

AIR MINISTRY

METEOROLOGICAL OFFICE

REPORT OF THE CONFERENCE
OF
EMPIRE METEOROLOGISTS
LONDON

August 20—September 3, 1929

Published by the Authority of the Meteorological Committee.



LONDON :
PRINTED AND PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE:

1930.

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LIST OF DELEGATES.

| | | |
|--|-------------------------------|--|
| Australia | Capt. H. J. Feakes, R.A.N. .. | Commonwealth Naval Representative in London. |
| Barbados | Mr. C. J. P. Cave | — |
| Canada and Newfoundland | Mr. J. Patterson | Director, Canadian Meteorological Service. |
| Ceylon | Mr. A. J. Bamford | Superintendent, Colombo Observatory. |
| East African Group (Kenya, North Rhodesia, Tanganyika, Uganda, Zanzibar) and | Mr. A. Walter | Director, British East African Meteorological Service. |
| S. Rhodesia | | |
| Sudan | | |
| Egypt (unofficial observer) | Mr. L. J. Sutton | Director, Meteorological Service. |
| Gambia | Mr. A. J. Brooks | Director of Agriculture. |
| Gold Coast | Mr. Auchinleck | Director of Agriculture. |
| | Mr. N. P. Chamney | Superintendent of Agriculture. |
| Great Britain | Dr. G. C. Simpson | Director, Meteorological Office. |
| Hong Kong | Mr. T. F. Claxton | Director, Royal Observatory. |
| India | Dr. C. W. B. Normand | Director-General of Observatories. |
| Irish Free State | Mr. M. H. Eliassoff | — |
| Leeward Islands | Mr. H. H. Croucher | Imperial College of Tropical Agriculture, Trinidad. |
| Malaya | Mr. J. Dewar | Assistant Surveyor-General. |
| New Zealand | Mr. D. C. Bates | — |
| Nigeria | Capt. J. Calder Wood | Deputy Surveyor-General. |
| | Mr. S. M. Jacob | Government Statistician. |
| Nyasaland | Mr. E. J. Wortley | Director of Agriculture. |
| Sierra Leone | Mr. R. Temple | Lands Officer. |
| Somaliland | Dr. R. S. Taylor | Principal Medical Officer. |
| South Africa | Mr. C. Stewart | Chief Meteorologist. |
| Trinidad | Capt. A. B. Smith, R.N.R. .. | Harbour Master. |
| Uganda | Mr. C. G. Hansford | Mycologist. |
| Windward Islands | Major E. E. Turner | Chief of Police, Grenada. |

AGRICULTURAL SECTION.

In addition to the delegates to the Conference, whose names are given on the preceding page, the following attended the meetings of the Agricultural Section.

| | | |
|------------------------|---------------------------------------|--|
| Australia | Mr. A. S. Fitzpatrick. | — |
| Ceylon | Mr. T. H. Holland | Manager, Experiment Station, Peradeniya. |
| Egypt | Dr. Lawrence Balls | Chief Botanist. |
| | Dr. J. Templeton | First Botanist. |
| Gold Coast | Mr. H. Nicholas | Superintendent of Agriculture. |
| | Mr. A. C. Miles | " " |
| New Zealand | Dr. G. H. Cunningham | Plants Research Officer. |
| Northern Ireland | Mr. Ian W. Seaton | Ministry of Agriculture. |
| Nyasaland | Capt. A. J. W. Hornby | Agricultural Chemist. |
| Sudan | Mr. W. A. Davie | Director of Agriculture and Forests. |
| Trinidad | Sir Algernon Aspinall, C.M.G., C.B.E. | Secretary, Imperial College of Tropical Agriculture. |

PROGRAMME.

The meetings from August 20-27 inclusive, were held at the Air Ministry, Adastral House, Kingsway, W.C.2.; those on August 28, 29 and 30, and September 4 in the Large Hall, Civil Service Commission, Burlington Gardens, W.1., and the eighteenth meeting at the Meteorological Office, Air Ministry, South Kensington.

TUESDAY, AUGUST 20TH.

Morning.

11 a.m.—Opening meeting to be presided over by the Secretary of State for Air.

Afternoon.

3 p.m.—Informal meeting to consider the details of the programme and subjects for the Agenda.

Evening.

8.30 to 11 p.m.—Reception by Dr. and Mrs. G. C. SIMPSON, at the Meteorological Office, South Kensington.

WEDNESDAY, AUGUST 21ST.

Morning.—Papers on Meteorology and Aviation.

10.30 to 11.15 a.m.—Aeroplanes and Aeroplane Routes. By Capt. F. ENTWISTLE, B.Sc., Superintendent, Aviation Services Division.

11.30 a.m. to 12.15 p.m.—Airships and Airship Operations. By Mr. M. A. GIBLETT, M.Sc., Superintendent, Airship Services Division.

12.30 p.m. to 1.0 p.m.—International Commission for Air Navigation. By Lieut.-Col. E. GOLD, D.S.O., F.R.S., Assistant Director.

Afternoon.—Visit to Croydon Aerodrome.

2.15 p.m.—Motor Coach leaves Kingsway (Adastral House).

6.30 p.m. (approx.)—Arrive in London on return.

THURSDAY, AUGUST 22ND.

All Day.—Visit to Royal Airship Works, Cardington.

9.0 a.m. (sharp).—Motor coach leaves Kingsway (Adastral House).

7.15 p.m. (approx.)—Arrive in London on return.

FRIDAY, AUGUST 23RD.

Morning.

10.30 a.m.—Discussion on Meteorology and Aviation.

Afternoon.

3 p.m.—Discussion on Meteorology and Aviation.

Evening.

7.45 p.m.—Government dinner at Lancaster House, St. James's.

SATURDAY, AUGUST 24TH.

Morning.

10.30 a.m.—Marine Meteorology.—(a) Meteorological Log; (b) Collection, Computation and Exchange of Marine Meteorological Data; (c) Ocean Currents. The discussion will be opened by Capt. L. A. BROOKE SMITH, R.N.R., Marine Superintendent.

Afternoon.—Kew Observatory.

3 p.m.—Kew Observatory, Old Deer Park, Richmond, open to Delegates and friends.

MONDAY, AUGUST 26TH.

Morning.

10 to 10.30 a.m.—Visit to British Tabulating Company, General Buildings, Aldwych, to see working of Hollerith machines with marine data.

10.45 a.m.—Marine Meteorology.—(a) The "Selected Ship"; (b) Ships' Wireless Weather Code. The discussion will be opened by Capt. L. A. BROOKE SMITH, R.N.R., Marine Superintendent.

Afternoon.

3 to 3.45 p.m.—Meteorology for the Army. The discussion will be opened by Mr. D. BRUNT, M.A., Superintendent, Army Services Division.

4 to 4.45 p.m.—Meteorology for the Royal Navy. The discussion will be opened by Cmdr. L. G. GARBETT, R.N., Superintendent, Navy Services Division.

TUESDAY, AUGUST 27TH.

Morning.

10.30 a.m.—Marine Meteorology.—(a) Weather Shipping Bulletins; (b) Wireless Gale and Hurricane Warnings; (c) Visual Gale and Hurricane Warnings. The discussion will be opened by Capt. L. A. BROOKE SMITH, R.N.R., Marine Superintendent.

Afternoon.

3 p.m.—General Questions.—(a) Polar Year; (b) Interchange of Personnel, etc.

WEDNESDAY, AUGUST 28TH.

Morning.

10.30 a.m.—Seasonal Forecasting. Paper by Sir GILBERT WALKER, F.R.S. Discussion.

Afternoon.

2.30 p.m.—General Climatology. The Collection, Tabulation and Publication of Climatological Data. Paper by Dr. C. E. P. BROOKS, Superintendent, General Climatology Division. Discussion.

Evening.

8.30 to 11 p.m.—Reception by Col. Sir HENRY LYONS, F.R.S., at the Science Museum, South Kensington.

THURSDAY, AUGUST 29TH.

JOINT SESSIONS WITH AGRICULTURAL SECTION (CHAIRMAN: SIR NAPIER SHAW, F.R.S.).

Morning.

10.30 a.m.—Historical Review. Plant Physiology and Meteorology. Light and Growth.

Afternoon.

2.30 p.m.—Fruit Production and Meteorology.

FRIDAY, AUGUST 30TH.

JOINT SESSION.

Morning.

10.30 a.m.—Climate and Animal Distribution. Weather and Insects. Weather and Fungus Diseases of Plants.

Afternoon.

2.30 p.m.—Use of Meteorological Data in the Improvement of Crop Estimates.

SATURDAY, AUGUST 31ST.

JOINT SESSION.

All day.—Visits to the Royal Horticultural Society's Gardens, Wisley, and the Lord Wandsworth Agricultural College, Long Sutton, to inspect agricultural meteorological work. Delegates have been invited to be the guests at lunch of the Royal Horticultural Society.

9 a.m.—Leave Burlington Gardens.

7.30 p.m.—Arrive in London on return.

MONDAY, SEPTEMBER 2ND.

JOINT SESSION.

All day.—Visit to Rothamsted Experimental Station to inspect agricultural meteorological work.

9 a.m.—Leave Burlington Gardens.

6.30 p.m.—Arrive in London on return.

TUESDAY, SEPTEMBER 3RD.

10.30 a.m.—Informal talk about meteorological instruments.

WEDNESDAY, SEPTEMBER 4TH.

2.30 p.m.—Final Joint Session.

REPORT OF THE MEETINGS OF THE CONFERENCE

MINUTES No. 1.

Opening Meeting on the 20th of August, 1929, at 11 a.m.

The meeting was held at the Air Ministry, Adastral House, Kingsway, W.C.2.

Lord Thomson, Secretary of State for Air presided over the opening ceremony, and personally welcomed the delegates before the meeting.

The following delegates were present:—Mr. G. Auchinleck (Gold Coast), Mr. A. J. Bamford (Ceylon), Lieut.-Col. D. C. Bates (New Zealand), Mr. A. J. Brooks (Gambia), Mr. C. J. P. Cave (Barbados), Mr. N. P. Chamney (Gold Coast), Mr. T. F. Claxton (Hong Kong), Mr. H. H. Croucher (Leeward Islands), Mr. J. Dewar (Malaya), Mr. M. H. Eliassoff (Irish Free State), Capt. H. J. Feakes, R.A.N. (Australia), Mr. S. M. Jacob (Nigeria), Dr. C. W. B. Normand (India), Mr. J. Patterson (Canada and Newfoundland), Dr. G. C. Simpson (Great Britain), Capt. A. B. Smith, R.N.R. (Trinidad), Mr. C. Stewart (South Africa), Mr. L. J. Sutton (Egypt), Dr. R. S. Taylor (Somaliland), Mr. R. Temple (Sierra Leone), Major E. E. Turner (Windward Islands), Mr. A. Walter (E. Africa, S. Rhodesia and Sudan), Capt. J. Calder Wood (Nigeria), Mr. E. J. Wortley (Nyasaland).

The following members of the staff of the Meteorological Office were also present: Mr. R. G. K. Lempfert, Col. E. Gold, Dr. F. J. W. Whipple, Capt. D. Brunt (Army Services), Cmdr. L. G. Garbett, R.N. (Navy Services), Mr. M. A. Giblett (Airship Services), Capt. F. Entwistle (Aviation Services).

Copies of the programme of the Conference, the list of delegates and agenda of the opening meeting were circulated.

1. **Address by the Secretary of State.**—Lord THOMSON, Secretary of State for Air, welcomed the delegates in the following words:—

Gentlemen, it is my pleasant task to-day to welcome you here to London and to England generally. The object of this Conference is to establish methods of co-operation in meteorological work, you are expected to discuss various questions on which it is hoped that we, as members of the British Empire, may co-operate helpfully with one another. Among the more important points which will be brought before the Conference is, to begin with, MARINE METEOROLOGY. It is a well-known fact that with the aid of wireless telegraphy it has been possible to receive and send messages to ships at sea, and much useful information has been derived therefrom. It has been noticed, however, that there is no general method for sending or receiving, and it is hoped that at this Conference we, as members of the British Empire, will establish between ourselves some common method so that all British ships at least can receive and impart information in accordance with similar instructions, and follow similar methods. By so doing a great deal of complication and difficulty will be avoided. There is very little doubt that if the British set the example in this respect it will be followed by most other maritime people in the world.

