(i) Identity of aircraft, whether friendly or hostile, type and number if known.

(ii) Name of Barrage.

(iii) Time and date of impact.

(iv) Height of balloon.

(v) Type of cable.

(vi) Details of armament fitted, and whether Mark I or Mark II Cramp used for fixing wedges.

(vii) Height of impact.

(viii) Effect on aircraft and crew.

(ix) Present location of crew and aircraft, if known.

(x) Whether "Squeekers" were operational, specify type.

(xi) Direction of impact in relation to the wind; state angle of aircraft in turn, climb, or dive.

(xii) Speed of aircraft at time of impact.

(xiii) Effect on cable and winch.

(xiv) Action of armament units.

(xv) Reason for any failure of armament.

(xvi) Date when armament was last inspected and serviced.

(xvii) Action of D.P.R.Link, if applicable.

(xviii) Was aircraft fitted with cable cutter, state action if known.

(xix) Name and Unit of officer who prepared the report.

NOTE. The officer making the report should amplify his answers wherever he considers it desirable.

APPENDIX "N"

Serial No. 128
Date 3.6.44
Page 1
Cancelling Serial No.115
dated 3.2.42

BALLOON COMMAND

AIR STAFF INSTRUCTIONS PART I

A.A. Defence - Machine Guns

Policy

1. (i) Selected Units of the Command in areas especially liable to low flying attack by enemy aircraft have been issued with machine guns. These machine guns will be mounted as twin A.A. Guns to the approved scale issued under this Headquarters Schedule reference KBC/1374/43/Arm. and any amendments thereto.

(ii) The policy for the engagement of enemy aircraft by all forms of A.A. fire is the responsibility of the A.A. Defence Commander in each area.

(iii) Barrage Commanders and Unit Commanders are to obtain the A.A. Defence Commander's agreement to the siting of machine guns and the fire orders to be issued to the gun crews.

Siting

2. The twin machine guns are to be sited:-

(i) To produce the maximum concentration of fire over the V.P.

(ii) To provide the maximum volume of fire in the lanes of approach to and departure from the V.P. not covered by other L.A.A. Guns.

(iii) To have a clear field of fire.

Manning of Machine Guns

3. (i) At balloon sites machine guns will be manned:-

(a) automatically on the sounding of local sirens.

(b) on the order of the Barrage Commander if a dangerous plot appears.

(ii) At centres and units other than balloon sites:-

(a) automatically on the sounding of local sirens.

(b) on the order of the Unit Commander on any other occasion at his discretion.

4. Subject to the provisions of para. 1(iii) above, instructions are to be given to the i/c crew to open fire without any further reference when a target is within 1000 yards under the following conditions:-

(i) Against aircraft definitely identified as hostile irrespective of whether a hostile act has been committed.

(ii) At flares dropped by hostile aircraft over a target area.

(iii) At parachute mines dropped over the target area, but before these fall within 400 feet of the ground.

5. The i/c crew is to be instructed to report as soon as possible to the Barrage Commander or Unit Commander, through the usual channels, the circumstances and results obtained when a target has been engaged.

6. Instructions contained in this Headquarters' letter KBC/S.57424/147/Arm dated 17th January, 1944 are cancelled.