There is another point which will be brought before you and that is the relation of meteorology with the services for which this building is especially constructed—I refer to AVIATION. In that respect we here in Britain have indulged in considerable activity during the past few years, ever since the war, and it is desired to put at your disposal all the information we have gathered in the course of those years with the object of obtaining some common method for relating the services of meteorology to aviation throughout the Empire. Personally, though claiming no technical knowledge of meteorology and knowing nothing about the details of aviation, ever since I have taken it in hand, so to speak, I have felt that the application of meteorology to aviation is the real secret of success in air transport. I am convinced that in the years to come aeroplanes, if properly guided by meteorological advice, will be able to save an immense amount of fuel, to seek out favouring winds and follow routes as yet undreamed of in navigating the surface of the world. What I have said applies even more to the navigation of airships. Airships will really be the handmaidens for meteorological services—or perhaps I should reverse the order—but in any case I cannot see how the navigation of airships is going to be effective without a very great development in meteorological science. The astounding performance of Dr. Eckener within the past few days is really only a very small beginning of what will, I believe, be accomplished by airships in the future. Those ships will be continually in touch with meteorological stations and will find their way through storm areas in exactly the same way as a mariner upon the sea finds his way through shoals and rocks, by charts. It is to my mind one of the most important functions of the Empire to-day to get throughout our far-flung territories the very best meteorological service that can be devised; it will from its very nature be of world-wide service and give us the unique position in the world that we have held hitherto in other branches of transport and which we naturally desire to maintain in the navigation of the air.

There is another point which will be brought to your notice and that is the connection between meteorological observations and AGRICULTURE. The Ministry of Agriculture has requested that two days at least of this Conference shall be devoted to studying agricultural questions. Agriculture, like aviation, must depend to some extent on knowledge of variations in the weather. It is many years since an old Bishop of Chester, called Wilkins, pointed out how much loss was incurred by agriculturists through weather and ignorance of weather conditions and seasonal variations. It was indeed this worthy Bishop who, I forget how many centuries ago, said that, in order to get full knowledge of meteorological conditions, it would be necessary to establish stations as far north as possible and as far south as possible. That is not being overlooked so far as I can judge by those who have organised this Conference, because I notice that one of the points you have to discuss is the POLAR YEAR. The Polar Year is to arrive in 1932-33 I understand, and what is exactly meant by a Polar Year I do not know. I trust I shall learn by reading your proceedings. I remember so well when Sir Hubert Wilkins was over here and we gave a lunch in his honour, I asked "Are you by any chance a descendant of that worthy Bishop?" he said "Of course I am, I have studied his works with the greatest care". This remote descendant, at least two centuries afterwards, was really inspired to make his explorations first in the Arctic and later in the Antarctic by the desire to realise the vision of his ancestor.

There are many other points which you are going to discuss, which I understand are not only to be scientific but of practical value. Possibly the best way of discussing such questions is to meet as you are meeting to-day and will meet for many days to come, because, by such direct intercourse you are better able to give and receive information. I can assure you of this, that, as a representative of the Government, and speaking for the Government, we take a very keen interest in your efforts and we wish you all success. We hope the fruits of this Conference will be the adoption of more uniform method in meteorology throughout the British Empire. It is with that wish that I will conclude my remarks and again repeat the welcome I offer you to London.

2. **Election of a President of the Conference.**—Mr. J. PATTERSON proposed that Dr. G. C. Simpson, Director of the Meteorological Office, London, should be elected President of the Conference. The proposal was seconded by Dr. C. W. B. NORMAND and was unanimously adopted.

The Secretary of State vacated the chair which was then taken by Dr. G. C. Simpson. Dr. Simpson expressed the thanks of the delegates to Lord Thomson for coming to preside at the opening ceremony and for his address.

3. **Address by the Director of the Meteorological Office, outlining the work before the Conference.**—Dr. SIMPSON proceeded to give a brief summary of the various items which it was proposed should be discussed at the meetings. He emphasised the progress which had been made in meteorology during and since the war—progress which he attributed in large measure to the development of aviation and wireless telegraphy. He said that immediately after the war Sir Napier Shaw, realising the importance of co-operation both international and within the Empire had arranged for a Conference of the directors of the meteorological services of the Empire. At that Conference, Australia, Canada, Ceylon, Great Britain, India, New Zealand and South Africa had been represented and three of the representatives were here at the present meeting.

Dr. Simpson then described the reasons which had led to the calling of the present Conference—the necessity for organization of airships and aeroplane routes, the great need for additional observations in the smaller colonies where no organized meteorological service exists, and the desirability that the experience of the various parts of the Empire should be placed at the disposal of the rest. He expressed his gratification that the Conference was so widely representative.

Dr. Simpson traced the development of organized meteorology from the separate and isolated national services in which it originated to the vast network which existed to-day, a network in which the various services were united by close international co-operation.

He then proceeded to go through the various items of the programme:

(i) **Aviation.**—The meeting on Wednesday morning was allotted to three papers on aviation—

(a) The problems of aeroplane aviation would be dealt with in a memorandum by Capt. Entwistle and the questions involved included the choice of routes and aerodromes, the ground organization after the route was fixed, the interchange of information along the route, and the provision for meteorological organization in the case of long-distance flights.

(b) The meteorological problems in relation to airship navigation though to a certain extent the same as those of aeroplanes required special consideration and would be dealt with in detail in a memorandum by Mr. M. A. Giblett.

The subjects included the supply of synoptic charts to airship navigators at short intervals, say every six hours; and the supply of adequate ground organization.

Further the question of the navigation of airships in thunderstorms required special consideration by meteorologists in view of the large upward currents which occurred.

(c) **International co-operation in aviation** had an economic as well as a meteorological aspect. Col. Gold, the president of the Sub-Committee on Meteorology of the International Commission for Aerial Navigation, (I.C.A.N.) would deal with the questions of the relationship of the meteorological services of the Empire with that organization.

Arrangements had been made for the delegates to see the meteorological organization in operation in this country for civil air routes by a visit to Croydon Aerodrome on Wednesday afternoon (August 21st) and for airships by a whole-day expedition to Cardington on Thursday (August 22nd).

(ii) **Marine Meteorology.**—The outstanding problem of marine meteorology was to come to an agreement as to what observations should be collected, how and when they should be made and how they should be collated. The questions were dealt with in a memorandum by Cmdr. L. A. Brooke Smith, R.N.R., and three mornings (Saturday, Monday and Tuesday) had been assigned to the discussion. A proposal would be put forward for the adoption of a uniform ship's log in all parts of the Empire and it was hoped that an arrangement might be made by which each part of the Empire would make itself responsible for the collection of data from a certain area.

The possibilities of using a Hollerith machine as an aid in the statistical processes of summarising the data would be explored.

It is further very desirable that the arrangements for transmitting messages by wireless telegraphy from ship to shore and from the shore to ship should be examined. With regard to the former (messages from ship to shore) some agreement was desirable as to the times at which the observations should be taken and despatched and as to the code with regard to the latter (messages from shore to ship), organization was required which would enable a ship to obtain data sufficient to allow a synoptic chart to be compiled on board; and it was desirable that the arrangements made should be uniform.

The possibility of a uniform system of visual gale warnings at coast stations would also be discussed.

(iii) **Meteorology for the Army and Navy.**—The meteorological requirements of the Army and Navy would be set out in memoranda by Mr. D. Brunt and Cmdr. L. G. Garbett which would be discussed on Monday afternoon (August 26th). Meteorological information was especially necessary for aircraft carriers and in connection with gunnery.

(iv) **The Polar Year, exchange of personnel**—and such other matters as might be suggested by delegates would be discussed on Tuesday afternoon (August 27th).

In connection with the Polar Year the suggestion had been made that the occasion of the first Polar Year of 1882-3 should be commemorated at its jubilee in 1932-3 by its repetition. Proposals were on foot for organizing special expeditions to Arctic and Antarctic regions in that year and it was hoped that the meteorological services of the Empire would take a prominent part in the work.

(v) **General climatology and seasonal forecasting.**—Climatology would form the subject of the meeting on Wednesday morning, August 28th, when proposals would be made for organizing methods on observation and publication. On Wednesday afternoon a paper by Sir Gilbert Walker on seasonal forecasting would be read, and contributions would also be made by Mr. C. Stewart and Dr. C. W. B. Normand.

(vi) **Meteorology and agriculture.**—At the request of the Ministry of Agriculture, Thursday and Friday, August 29th and 30th, would be devoted to questions relating to meteorology and agriculture.

Dr. Simpson then briefly enumerated the arrangements for social functions which had been made and which were set out in the programme.

He announced that an informal meeting would be held at 3 o'clock to enable delegates to put forward suggestions of subjects which they wished to discuss.

Mr. J. PATTERSON expressed the thanks of the delegates to Dr. Simpson for the arrangements which he had made for the meeting and for the very complete agenda which he had drawn up. He expressed his conviction that the Conference would be productive of good results.

The meeting adjourned at 12.15 p.m.

August 23, 1929.

(Signed) G. C. SIMPSON.

MINUTES No. II.

Second Meeting on the 21st of August, 1929, at 10.30 a.m.

The following delegates were present: Dr. G. C. Simpson (Great Britain: *President*) in the Chair, Mr. G. Auchinleck (Gold Coast), Mr. A. J. Bamford (Ceylon), Lieut.-Col. D. C. Bates (New Zealand), Mr. A. J. Brooks (Gambia), Mr. C. J. P. Cave (Barbados), Mr. N. P. Chamney (Gold Coast), Mr. T. F. Claxton (Hong Kong), Mr. H. H. Croucher (Leeward Islands), Mr. J. Dewar (Malaya), Mr. M. H. Eliassoff (Irish Free State), Mr. C. G. Hansford (Uganda), Mr. S. M. Jacob (Nigeria), Dr. C. W. B. Normand (India), Mr. J. Patterson (Canada and Newfoundland), Capt. A. B. Smith, R.N.R. (Trinidad), Mr. C. Stewart (South Africa), Mr. L. J. Sutton (Egypt), Dr. R. S. Taylor (Somaliland), Mr. R. Temple (Sierra Leone), Major E. E. Turner (Windward Islands), Mr. A. Walter (E. Africa, S. Rhodesia and Sudan), Capt. J. Calder Wood (Nigeria), Mr. E. J. Wortley (Nyasaland), Squadron-Leader H. N. Wrigley (Australia).

The following members of the staff of the Meteorological Office were also present: Mr. R. G. K. Lempfert, Col. E. Gold, Mr. D. Brunt, Mr. J. S. Dines, Capt. F. Entwistle, Mr. M. A. Giblett, Cmdr. L. G. Garbett, R.N.

1. **Documents circulated.**—(a) Minutes of the opening meeting, 20th August, (Minutes No. I).

(b) Memorandum on Meteorology and Aviation in the British Empire (Appendix I).

(c) Memorandum on Meteorology and Airships in the British Empire (Appendix II).

(d) Meteorology and the International Commission for Air Navigation. Memorandum by Col. Gold (Appendix III).

(e) Agenda for discussion on Aviation and Airships on Friday, August 23rd, 1929.

2. **Aeroplanes and Aeroplane routes.**—Capt. F. Entwistle (Superintendent of the Aviation Services Division) gave an account of his memorandum on Meteorology and Aviation (Appendix I).

3. **Airships and Airship Operations.**—Mr. M. A. Giblett (Superintendent, Airship Services Division) gave a brief account of his memorandum on Meteorology and Airships (Appendix II).

4. **International Commission for Air Navigation.**—Col. E. Gold gave a brief account of the history of the formation of the International Commission for Air Navigation as set out in his memorandum (Appendix III).

The meeting adjourned at 1.5 p.m.

August 24th, 1929.

(Signed) G. C. SIMPSON.

MINUTES No. III.

Third Meeting, on the 21st of August, 1929, at 2.15 p.m. Visit to Croydon Aerodrome.

The following delegates took part in the visit:—Dr. G. C. Simpson (Great Britain: *President*), Mr. G. Auchinleck (Gold Coast), Mr. A. J. Bamford (Ceylon), Lieut.-Col. D. C. Bates (New Zealand), Mr. N. P. Chamney (Gold Coast), Mr. T. F. Claxton (Hong Kong), Mr. H. H. Croucher (Leeward Islands), Mr. J. Dewar (Malaya), Mr. C. G. Hansford (Uganda), Mr. S. M. Jacob (Nigeria), Dr. C. W. B. Normand (India), Mr. J. Patterson (Canada), Capt. A. B. Smith, R.N.R. (Trinidad), Mr. C. Stewart (South Africa), Mr. L. J. Sutton (Egypt), Dr. R. S. Taylor (Somaliland), Mr. R. Temple (Sierra Leone), Major E. E. Turner (Windward Islands), Mr. A. Walter (East Africa, S. Rhodesia, Sudan), Capt. J. Calder Wood (Nigeria), Mr. E. J. Wortley (Nyasaland). There were also present:—Mr. R. G. Simmers (Meteorologist to the forthcoming *Discovery* Antarctic Expedition) and the following members of the staff of the Meteorological Office:—Mr. R. G. K. Lempfert, Capt. F. Entwistle, Mr. M. A. Giblett.

The delegates arrived at Croydon at 3 p.m. and were received by Major L. F. Richard (Chief Aerodrome Officer), Mr. F. Tymms (representing the Director of Civil Aviation) and Capt. A. S. Wilcockson (Acting Air Superintendent, Imperial Airways, Ltd.). They then inspected the main entrance hall, Major Richard explaining the system for reception of passengers, etc. Mr. Witcombe (Officer-in-Charge, Meteorological Office) explained the two large maps at the end of the hall, on which the weather reports from stations on the London-Continental air routes are posted as they are received.

The party then adjourned to the Board Room, where Mr. Tymms addressed them on "Civil Aviation Development," describing the increase in civil aviation in Europe in recent years and also forthcoming Imperial developments. He also emphasized the importance of ground organization in connection with the development of air routes. Mr. Tymms explained that Air Vice Marshal Sir Sefton Brancker had hoped to meet the delegates and address them personally, but that he was away on duty. A short discussion followed Mr. Tymms's address.

By the courtesy of Imperial Airways, Ltd., twenty of the delegates made a short flight in a three-engined "Argosy," one of the machines used on the regular Continental services. The inspection of the aerodrome was then resumed. The Meteorological Office was visited first and the organization for collecting and disseminating meteorological information along air routes explained. The delegates were then conducted by Major Richard to the Control Tower, where they inspected the arrangements for guiding and controlling the commercial aircraft on the civil air routes and also for determining the positions of aircraft by wireless direction finding.

After tea in the Aerodrome Hotel, the delegates left for London about 5.45 p.m.

August 27th, 1929.

(Signed) G. C. SIMPSON.

MINUTES No. IV.

Fourth Meeting on the 22nd of August, 1929, at 9 a.m.

Visit to Royal Airship Works, Cardington.

The following delegates were present:—Dr. G. C. Simpson (Great Britain: *President*), Mr. Auchinleck (Gold Coast), Mr. A. J. Bamford (Ceylon), Lieut.-Col. D. C. Bates (New Zealand), Mr. N. P. Chamney (Gold Coast), Mr. T. F. Claxton (Hong Kong), Mr. H. H. Croucher (Leeward Islands), Mr. J. Dewar (Malaya), Capt. H. J. Feakes, R.A.N. (Australia), Mr. C. G. Hansford (Uganda), Mr. S. M. Jacob (Nigeria), Dr. C. W. B. Normand (India), Mr. J. Patterson (Canada), Capt. A. B. Smith, R.N.R. (Trinidad), Mr. C. Stewart (South Africa), Mr. L. J. Sutton (Egypt), Dr. R. S. Taylor (Somaliland), Mr. R. Temple (Sierra Leone), Major E. E. Turner (Windward Islands), Mr. A. Walter (East Africa, S. Rhodesia, Sudan), Capt. J. Calder Wood (Nigeria), Mr. E. J. Wortley (Nyasaland).

The following members of the staff of the Meteorological Office (Headquarters) were also present:—Mr. R. G. K. Lempfert, Mr. F. Entwistle (Aviation Services) and Mr. M. A. Giblett (Airship Services). Mr. R. G. Simmers, Meteorologist to the Australian New Zealand and British Antarctic Expedition, 1929, was also present.

The party left Kingsway by motor coach at 9 a.m., arriving at Cardington shortly after 11 a.m. The morning was spent in visiting the mooring tower, fabric shops and the airship shed where H.M. Airship R.101 was inspected.

The afternoon was devoted to an inspection of the meteorological arrangements, to demonstration of small hydrogen generators for pilot-balloon work, and to the inspection of an exhibit of photographs, diagrams and records illustrating the application of meteorology to airships.

The party left Cardington by motor coach shortly after 5 p.m. for London.

September 3, 1929.

(Signed) G. C. SIMPSON.

MINUTES No. V.

Fifth Meeting Friday, the 23rd of August, 1929, at 10.30 a.m.

The following delegates were present:—Dr. G. C. Simpson (Great Britain: *President*) in the Chair, Mr. G. Auchinleck (Gold Coast), Mr. A. J. Bamford (Ceylon), Lieut.-Col. D. C. Bates (New Zealand), Mr. A. J. Brooks (Gambia), Mr. C. J. P. Cave (Barbados), Mr. N. P. Chamney (Gold Coast), Mr. T. F. Claxton (Hong Kong), Mr. H. H. Croucher (Leeward Islands), Mr. J. Dewar (Malaya), Mr. M. H. Eliassoff (Irish Free State), Capt. H. J. Feakes, R.A.N. (Australia), Mr. C. G. Hansford (Uganda), Mr. S. M. Jacob (Nigeria), Dr. C. W. B. Normand (India), Mr. J. Patterson (Canada), Capt. A. B. Smith, R.N.R. (Trinidad), Mr. C. Stewart (South Africa), Mr. L. J. Sutton (Egypt), Dr. R. S. Taylor (Somaliland), Mr. R. Temple (Sierra Leone), Mr. E. E. Turner (Windward Islands), Mr. A. Walter (E. Africa, S. Rhodesia and Sudan), Capt. J. Calder Wood (Nigeria), Mr. E. J. Wortley (Nyasaland), Squadron Leader H. N. Wrigley (Australia).

There were also present:—Mr. A. W. Paterson and the following members of the staff of the Meteorological Office:—Mr. R. G. K. Lempfert, Col. E. Gold, Mr. E. G. Bilham, Mr. D. Brunt, Capt. F. Entwistle, Cmdr. L. G. Garbett, R.N., Mr. M. A. Giblett.

1. **Minutes.**—The Minutes of the first meeting were signed as correct.
2. **Documents circulated.**—(a) Minutes of second meeting, 21st August.
(b) Note by Mr. A. Walter on "Weather Telegrams from Reporting Stations". (Appendix IV.)
(c) Note of Lord Thomson's speech at the opening meeting.
3. **Sub-Committees.**—The following sub-committees were appointed before the meeting:—

(a) *Meteorological organization on Cairo-Cape Town Air Route.*—(To meet on Monday, August 26th at 5 p.m.)—Mr. C. Stewart (S. Africa) *Chairman*, Mr. C. G. Hansford (Uganda), Mr. L. J. Sutton (Egypt), Mr. A. Walter (E. Africa, S. Rhodesia and Sudan), Mr. E. J. Wortley (Nyasaland), Mr. Tymms, Wing-Comdr. Reilly, Flight-Lieut. Nixon, Capt. F. Entwistle, Mr. M. A. Giblett.

(b) *West Indian hurricanes.*—(To meet on Monday, August 26th, at 5 p.m.)—Dr. G. C. Simpson, *Chairman*, Mr. C. J. P. Cave (Barbados), Mr. H. H. Croucher (Leeward Islands), Mr. J. Patterson (Canada), Capt. A. B. Smith (Trinidad), Mr. E. E. Turner (Windward Islands).

(c) *Meteorological requirements at Aden.*—(To meet on Tuesday, August 27th, at 5 p.m.)—Dr. G. C. Simpson, *Chairman*, Mr. A. J. Bamford (Ceylon), Dr. C. W. B. Normand (India), Mr. L. J. Sutton (Egypt), Dr. R. S. Taylor (Somaliland), Mr. A. Walter (E. Africa), Mr. D. Brunt, Capt. F. Entwistle, Mr. M. A. Giblett.

(d) *Organization of West African Meteorological Services.*—(To meet on Saturday, August 24th, at 9.30 a.m.)—Dr. A. J. Brooks (Gambia), Mr. N. P. Chamney (Gold Coast), Mr. J. Dewar (Malaya), Mr. S. M. Jacob (Nigeria), Mr. R. Temple (Sierra Leone), Mr. A. Walter (E. Africa), Capt. J. Calder Wood (Nigeria), Dr. C. E. P. Brooks.

(e) *Meteorological arrangements for R.A.F. non-stop flight to South Africa.*—(To meet at 9.30 a.m. on Friday, August 23rd.)—Mr. S. M. Jacob (Nigeria), Mr. C. Stewart (S. Africa), Mr. L. J. Sutton (Egypt), Capt. Calder Wood (Nigeria), Capt. F. Entwistle.

(f) *Review of meteorological arrangements at Karachi for England to India air routes.*—Dr. C. W. B. Normand (India), Mr. A. J. Bamford (Ceylon), Capt. F. Entwistle, Mr. M. A. Giblett.

(g) *Meteorological arrangements for airships at Montreal.*—Mr. J. Patterson (Canada), Flight-Lieut. Nixon, Wing-Comdr. Reilly, Mr. M. A. Giblett.

4. **Discussion on Aviation and Airships.**—General statistical summaries (Appendix I), § I 2, § I 3 E, § II, § III (a); Appendix II, § II 6, § II 8, § IV 4, § V 2.

Capt. ENTWISTLE recapitulated the summaries which were considered desirable from the point of view of aviation and airship requirements, and which were detailed in the memoranda.

He stated that data of winds in the upper air were of great importance for aviation purposes, and the ultimate aim was to obtain a survey of winds at different heights over the entire globe. In particular it was hoped that stations would be established for upper-wind observations at ocean islands such as Seychelles and Tristan da Cunha, and that it would be found possible to investigate especially the conditions over the areas of the trade wind.

He asked for a discussion as to the form of summary and as to the possibility of obtaining the data required from the several parts of the Empire.

Mr. GIBLETT stated that for airships, data of thunderstorms and of upper winds were of primary importance. For the former it was suggested that the number of days per month on which thunder was heard should be adopted for statistical summaries; at key stations information of the diurnal variation of "thunder heard" would also be required. He added that for seasonal variation monthly (and not quarterly) values were required, and for diurnal variation, hourly values.

For upper winds the form proposed by the I.C.A.N. (Appendix II, Annex B) was in use in this country, and in many countries abroad. For airship work as well as for aeroplanes, observations on ocean islands were required, data from Cocos Island in particular would be of value. He pointed out that the proposed airship routes round West Africa and from India to Australia lay largely in the trade-wind belt. Investigations in the North Atlantic showed that the trade wind became shallower near the African coast, and there were indications of the same feature between St. Helena and the mainland. Airships might be able to obtain favourable winds by the trade wind in the South Atlantic when bound for South Africa, and by surmounting the trade wind in the North Atlantic when bound for Great Britain.

He expressed the opinion that the most satisfactory method of investigating the trade wind in the neighbourhood between Cocos Island and Perth, and also between the equator and Cape Town over the South Atlantic was to have a ship specially allocated for the purpose.

I. VISIBILITY.

Mr. BAMFORD (Ceylon) asked for more guidance in methods of estimating visibility. The observation presented difficulty to those responsible for training oriental observers, especially at stations where there was no wide horizon and where there were no fixed objects to observe. He suggested tentatively that there might be some standardising scale, such for instance, as observations of a magnified playing card.

Mr. STEWART (South Africa) pointed out that visibility varies considerably in different directions, and between town and country and may depend to a large extent on wind direction.

Mr. PATTERSON (Canada) referred to the instructions as to observing visibility set out in the "Meteorological Observer's Handbook" (1926) where visibility was reported by letters A B C D . . . which did not in all cases agree with the

limits of the international scale, in his opinion there should be one standard scale 0 to 9. In this connection Col. Gold pointed out that the observations recommended in the "Meteorological Observer's Handbook" were purely national and were supplementary to the international scale, and did not really introduce a new scale. If additional observations especially of low visibility were required also in other parts of the Empire it would be desirable if possible to secure uniformity. Mr. Patterson further emphasised the difficulty of observations of visibility greater than say, two miles, and said that a wedge method had been tried in Canada and offered possibilities of development. He asked whether provision was made for occasions when the distance of visibility was reduced on account of forest fires and gave an instance of a machine crashing as a result of the reduction so caused.

Mr. WALTER (East Africa) agreed with Mr. Bamford as to the desirability of a standard method of observation; he thought that summaries of observations at 7h., 13h., 18h., were insufficient for stations such as those in East Africa, where the visibility changed very rapidly in the early morning. Observations at 7h., gave no information for the critical hours at which an aeroplane usually took off unless information was available of the type of weather in progress.

In East Africa visibility depends largely on the type of weather, and he suggested that where possible it should be determined at several hours in the early morning so that the observations could be classified in types and on any occasion the type of weather at the time could be reported.

Mr. HANSFORD (Uganda) endorsed Mr. Walter's remarks as to the need for information of diurnal variation on accounting the rapid change of visibility in the early morning.

Dr. TAYLOR (Somaliland) suggested that for short distances observations might be made on a toothed outline in which the toothing was of various degrees of coarseness.

Mr. DEWAR (Malaya) asked whether any provision was made for the differentiation of observations of visibility at stations when there might be mist below and clear sky above.

Capt. ENTWISTLE in reply emphasised the fact that the fundamental scale was that which had been adopted internationally and that any additional observations of low visibilities were supplementary to that and did not form part of the summaries. He agreed that visibility varied considerably with direction, and reported that provision had been made for this at coast stations where observations are made separately towards the land and towards the sea. He said that a visibility meter designed by Wigand, had been tried in this country, but that although it was promising it could not yet be regarded as entirely satisfactory. The main difficulties were first that the visibility over a short distance was not necessarily representative of that over a wide area, and secondly in the calibration. He stated that extensive experimental work on visibility was being carried out in this country and that he was hopeful that a satisfactory method of estimating this element might ultimately be arrived at.

With regard to the diurnal variation it was suggested that observations should be made as a minimum at three hours of the day, but that this should not preclude summaries for additional hours where these were considered desirable.

No distinction is made in the visibility figure in the code as to the cause of bad visibility, but where the information is not given by the figures for "present weather" it might with advantage be added in plain language at the end of the message. The summaries are made irrespective of the cause of the bad visibility. No provision is made for reporting valley fogs, though again the information is useful and could be added in plain language.

Col. GOLD pointed out that observations of visibility were required for at least three different hours, some stations might require to supplement the minimum requirements by observations at other hours possibly at different hours for different stations. It was desirable to give what information was necessary but not to overload the summaries.

Mr. AUCHINLECK suggested that a resolution might be framed as to the desirability of getting curves of diurnal variation of visibility.

The PRESIDENT pointed out that the method of observation which was suggested had proved practicable and had given information that was of value in selecting a site for an aerodrome. The data were specially useful in the case of low visibilities and these were the observations which were of least difficulty.

II. OBSERVATIONS OF HEIGHT OF LOW CLOUD.

(a) *Methods of observation.*—Capt. ENTWISTLE referred to the difficulty of obtaining reliable estimates of height from untrained observers, and said that on that account the observations in the summaries prepared in this country were limited to pilot-balloon stations. Observations of continuous cloud sheets were of primary importance but information as to broken clouds was also desired.

Mr. PATTERSON said that in Canada subsidiary stations were supplied with small toy balloons in place of pilot balloons, and the method had proved satisfactory and inexpensive. Capt. ENTWISTLE stated that the method had been used in this country with small balloons rising at 400 ft./min. which could be followed by the naked eye, and had proved satisfactory. The method could only be used for low cloud, but from the aviation point of view it was in such conditions that accurate information was necessary.

Mr. BAMFORD (Ceylon) asked for the experience of other observers as to the use of a range-finder for determining cloud heights. It was agreed that it could only be used for cloud with a definite edge. Capt. ENTWISTLE said one objection to its use was that of expense; Cmdr. GARBETT reported that at sea with large range-finders of 20 or 30 feet, the difficulty of picking out the cloud had proved considerable, especially when there was much motion on the ship; Capt. CAVE said he had used 3-ft. range-finders on clouds up to A-cu. with considerable success, and with 6-ft. range-finders it had been possible to use the instrument on cirrus overhead.

(b) *Standard of height.*—The question as to whether the heights should be given above station level or above mean sea level was raised by Mr. WALTER. Capt. ENTWISTLE said that the practice was to give heights above sea level in forecasts made for cross-country flights over wide areas, but for actual observations heights were given above ground. The information might be amplified in the former case by adding a note, e.g., that the cloud would reach the surface over high ground. Definite instructions would be given as to what was required in the summaries.

(c) *Training of native observers.*—Capt. CALDER WOOD asked for the experience of delegates as to the possibility of training native observers to make upper air observations, and especially observations of cloud heights. Dr. NORMAND said he had found no difficulty in India in training observers in routine work but was unable to train them to give reliable estimates of cloud heights. Mr. WALTER said his experience was similar to Dr. Normand's though he had not had much experience with native observers. The new station in Tanganyika was placed near a native school in hopes of training the natives. Mr. CROUCHER said he had found East Indian observers easier to train than negroes.

(d) *Additional observations for airships.*—Mr. GIBLETT said a case of special interest to airships was that in which a high hill in the neighbourhood of an airship base which might be totally obscured by cloud. At St. Helena an observer had been asked to observe a number of peaks and report whether they were totally obscured, partially obscured or completely visible. Such information would be especially welcome, for example, for Table Mountain and the high land near Montreal.

(e) *Units.*—Mr. PATTERSON raised the question as to the unit in which cloud height should be reported, metres or feet. Col. Gold said the international convention specified the use of the metric system as far as possible. In practice he thought the unit must depend on the units used for the altimeter graduations which in this country were in feet.

III. THUNDERSTORMS.

(a) *Method of Specification.*—Mr. GIBLETT reported that for airship purposes it was suggested that the method of specification should be the frequency of days on which thunder was heard.

Various objections to the specification were made. Mr. DEWAR said that in Malaya thunder might be heard all day. Observations in Malaya were made of the frequency of actual thunderstorms and this same specification was adopted at the lighthouses in the Netherlands Indies and on the Straits Steamship Companies' steamers, which also provided observations. Col. BATES (New Zealand), Mr. HANSFORD (Uganda), Mr. STEWART (South Africa) said that lightning was frequently observed when no thunder was heard. In particular in South Africa, occasions were on record

when a cloud discharged lightning overhead, or when a hailstorm occurred and no thunder was audible. A table of the hourly frequency of occurrence of lightning over a period of five years had been drawn up and would be printed in the official year book.

Col. BATES (New Zealand) suggested that a report of the occurrence of a thunder-cloud would be useful in forecasting thunderstorms. He would himself prefer lightning as the specification in the summaries. He said that as a rule, in New Zealand he had observed that thunder occurred in winter at night and in summer in the afternoon.

The possibility of using a thunderstorm as the method of specification was considered, as it was possibly the most satisfactory for natives to observe and was supported by some delegates as the most suitable. A difficulty arose as to the definition of a thunderstorm and whether or not precipitation was a necessary accompaniment. Mr. STEWART said that in South Africa dry thunderstorms occurred and were indeed the most dangerous.

It was suggested that if lightning was adopted as the specification a spurious effect might be introduced on account of the greater ease with which it could be observed by night than by day. Mr. LEMPERT further pointed out that difficulty might be experienced in separating flashes caused by electric trains from true lightning. Capt. CAVE said that the audibility of thunder was about 20 miles, and an observation would accordingly mean the occurrence of a storm within that radius.

Mr. GIBLETT said that the definition of thunder heard had been adopted for airship routes because the airship captain required information over a wider area than would be given by an observation of thunderstorms, but not so wide as that given by the visibility of lightning. At the base stations, however, data of the frequency of thunderstorms would be required in addition; and also of their diurnal variations.

Col. GOLD recalled the fact that the International Meteorological Organization also recommended that storms and thunder heard should be separately recorded. He said it was desirable that the requirements of general climatology should not be lost sight of in considering those of aviation. Mr. WALTER suggested that the interval between the lightning and thunder might provide a basis of specification.

The meeting was of opinion that for aviation purposes the specification of frequency of thunder heard should be adopted, but that the observations should be supplemented by the frequency of thunderstorms and possibly by observations of lightning.

(b) *Diurnal variation*.—Mr. DEWAR asked whether provision was made in such places as the Straits of Malacca, for observations over the land and over the sea. Mr. GIBLETT agreed that some provision was necessary as it might be possible to take advantage of the differences in the diurnal variation. Mr. WALTER suggested that some indication of diurnal variation was desirable and suggested observations at, say, six-hourly intervals. Mr. GIBLETT said that it was suggested that for stations along the routes frequencies only should be given, and that hourly values should be obtained at base stations. If some stations could give six-hourly values they would be useful provided that the number of days could still be derived from the data.

Mr. PATTERSON suggested that if the observer recorded the time of observation of thunder as was done in Canada, the diurnal variation could be derived from the observations.

IV. UPPER WINDS.

(a) *Technique of pilot-balloon observations and observations with the Besson nephoscope*.—The PRESIDENT asked for the experience of the delegates as to any difficulties in the technique of the observations. Col. BATES reported that valuable observations had been obtained in New Zealand by means of the Besson nephoscope.

(i) The supply of hydrogen :—

India (Dr. NORMAND).—The hydrogen is the main difficulty. It is made electrolytically at the central station at Agra and is issued from there to the subsidiary stations.

East Africa (Mr. A. WALTER).—Hydrogen is one of the two main difficulties, the process of generating from aluminium and caustic soda has been adopted.

Canada (Mr. J. PATTERSON).—The transportation of hydrogen is one of the main difficulties, and the cost to Arctic regions is prohibitive. Calcium hydride and water were used when the former was obtainable, and were very satisfactory. The question of issuing supplies to islands which were only visited in the summer required a large stock of cylinders.

Capt. CAVE suggested that observations in the West Indies where the transport of hydrogen was a great difficulty might be facilitated if the Meteorological Office could make arrangements with steamship companies for cheap rates of transport.

Ceylon (Mr. A. J. BAMFORD).—Hydrogen is made on the spot from aluminium and caustic soda, generators were made originally out of six or eight-gallon tins, and the process can be carried out without specially skilled assistance or the need of pressure cylinders.

(ii) Balloons :—

India (Dr. NORMAND).—Originally rubber was not satisfactory and gutta percha was used. This is inexpandable but the heights reached are sufficient for pilot-balloon work. Labour is cheap and the balloons are made at the observing stations from four segments of gutta percha cut from templates. The gutta percha is stored in water. Rubber has been used more extensively in recent years, but the quality varies considerably, low quality involves great loss of hydrogen which must be avoided as it is the most expensive element in obtaining the data. The observers are whole-time observers trained at Agra.

East Africa (Mr. A. WALTER).—The preservation of balloons presents some difficulty, losses are considerable and the quality varies greatly. The loss is reduced by storage in cool chambers, and it is proposed that first-order stations should be equipped with small portable refrigerators, and that the balloons should be issued fortnightly to observing stations.

Canada (Mr. J. PATTERSON).—The question of the supply of balloons to stations such as Sable Island (off Nova Scotia), St. Paul's Island in the Gulf of St. Lawrence, and to Belle Isle, which are only visited in the summer has to be dealt with. He had found that the balloons were satisfactorily preserved if they were kept frozen all the time, or kept cool but not frozen, but that they perished if they were allowed to freeze and thaw at intervals. He described a new process of producing rubber goods. A Canadian company had produced satisfactory balloons by this method at a price of about £4 for a balloon capable of being expanded to 10 feet in diameter.

Mr. TAYLOR, of Somaliland, suggested that rubber might be preserved in the vapour of kerosene.

With regard to (ii) balloons and (i) hydrogen Mr. BILHAM (Superintendent of Instruments in the Meteorological Office) reported as follows :—

(ii) Balloons.—The standard patterns of fine cut-sheet balloon are :—
70-inch circumference (inflated), 5d. each.
90-inch circumference (inflated), 8d. each.

Two firms have recently tried the process described by Mr. Patterson but have experienced difficulties, and one at least has discontinued it.

The losses in this country through deterioration amount to about 10 per cent.; this is partly due to the fact that balloons supplied to home stations may be as much as three or four months old at the time of supply. Balloons sent abroad are always new.

Reports as to the effect of tropical conditions vary. Jamaica has great difficulty though storing in turpentine vapour has been tried, whereas from Kameran Island (Red Sea) no complaints have been received.

Preservation by freezing seems fairly satisfactory if care is taken that the rubber is kept continuously below freezing and that it is completely thawed all over before use. A uniform temperature of about 60° F. seems, however, to give the most satisfactory results.

(i) Hydrogen.—At Cardington experimental generators costing about £30 or £40 are in use, and hydrogen is made by the silicol-caustic-soda process at a cost of about 3d. per balloon filled. Transport of hydrogen cylinders is definitely uneconomical and pilot-balloon work depends on efficient and economical generation of hydrogen. Particulars of the generation from aluminium and caustic soda described by Mr. Walter and Mr. Bamford would be welcome.

Since the war the cost of calcium hydride has been prohibitive.

(iii) Method of obtaining the height, and height to which data are required :—

India (Dr. C. W. B. NORMAND).—The tail method is used and is regarded as essential.

East Africa (Mr. A. WALTER).—The tail method is used for obtaining height. It is desirable that there should be some agreement as to what height observations are required and what should be reported in the telegrams. Observations have sometimes been made for over 2 or 2½ hours and frequently for over an hour, but they are very trying and if the data are not essential for aviation they would be limited to observations for research work.

He asked if there was any method of identifying leaks which would reduce the rate of ascent and give rise to reports of high velocities which had no real existence. He was accustomed to regard such velocities as genuine only when they were followed by low velocities at a greater height.

Canada (Mr. J. PATTERSON).—The height is obtained by assuming a constant rate of ascent in the upper layers and making allowance for an increased rate of ascent in the first five minutes.

(b) *Pilot-balloon data available*.—The President then asked for information as to what stations were in operation or in prospect in the different parts of the Empire.

Africa.

East Africa (Mr. A. WALTER).—A station has been in operation at Nairobi for 3½ years, and six more will be established this year as well as an inspection lorry which will make observations at the station inspected.

Egypt and Sudan (Mr. L. J. SUTTON).—Two services are in operation : (1) the Air Ministry Service which makes observations at one or two stations in Egypt and also in Palestine ; (2) the Egyptian Meteorological Service which maintains one pilot-balloon station at Helwan. No other stations are in operation at present though it is hoped to establish a station in the extreme west at Sollum and in the south at Aswan.

No stations were established in the Sudan, and it was unlikely that arrangements for stations could be made in the immediate future. A few observations had been made by special expeditions nearly twenty years ago at Khartoum, Mongalla and Rosines in connection with the study of the rains. When possible, permanent stations would be established at Khartoum, Malakal and Mongalla. Observations had been made by the Royal Air Force for a short time at Wadi Halfa and for about two years at Khartoum.

(Mr. GIBLETT).—Three stations are operated by the Air Ministry at Aboukir, Ismailia and Heliopolis, also stations at Ramleh in Palestine and Amman in the Trans-Jordan.

Gambia (Mr. A. J. BROOKS).—No purely meteorological station is established, meteorological records are kept by the Department of Agriculture.

Gold Coast (Mr. N. P. CHAMNEY).—No observations are made at present, but it is hoped to have some soon ; (Mr. AUCHINLECK) Meteorological observations are made mainly from the point of view of agriculture, and it is possible that upper air observations may be directly useful in view of their bearing upon the quantity of rainfall.

Nigeria (Capt. J. CALDER WOOD).—Meteorological observations are controlled by the Survey Department and consist of observations of pressure, temperature and rainfall. It is hoped at the end of the year to arrange for a pilot-balloon observation. Further developments await the outcome of the present Conference.

Nyasaland (Mr. E. J. WORTLEY).—The Agricultural Service keeps the meteorological records from an agricultural standpoint. It is desirable to know what are the minimum requirements of aviation.

Sierra Leone (Mr. R. TEMPLE).—No observations of upper air currents are made.

Somaliland (Dr. R. S. TAYLOR).—No observations are made at present, but it is hoped to make some in the future.

South Africa (Mr. C. STEWART).—Three stations are in operation : one attached to the Air Force at which observations are made at 9h., 12h., and 15h., and two temporary stations, one on the coast and one inland, or both in the interior at considerable distances apart, which operate for a year and are then transferred to another locality.

South Rhodesia (Mr. A. WALTER).—Observations are made at Salisbury.

America.

Canada (Mr. J. PATTERSON).—Thirteen stations are in operation with ascents once a day in the morning. One at High River, Alberta, in the west, and the remaining 12 eastwards from Toronto, stretching as far out to sea as possible. The station at Toronto has been in operation for nine years.

Barbados (Capt. CAVE).—Experimental work is to begin by the Department of Agriculture sending up pilot balloons. The observations will be useful for agriculture and climatology as well as for aviation.

Trinidad (Capt. A. B. SMITH, R.N.R.).—No observations are made on account of financial difficulties and there is no prospect at present. The Americans have made no observations. It is desirable to know what is the possibility of assistance from the Air Ministry both for pilot-balloon work and with regard to supply of instruments.

Leeward Islands (Mr. H. H. CROUCHER).—No observations are made and there is no possibility of any being made in the near future, on account of the financial difficulty, though they might be made if that could be overcome. Conditions are not likely to be covered by observations from Barbados and Trinidad.

Observations are made at Cuba and at Jamaica.

Windward Islands (Major E. E. TURNER).—No data are available, but possibly Barbados and Trinidad can supply information.

Asia and Near East.

Ceylon (Capt. A. J. BAMFORD).—Two stations are in operation at Colombo and Diyatalawa. At the former observations twice a day have been made for eight years. At the latter observations are not so regular.

India (Dr. C. W. B. NORMAND).—Regular pilot-balloon observations at one or two stations were started about 18 years ago. Twenty-six stations are now in operation mainly in India and fairly well distributed, extending to Rangoon on the east. Three stations for airship service were established outside the country at Gwadar, Mascat and Bahrein, as stations in Persia were not possible. A station is also in operation at Port Blair. The establishment of further extension has been considered and sanction has been obtained for a station at Aden to be established immediately, and one at Seychelles in the middle of 1930.

Nigeria (Mr. S. M. JACOB) said that on a point of historical accuracy he would like to say that upper-air work, both by pilot and observation balloons was carried out in India, by Mr. J. H. Field, in 1909. This was done by means of a great number of balloons sent up from Jhang, a district in the south-west of the Punjab.

Mr. Jacob said that he believed that balloons had been used for the purpose of upper air work prior to this date by Mr. Field, but the above ascents were the first to be made in India on any considerable scale.

Hong Kong (Mr. T. F. CLAXTON).—One station is in operation with observations twice a day when possible. They are supplemented occasionally by observations of temperature from the Royal Air Force and the aircraft-carrier. A subsidiary station is also in existence for two theodolite observations.

It is desirable to know if the Air Ministry considers that arrangements for an airship route from Rangoon to Hong Kong is in prospect, as such knowledge may affect the action of the Hong Kong Government.

Iraq (Mr. GIBLETT).—Five stations are operated by the Royal Air Force at Mosul, Rutbah, Hinaidi, Diwanayah and Shaibah.

Malaya (Mr. J. DEWAR).—Twelve main stations (which include two high-level) have been established in the last two years for all observations except pilot balloons, but it is hoped to undertake pilot-balloon work in 1930. Full information is set out in a memorandum which is available.

Australasia.

Australia (Squadron-Leader WRIGLEY).—Observations are made at Melbourne and Sydney twice daily at 2330 and 0530 G.M.T. ; at Adelaide twice daily at 2359 and 0600 G.M.T. ; and at Willis Island (16° 6' S., 149° 55' E.) daily at 0515 G.M.T. for the period from November to April inclusive.

New Zealand (Col. D. C. BATES).—Observations are made at Wellington and also at Samoa. It is probable that in the near future observations will be made at aerodromes for land machines at Christchurch and by seaplanes at Auckland. Difficulty had been experienced both with regard to the supply of hydrogen and balloons and information as to the price of balloons would be acceptable.

Europe.

Great Britain.—Observations are made at Leuchars, Renfrew, Aldergrove, Sealand, Cranwell, Upper Heyford, Cardington, Felixstowe, Cattewater, Worthydown, Calshot, South Farnborough, Croydon, Lympne, Manston, Shoeburyness, Kew, Eskdalemuir, Aberdeen, Valentia and Larkhill.

Irish Free State (Mr. H. ELIASOFF).—No station is in operation at present. Observations would be made by the Air Force and after the findings of the last Committee endeavour will be made to obtain observations.

Ocean Islands.

Stations are established at St. Helena, Kameran Island in the Red Sea, Jamaica, Mauritius and Malta.

(c) *Form for recording upper wind observations.*—Col. GOLD.—The suggested form is set out in Appendix II, Annex B. It is self explanatory and is designed for practical purposes. Pilot-balloon observations give the wind through a layer and not at a definite level; a range of 1,000 feet centred at the level is used for the purpose of the summary. The form was drawn up for height above ground, but it has been found desirable to use heights above mean sea level and the standard summaries should be for 1,000 m. (3,000 feet), 2,000 m. (6,000 feet), 3,000 m. (10,000 feet) *above sea level*, with a supplementary table for 500 m. *above ground*.

The observations should be "about local mid-day" which for most European stations is about 1300 G.M.T.

The limits of speed are wide but they are those which are of importance for aviation and if further details are required they should be given separately. The range of velocity should be the same in whatever units the velocity is expressed. The definition of N. is such that a wind entered as N. has a range of two points on either side of N.

Mr. GIBLETT.—With regard to airships the actual data supplied either as individual reports or in the form of summaries need not exceed 10,000 feet above mean sea level. But each service in developing its own technique of forecasting must determine the extent to which higher ascents may assist in this respect.

As in the case of thunderstorms, it is desirable to have tables of upper wind at several hours in the day. For each observations to be comparable they must be made by the tail method or an equivalent method otherwise a false diurnal variation may result from the effect of the diurnal variation of the upward currents.

Capt. ENTWISTLE agreed with Mr. Giblett's remarks, and stated that for civil aviation data to 10,000 feet were usually sufficient though for certain operations the Royal Air Force required winds to 20,000 feet on individual occasions. If long ascents were made for forecast purposes it was desirable that the observations should not result in delay in furnishing the data for the lower levels.

Mr. PATTERSON (Canada) said that for distribution and international purposes the form met the requirements of aviation. In his opinion the main difficulty was that of units. He urged for a uniform method in recording and tabulating the values and described the practice in use in Canada.

Capt. ENTWISTLE said that the difficulty of units arose especially where British routes linked up with foreign air lines. For instance, cloud heights were given on the Continent in metres, and in this country in feet.

Mr. GIBLETT stated the normal practice for airship operations was to report upper wind speed in statute miles per hour; the conversion to knots being carried out by the airship navigator. Heights are given in feet.

The meeting adjourned at 1.30 p.m.

After the meeting Col. Gold exhibited the first record of wind obtained from the Inchcape (Bell) Rock, by a Dines pressure-tube anemometer. The record showed several interesting features.

August 27, 1929.

(Signed) G. C. SIMPSON.

MINUTES No. VI.

Sixth Meeting, Friday, the 23rd of August, 1929, at 3 p.m.

The following delegates were present: Dr. G. C. Simpson (Great Britain, *President*) in the Chair, Mr. G. Auchinleck (Gold Coast), Mr. A. J. Bamford (Ceylon), Lieut.-Col. D. C. Bates (New Zealand), Mr. N. P. Chamney (Gold Coast), Mr. T. F. Claxton (Hong Kong), Mr. H. H. Croucher (Leeward Islands), Mr. J. Dewar (Malaya), Capt. Feakes, R.A.N. (Australia), Mr. C. G. Hansford (Uganda), Mr. S. M. Jacob (Nigeria), Dr. C. W. B. Normand (India), Mr. J. Patterson (Canada), Capt. A. B. Smith, R.N.R. (Trinidad), Mr. C. Stewart (South Africa), Mr. L. J. Sutton (Egypt), Dr. R. S. Taylor (Somaliland), Major E. E. Turner (Windward Islands), Mr. A. Walter (East Africa, S. Rhodesia, Sudan), Capt. J. Calder Wood (Nigeria), Mr. E. J. Wortley (Nyasaland), Squadron-Leader H. N. Wrigley (Australia). There were also present the following members of the staff of the Meteorological Office: Col. E. Gold, Capt. F. Entwistle, Cmdr. L. G. Garbett, R.N., Mr. M. A. Giblett.

1. **Documents circulated.**—Agenda and papers for the meeting on Wednesday, 28th August—

(a) The collection, tabulation and publication of climatological data (Appendix XII).

(b) A preliminary note on the rainfall of West Africa, by Mr. N. P. Chamney (Appendix XIV).

(c) The Empire in relation to international meteorology (Appendix XI).

(d) The diurnal variation of meteorological elements, by Mr. A. Walter (Appendix XIII).

(e) On long-range forecasting (Appendix XV).

Draft resolution as to the adoption of the metre as the unit for the expression of height.

2. **General statistical summaries.**—(a) *Observations of upper wind* (continued).—Mr. GIBLETT again emphasised the need for observations in the trade-wind regions, especially in the South Atlantic, between the west coast of equatorial Africa and Cape Town, and in the South Indian ocean between Cocos Island and Western Australia. He said it was suggested that a ship should be allocated for observations in those regions, and asked for the opinion of delegates on the proposal. Co-operation with Ocean Islands such as Seychelles, Tristan da Cunha, Cocos Island and Ascension would be specially valuable. Dr. NORMAND said observations were made regularly at Port Blair, and a scheme was in contemplation for placing a meteorologist with an observer on a B.I. steamer to take upper-air observations on occasional trips between Madras and Rangoon, and between Bombay and Seychelles. In reply to the President, Mr. Stewart said there was no immediate prospect of the South African service obtaining data from Tristan da Cunha.

There was general agreement as to the value of the observations.

(b) *Observations of temperature.*—Delegates were asked to give information as to any observations available of upper air temperatures by methods which rendered the data available on the same day as the ascent.

Canada (Mr. J. PATTERSON).—No observations are made at present, but it is hoped that some may be organized in co-operation with the flying clubs and with the R.C.A.F. at Camp Borden.

Hong Kong (Mr. T. F. CLAXTON).—Observations are made by aircraft carriers and from the R.A.F. base situated a few miles from the harbour, but they are not a matter of daily routine.

India (Dr. C. W. B. NORMAND).—Observations by the R.A.F. are made practically every day at Quetta and Peshawar and at Karachi on about 15 days a month.

Malaya (Mr. J. DEWAR).—It is hoped to obtain observations in future in co-operation with the Air Force at Singapore.

The PRESIDENT reported that in Great Britain two aeroplanes were available for meteorological observations. He emphasised the large cost of aeroplane observations.

Capt. ENTWISTLE said that in Germany arrangements were being made by which six civilian machines would be detailed for regular observations of upper air temperature at different stations.

The possibility of using other methods of observation was discussed. Col. BATES suggested the use of box-kites, but apparently no regular observations were made by this method in the countries of the Empire, though Mr. Walter stated that kite gear was among the meteorological equipment at Mauritius.

Dr. NORMAND described a method which had been used with success in India by Mr. Field and Mr. Chatterji. A balloon was sent up with a time fuse which caused it to drop at a definite height. The balloon carried dry and wet bulb thermometers and a clock, and was followed by observations with a theodolite. The method was devised originally for quite low levels, say 4,000 feet, but had recently proved so successful in an expedition in Bengal that it was extended there to heights of 10,000 feet. It was found there that all the instruments were returned on the day of the ascent, and indeed the data were available after a comparatively short interval. Mr. WALTER said that provision had been made for similar observations to be made at Mauritius, the method was specially suitable for use in that island as the reversal of the wind in the upper layers caused the balloon to return overhead after an interval of about twenty minutes.

3. Statistical summaries for aerodrome sites and for airship bases.—Appendix I, §12; Appendix II §II, 7 and 9, §IV 5, §V 3.

Capt. ENTWISTLE stated that among the special data required at aerodrome sites, observations of the diurnal variation of fog were of primary importance; data of air density were also necessary, especially at high-level stations in the tropics—it was suggested that these should be in the form of monthly summaries including both the mean and minimum values in each month.

Mr. GIBLETT said that extensive tabulations (Appendix II, §IV 5) were being asked for at airship bases, but such bases would be comparatively few in number. The data required would probably include hourly values of all elements. He referred especially to the proposal that the tabulation of hourly values of surface wind should be taken from the mean value in the ten minutes preceding each exact hour. This suggestion was made in view of the fact that single observations were always given to airship commanders in that form, and it was desirable that the mean values should be comparable therewith. It was suggested also that data of the maximum gust should be given. Mr. Giblett added that the data were required for the existing airship bases at Montreal and Karachi, and possibly in the future at a site north of Durban. It was stated that as soon as the position of future bases could be definitely foretold the meteorological authorities would be well advised to take immediate steps to obtain autographic records from the sites.

Col. GOLD said that, on account of the rapid variation of wind with height in the surface layers, it was important that measurements of surface wind should be accompanied by a specification of the height of the anemometer above ground, and by some information as to the nature of the immediate surroundings. With regard to tabulating hourly values of wind from the ten-minute intervals, tabulations of the values from the ten-minute intervals would, he thought, meet the requirements of climatology.

Mr. PATTERSON pointed out that he saw no difficulty in tabulating wind over ten-minute intervals in the case of records from pressure-tube anemometers, and it might indeed simplify the tabulations in such cases. He thought, however, that the method would introduce errors in the results of total daily run if it were adopted in the case of records from a cup anemometer, except with winds of low velocity or when the records had a very open time scale. In this connection Mr. GIBLETT pointed out that the tabulations were only required at airship bases, and it was suggested that these should all be equipped with anemometers of the pressure-tube type.

Mr. WALTER said that the practice in East Africa was to draw a mean curve through the anemometer trace and read off hourly values from the mean curve; such a method was economical of time when extensive tabulations were being made. After some discussion between Mr. Walter, Mr. Giblett and Col. Gold it was agreed that such values would differ little from the ten-minute mean, provided that the method was used on records with the ordinary time scale.

There was general agreement that no difficulty would be experienced in tabulating hourly values from ten-minute intervals ending at the hour rather than from the mean value through the hour.

Col. BATES emphasised the importance of giving the range of gusts as well as the maximum velocity and said that in his opinion it was one of the most important features. Mr. PATTERSON associated himself with that opinion.

Mr. GIBLETT agreed that additional data were desirable but thought that the range alone was insufficient and asked the permission of the meeting to delay formulating a final proposal as to the requirements until it was possible to take full account of the results of the research into wind structure which was in progress at Cardington. It was agreed that further information in addition to the value of the maximum gust was desirable.

4. General accounts of meteorological conditions over Dominions and Colonies and adjacent areas, and over specified air routes.—(Appendix I § I, § I 3 E, § II, § IIIa).—

Capt. ENTWISTLE pointed out that even the best summaries at fixed stations would not meet all the requirements of aviation. For example, if between two stations there is high ground which may be cloud-covered, or if there are large differences in visibility in the neighbourhood of the coast, observations on such points are of considerable value; as well as observations of the frequency of special phenomena such as dust storms and of the type of weather when they occur. The information is required over all areas but in a more detailed form over the actual air routes. The value of co-operation between the meteorological services and the pilots who had undertaken pioneer flights over projected air routes was emphasised in this connection.

5. Accounts of special phenomena at airship bases. Loan of autographic records.—(Appendix II, §§ II 7, 9; § IV 5; § V 3).—

Mr. GIBLETT stated that the information required by Capt. Entwistle for aeroplanes was required also for airships; in particular, data regarding the occurrence of thunder, hail, waterspouts and tornadoes both at aerodromes and on the routes would be welcome, as well as notes of the characteristics of individual thunderstorms. He said that there were certain occasions when it would be desirable that the autographic records at airship bases should be available for examination with a view to the study of details which were of special importance either for airships or for other special services.

Mr. PATTERSON said that there would be no difficulty in making the records available, he suggested that the most suitable way, and one which had already been adopted successfully in the case of magnetic records, was to make a photograph on a lantern slide which could then be magnified to the size required.

The PRESIDENT asked that directors would bear in mind the requirements of aviation and airships in making the tabulations of special data. With regard to the loan of records the form which the loan took would of course depend on the individual country.

6. Type of working chart and methods of charting for use at the principal aerodromes and airships bases.—(Appendix I, § I 3 B, § III; Appendix II, § III 7; § IV 6 (a) and (b)).

Specimens of the forms of chart adopted by the Meteorological Office in London were circulated. Mr. GIBLETT explained the desirability that the charts which a pilot would have to consult at the various stations on his route should have their main features in common, he referred especially to the desirability of uniformity in colour, in the contours marked and in the method of shading, in the projection, and in the scale, and asked for the experience of other services as to the most suitable forms to adopt. In Great Britain the charts are printed in green, and carry contours of 200 m., 1,000 m., 2,000 m., 3,000 m., the projection for high latitudes is a conical orthomorphic projection which ensures that the angles at which two lines cut shall be the same on the chart as on the globe, if a Mercator projection were used in the equatorial regions it would have similar properties. Three scales are in use: 1 in 5,000,000; 1 in 10,000,000 (approximately); and 1 in 20,000,000.

Capt. ENTWISTLE stated that it was equally desirable that uniformity in the working charts used at aerodromes should be reached as far as possible. Air pilots were now accustomed to consult the charts before starting on a flight, and, indeed, were at a loss when no charts were available. The same charts had been adopted in this country for both aviation and airship services.

Dr. NORMAND (India) agreed that contours were required on the charts. The chart in use at Karachi was originally a copy of a portion of the Air Ministry chart, but a circle was substituted for a dot in marking the positions of the stations and the interior of the circle was used for observations of cloud. More recently charts had been printed in brown as green ink was used for entering rainfall data; brown was found to be satisfactory.

Mr. SUTTON said that brown had been adopted for the charts of the Egyptian service, after trials with both blue and green. Contour lines were not given on the maps in use at present but he saw no difficulty in adding them. He agreed with Dr. Normand as to the convenience of using a circle to mark cloud amount which in the Egyptian maps was indicated by one to four lines within the circle. In order to facilitate identification initial letters were placed at the points marking the station.

Mr. PATTERSON (Canada) recognised the desirability of uniformity, though it would mean introducing new maps in the Canadian service, the maps in use at present were similar to those used by the United States Weather Bureau, and carried no contours. He thought the circle showed advantages over the dot for marking the positions of the stations.

Mr. WALTER (East Africa) suggested that in view of the probable increase in airship services it would make for uniformity if, when once agreement were arrived at, the maps were prepared in a central office in London and sold to the services concerned.

The PRESIDENT said there would be no difficulty in arranging for the maps to be drawn in London, the question of printing could be arranged with the representatives of the various dominions in this country.

Capt. ENTWISTLE further emphasised the importance which orographic features play in meteorological processes. The question of the tinting of the charts as distinct from the colour was of importance, brown charts used on the Continent and tried in London had not proved satisfactory, but that was due not to the colour but rather to the actual tints employed. The specimen of Dr. Normand's chart though brown, was lighter in tint and appeared to meet requirements.

The importance of securing uniformity in the method of entering the several elements (wind, temperature, cloud, visibility, isobars and weather) on the main chart was emphasised.

The PRESIDENT said that the practice adopted in Great Britain was set out in Form 2458; other countries had no doubt adopted slightly different methods. He suggested that when any changes were made in the form of charting in any country consideration should be given to the methods in use elsewhere with a view to arriving at a uniform practice throughout the Empire.

After discussion it appeared desirable that some guidance should be available for countries which had as yet no definite practice and a sub-committee to consider the form of charts and method of charting* was appointed. Dr. C. W. B. Normand (India), *Convener*, Col. D. C. Bates (New Zealand), Mr. J. Patterson (Canada), Mr. L. J. Sutton (Egypt) and Mr. Walter (East Africa) were nominated as members, and it was understood that the Sub-committee might include other delegates interested, and that Col. Gold, Capt. Entwistle and Mr. Giblett would attend the meetings.

7. Codes for transmission of reports and forecasts.—(Appendix I, § I 3 B (v); Appendix II, § IV 6).—Capt. ENTWISTLE emphasised the need for uniformity especially in the codes used for the communication of information to pilots. The codes used in this country were those recommended by the I.C.A.N., they were designed primarily for use in Europe and in some cases did not provide for all the meteorological phenomena experienced in tropical countries.

Mr. WALTER (East Africa) pointed out that in tropical countries some of the data reported in the code showed no variation from day to day, this was true especially of barometric tendency which in low latitudes depends entirely on the diurnal variation. In East Africa he had found it necessary to add information as to the direction, time and velocity of squalls. He suggested that it might be possible to have two codes, one for tropical latitudes and one for high latitudes. (Details of the proposal are set out in Appendix IV.)

* Later in the meeting it was agreed that the Sub-committee should consider also the question of codes.

Dr. NORMAND said that in India separate codes had been developed suited to the requirements of the country; it was the aim, however, to conform in time to the international codes, but this would necessitate provision being made in the codes for such phenomena as dust storms and dust haze.

Col. GOLD said that there were two steps in the formation of a code, the first was agreement as to what should be reported, and the second as to the form in which the reports should be made. The international organization was anxious that in any revision of the code provision should be made for the more important phenomena observed in tropical countries except such as were better reported by a special message. He asked that representatives would study what provision was made in the present codes and would send suggestions as to any additions that were desirable.

It was agreed that the sub-committee appointed to consider the form of charts and methods of charting might take account also of the form of code.

8. Allocation of areas of responsibility for issue of reports and forecasts for Empire air routes.—(Appendix I, § III; Appendix II, § III 2, 3, § IV 6 (d).)—Reference was made to Figs. 1 and 2 of Appendix II, Fig. 2 shows the areas on the England to India air route which are covered by forecasts issued from Cardington, Malta, Ismailia and Karachi respectively; and Fig. 1 sketches tentative boundaries for similar areas on the other routes. Mr. GIBLETT briefly sketched the reasons which had led to the choice of the boundaries indicated, and it was suggested that further details might be discussed at the various sub-committees for which arrangements had been made.

General approval was given as to the broad outlines of the scheme suggested.

9. International Commission for Air Navigation.—The following resolution which had been circulated was unanimously approved:—

It is desirable that the meteorological services of the self-governing Dominions and India should be directly represented on the Meteorological Sub-Commission of the International Commission for Air Navigation. It would facilitate the attendance of overseas representatives at these meetings which are normally held in Paris, if they were arranged to be held as far as possible near the times of the meeting of the International Meteorological Committee, the International Commission for Synoptic Weather Information or the International Geophysical Union.

10. Future Procedure.—The President drew the attention of delegates to the note at the head of the agenda for the discussion in which it was stated that "the object of the discussion is to compare the proposals which are put forward in the memoranda (Appendices I and II) with existing practice in various parts of the Empire or with such developments as are likely to be practicable. The views which are expressed by the various delegates will be recorded in the minutes and further memoranda will be circulated at a later date, embodying definite proposals as a result of the discussion. The final proposals will be based on those now before the Conference, but modified in the light of the discussion in such a way that they would still meet requirements while involving the minimum amount of change in the present practice throughout the Empire," and said that if delegates had further questions of detail to raise Capt. Entwistle and Mr. Giblett would be glad to discuss them.

As a result of the information collected at the Conference he would undertake to draw up memoranda for circulation to the various Dominions and Colonies setting out details as to the way in which the various countries, whether or not they possessed organized meteorological services, could co-operate both individually and collectively in providing the meteorological organization necessary to meet the special requirements of aviation and airships. Such memoranda would include details as to the type of data required, the instruments to be used, the cost of such instruments and instructions as to the choice of sites especially for aerodromes and airship bases.

Delegates were in general agreement that the procedure suggested would be satisfactory.

[With regard to the instruments which it was proposed to issue to airship bases (Appendix II, § IV 3 (b)) Capt. BAMFORD asked for the addition after nephoscope of the words "or equivalent apparatus for measurement of cloud movements". He

stated that "at certain tropical stations the use of a nephoscope gives very poor results compared with those obtained over the rifle sights of a theodolite, while a range-finder (if available) can often be used to advantage. A description of a rapid method of plotting velocity and height ratios from theodolite readings can be seen in the *Ceylon Journal of Science*, Section E, Part I"].

The meeting adjourned at 5.5 p.m.

August 27, 1929.

(Signed) G. C. SIMPSON.

MINUTES No. VII.

Seventh Meeting, Saturday, the 24th of August, 1929, at 10.30 a.m.

The following delegates were present: Dr. G. C. Simpson (Great Britain: *President*) in the Chair, Mr. A. J. Bamford (Ceylon), Lieut-Col. D. C. Bates (New Zealand), Mr. N. P. Chamney (Gold Coast), Mr. T. F. Claxton (Hong Kong), Mr. H. H. Croucher (Leeward Islands), Mr. J. Dewar (Malaya), Capt. H. J. Feakes, R.A.N. (Australia), Mr. C. G. Hansford (Uganda), Mr. S. M. Jacob (Nigeria), Dr. C. W. B. Normand (India), Mr. J. Patterson (Canada), Capt. A. B. Smith, R.N.R. (Trinidad), Mr. C. Stewart (South Africa), Mr. L. J. Sutton (Egypt), Dr. R. S. Taylor (Somaliland), Mr. R. Temple (Sierra Leone), Major E. E. Turner (Windward Islands), Mr. A. Walter (East Africa, S. Rhodesia, Sudan), Capt. J. Calder Wood (Nigeria), Mr. E. J. Wortley (Nyasaland).

There were also present: Capt. Ellery (Board of Trade), and the following members of the staff of the Meteorological Office, Col. E. Gold, Mr. R. G. K. Lempfert, Capt. L. A. Brooke Smith, Cmdr. L. G. Garbett, Mr. M. A. Giblett.

1. **Documents circulated.**—Marine Meteorology, Notes by Capt. L. A. Brooke Smith, R.N.R. (Appendix V).

Specimen copies of the *Marine Observer*, the "Meteorological Observer's Handbook" and complete sets of the marine forms in use in the Meteorological Office, London, were supplied to each delegate.

2. **Discussion on Meteorology and Aviation.**—The President asked that any delegate who wished to do so would send in a note for inclusion in the report, on any additional points that he wished to bring forward.

3. **Marine Meteorology.**—The President called upon Capt. Brooke Smith, Marine Superintendent of the Meteorological Office, to give an account of his memorandum (Appendix V).

Capt. BROOKE SMITH, after welcoming the delegates, proceeded to describe the work which was being done by the Marine Division. He indicated what organization was necessary and laid particular stress on aspects of the work in which co-operation with other parts of the Empire was of importance.

He recalled the fact that the Merchant Service provided the main lines of communication between different parts of the Empire, and said that the voluntary work for marine meteorology had been developed by seamen, and would be carried on to the best advantage if it were organized in a manner suited to seamen. Though it was difficult on the one hand for those on land to appreciate the special needs of the seaman, and on the other for the seaman to realise that scientific knowledge of the sea could be obtained by academic study without practical experience, yet of recent years there had been a larger measure of co-operation and confidence; he attributed this in part to the fact that the work was carried on with a measure of self-government, under officers of the merchant service, with access to professional assistance, and in co-operation with the superintendents of other divisions of the Office. He said that in the course of his duty as Marine Superintendent he had had the advantage of the report of a Committee appointed by the Chamber of Commerce to examine the work informally, he had also had the opportunity of visiting the ports and obtaining the views and experience of seamen with regard to the special problems involved, and had further benefited from time to time by informal conferences with representatives of the Chamber of Shipping, of the Honourable Company of Master Mariners, of the Marconi Company and of various shipping companies. The proposals were accordingly based on the consensus of opinion of master mariners and mates, W/T operators and other experienced seamen.

Capt. Brooke Smith referred to the recent International Conference on the Safety of Life at Sea, at which 18 maritime countries including five of the British Empire, were represented. He reported that in accordance with Article 35—

"The contracting governments undertake to encourage the collection of meteorological data by ships at sea, and to arrange for their examination, dissemination and exchange in the manner most suitable for the purpose of aiding navigation".

He proceeded to outline the general organization for marine meteorology at present in force and to show how it might be developed to conform with the requirements of the convention.

(i) **General organization.**—(a) The observing fleet.—A general chart of the world showing the trade routes was exhibited. Capt. Brooke Smith showed that, using the organization provided by the shipping schedules, by the selection of suitable ships a skeleton network was provided, and with a similar system in other maritime countries a fairly complete network of observations would be available except in the Arctic and Antarctic oceans.

He said that at the present time the Marine Division of the London Office organizes a fleet of about 500 regular observing ships, the names of which are published monthly in the Fleet list at the end of the *Marine Observer*. Although all these are now British ships yet some 19 are registered in the Dominions, and in order to avoid overlapping it is proposed, as opportunity offers, that these ships should be removed from the list of the London Office and referred to the meteorological service of the country in which they are registered. Capt. Brooke Smith emphasised the fact that the organization of a volunteer observing fleet involved not only the cost of a large number of tested instruments, but provision for visiting and arrangements for agents who would keep in touch with the ships at the various ports.

He reported that at present—

(a) 115 merchant ships and 10 H.M. ships keep complete meteorological logs, using tested instruments supplied by the Meteorological Office,

(b) 330 keep an abbreviated form of report, using ships' instruments,

(c) 30 ships on the trans-Atlantic route, using tested instruments, make regular reports by W/T to the London Meteorological Office and to the United States Weather Bureau, many of these repeat the W/T report to all ships in plain language; in addition,

(d) 15 ships record and report special local observations, among these he mentioned specially the training ships Conway and Worcester and the Pangbourne Nautical College for which a special cadets log had been drawn up in order that the cadets might be trained in meteorological work,

(e) 10 cross-Channel steamers make special observations and some of these transmit the observations to shore by W/T at their own expense; others report by land wire on arrival.

With regard to the agreement laid down by the Convention on Safety of Life at Sea, by which certain selected ships would make meteorological observations at fixed times G.M.T., and report these observations to all ships and to certain coast stations, Capt. Brooke Smith stated that all log-keeping ships and the 30 trans-Atlantic W/T reporting ships were "selected ships," and in addition those other ships which took observations with their own instruments, provided that the barometer was a mercurial one, gave the value of pressure accurately to the nearest millibar.

(b) The Central Office.—A brief description was given of the organization of the Marine Division in the London Office. The work was divided under three branches: Section A was mainly administrative, and dealt with correspondence, the register of logs, etc., Section B was responsible for the extraction and compilation of data, and Section C with the preparation of charts for publication, the issue of the *Marine Observer*, the compilation of information regarding weather signals, W/T and visual.

(c) Co-operation between the observing fleet and the Central Office is provided for both by an officer being stationed at Liverpool, whose duty it is to visit ships, inspect instruments, and give such instructions and information as may be desired by officers; and by eleven marine agents, seven in the British Isles and four in the Dominions (Vancouver, Hong Kong, Sydney, Fremantle), all except one being master mariners.

He attached especial importance to this aspect of the work.

(ii) *The Convention on Safety of Life at Sea*.—With regard to the provision of the selected ships required to make W/T reports at selected hours, it was reported that on the basis of total merchant tonnage the number allotted to the British Empire as a whole was 356, and it was suggested that the Dominions should consider the possibility of maintaining 100 of that total. These 100 ships should be chosen from those registered in the Dominions and from such ships on the Home register as were not already included those chosen by Great Britain. In this connection Capt. Brooke Smith urged the importance of the establishment, where possible, of a Marine Division attached to the various meteorological services in order to facilitate co-operation with observing ships, and he emphasised the need for such work to be conducted by master mariners.

Attention was drawn to Article 34 of the Convention on Safety of Life at Sea, in which it was laid down that any ships should report a dangerous tropical revolving storm.

A minor amendment to Article 33 of the Convention was noted—

"The provisions of this Chapter referring to ships, unless otherwise expressly provided, apply to all ships on all voyages".

(iii) *The Meteorological Log*.—Capt. Brooke Smith recalled the fact that the form of log was based on the findings of the first Conference on Marine Meteorology at Brussels in 1853, and the amendments at the Conference in London in 1874. The form had been slightly modified in recent years to provide for observations of current drift and by the omission of compass bearings. Wind direction is entered in points, and all directions are true. Capt. Brooke Smith emphasised the importance of using a form of log which fitted in with the routine of the ship and so enabled the observing officer to have suitable opportunity for making the entries. He submitted that the complete log with space for additional remarks and sketches, and provision for the entry of W/T reports included all the information that was necessary.

Consultation with observers during many years had shown that the Beaufort scale of wind and the Beaufort notation of weather were regarded as satisfactory by seamen, but that the scale for sea and swell was not. Many attempts at devising a new scale had been made and finally one drawn up by Admiral H. P. Douglas (Appendix V, Annex A) was selected. The scale had been circulated to the meteorological and hydrographic services, and the majority of the opinions elicited were favourable. A proposal was accordingly being put forward that the scale should be adopted internationally.

(iv) *Collection, computation and exchange of marine meteorological data*.—Capt. Brooke Smith said that data from meteorological logs extending over seventy-five years were available, but many of the logs had not been extracted. A scheme had been put forward for extracting and compiling the data (wind, cloud, weather, dry, wet and sea-surface temperature) by the Hollerith system, for indexing important remarks and for setting out the results on charts of a uniform plan on a scale of two inches for 10° of longitude. It was proposed to use the Baillie rose for wind and a modification of that rose for ocean currents, and to publish a monthly chart for winds, a quarterly chart for currents and small inset charts for other elements.

It was estimated that the work for the North and South Pacific, and for the North Atlantic could be carried out at the Central Office in London by six clerks in six years at a total cost of about £8,000. The co-operation of the various countries of the Empire was asked for, in order that the data might thus be made available for all countries.

Capt. Brooke Smith reported that the present practice (adopted in 1921) was to extract completely the logs on receipt on to Hollerith cards, which were then available for exchange with other countries as required. The observations could also now be printed by the Hollerith system, and in order to remove all ambiguities in the printed observations it had been found that minor changes in the code were necessary, and after consultation, and due notice having been given to all countries, it was intended that the new code should be introduced on the 1st of January, 1930.

(v) *Ocean Currents*.—Capt. Brooke Smith explained the measurements of ocean currents and emphasised their importance for navigation. He said that the information was derived from the difference between observed and dead-reckoning positions at the end of a run, and the period of observation was usually either from noon to noon or between observations by stellar fixes at sunset and dawn. In view of the great improvement in navigation during the last twenty years the observations of

ocean currents were becoming increasingly more reliable and in working up the data the year 1910 had been fixed as the earliest date for which observations were used. He added that charts of currents along the main trade routes were being compiled in the Marine Division and published in the *Marine Observer*.

Dr. NORMAND (India) thanked Capt. Brooke Smith for the clear explanation which he had given of the work of the Marine Division, and expressed his appreciation of the work which the division had done in the past. He said that in India there had been no Marine division, as such, in the period 1906–28; during the last ten years of the nineteenth century there was a division working on a minor scale on the meteorology of the Indian Seas, the data collected had been tabulated and summarised and issued as the Meteorological Atlas of the Indian Seas. Since that time observations in those regions had not been summarised in India for climatological purposes, and officers had not been asked to supply logs. The practice had been for a clerk at Calcutta and at Bombay to board the ships, copy the logs and send the copies to the Central Office; the information was used mainly for observations of cyclones and the data had been plotted only for days of disturbed weather, data for other days was not utilised. Within the last eighteen months the Indian Government had sanctioned the appointment of an officer for marine meteorological work with the aim of getting into touch with the Mercantile Marine. No educated Indians were available with experience of the Mercantile Marine but an officer was at present being trained especially from the point of view of the meteorology of the sea. With regard to assistance in obtaining observations from selected ships he thought there would be little difficulty in getting the Indian Government to equip and maintain a number of ships for that purpose and he would personally be glad to co-operate in that way. He agreed that a uniform form of log was desirable and he would be willing to adopt that which the experience of the Marine Division in London had shown to be desirable. With regard to the extraction of data he asked whether any of the data on which the Hollerith system was to be employed had already been utilised.

Mr. T. F. CLAXTON (Hong Kong) said that he had found difficulty in Hong Kong in getting sufficient observations from ships, but since his visit to London he had realised how large a number of data was available and the enormous amount of work which was being done. There was no organization in Hong Kong which would permit of the complete discussion of all the observations provided for in the English log and he proposed in future, therefore, to confine his attention to obtaining wireless weather reports and observations of typhoons and special phenomena. He was, however, anxious to further the work of the Marine Division as far as lay in his power.

Mr. Claxton referred to a chart of the China Sea which had been published in Hong Kong, in which it was shown that the isobars were distorted in the neighbourhood of the islands of Formosa, Hainan and the Philippines.

Mr. J. PATTERSON (Canada) said that Canada had not had much experience in the collection of meteorological logs; the information had not been required until recently when it was possible to obtain wireless reports from the Pacific. The Weather Bureau at Washington had made arrangements with the ships' officers for reports from as far west as possible to be transmitted every day to San Francisco. From there they were forwarded to Washington and thence to Toronto.

He said that Sir Frederick Stupart was interested in the causes of weather in the North Pacific, and for five or six years thermograms, giving accurate observations of water temperature along the steamer lines were available. The observations gave interesting information as to the seasonal changes, and especially as to the Japanese current which disappears in a sharp line of demarcation within a few degrees of the Japanese coast. Some of the coldest water on the route is close to the place where the Japanese current disappears.

He agreed that the question of obtaining information from ships was becoming of increasing importance and that the data would be required for forecasting along the airship routes.

He said that the question of further provision for marine meteorology would have to be considered, at present Canada had an agent for marine meteorology only on the Pacific Coast. Mr. Patterson referred to unnecessary over-lapping in the region of the Pacific.

Capt. H. J. FEAKES, R.A.N. (Australia) said he thought the issue of logs for instruction in the training centres was a valuable step towards providing officers in future, who would have experience of both the practical and the scientific side of

marine meteorological work. Though he could not speak officially for the Australian Government he was of opinion that Australia would be glad to take over her quota of selected ships.

Mr. C. STEWART (South Africa) described his experience in the issue of barometers to ships in the past, he said he was confident that South Africa would be willing to equip any number of ships up to three dozen.

Capt. A. B. SMITH (Trinidad) expressed his thanks to Capt. Brooke Smith. He said that Trinidad was not likely to be able to give much assistance as there was little regular shipping. On account of its geographical position its organization must be worked out in conjunction with that of North and South America, but he saw no reason why it should not be in conformity with British methods.

Capt. BROOKE SMITH, speaking in reply, said that none of the data which it was proposed to submit to the Hollerith method had been used before. He emphasised the fact that only data made with tested instruments and included in full logs would be utilised. In reply to Mr. Patterson he said that the number of selected ships which fell to Canada's share was indicated on page 6 of the memorandum. Four Canadian ships were at present included in the British Fleet list and should be transferred as opportunity offered to the Canadian list.

The meeting adjourned at 12.20 p.m., and the delegates were invited to visit the Marine Division where details of the organization and of the Hollerith system of extraction and computation of marine data were demonstrated.

August 27, 1929.

(Signed) G. C. SIMPSON.

MINUTES No. VIII.

Eighth Meeting, on the 26th of August, 1929, at 11 a.m.

The following delegates were present: Dr. G. C. Simpson (Great Britain: *President*) in the Chair, Mr. G. Auchinleck (Gold Coast), Mr. A. J. Bamford (Ceylon), Lieut.-Col. D. C. Bates (New Zealand), Mr. A. J. Brooks (Gambia), Mr. N. P. Chamney (Gold Coast), Mr. T. F. Claxton (Hong Kong), Mr. H. H. Croucher (Leeward Islands), Mr. J. Dewar (Malaya), Mr. M. H. Eliassoff (Irish Free State), Capt. H. J. Feakes, R.A.N. (Australia), Mr. C. G. Hansford (Uganda), Mr. S. M. Jacob (Nigeria), Dr. C. W. B. Normand (India), Mr. J. Patterson (Canada), Capt. A. B. Smith, R.N.R. (Trinidad), Mr. C. Stewart (South Africa), Mr. L. J. Sutton (Egypt), Mr. R. Temple (Sierra Leone), Major E. E. Turner (Windward Islands), Mr. A. Walter (East Africa, S. Rhodesia and Sudan), Capt. J. Calder Wood (Nigeria), Mr. E. J. Wortley (Nyasaland).

There were also present: Capt. Ellery (Board of Trade), and the following members of the staff of the Meteorological Office: Col. Gold, Capt. L. A. Brooke Smith, R.N.R., Mr. D. Brunt, Mr. J. S. Dines, Cmdr. L. G. Garbett, R.N.

An apology for absence on account of illness from Capt. Cave was read.

Before the meeting the delegates assembled at the offices of the British Tabulating Company, General Buildings, Aldwych, W.C.2, where a demonstration was given of the working of the Hollerith machines with marine data. The processes of punching the cards from the coded log, printing, sorting and adding were shown. It was stated that a skilled operator could punch 300 cards an hour, the data from the cards could be printed at the rate of 75 a minute (4,500 an hour), sorted at the rate of 24,000 an hour; and the number of cards could be added at the rate of 150 a minute (9,000 an hour). The use of the method in practice was demonstrated by working out from the cards the frequencies of different degrees of visibility for the area 40-45° N., longitude 5°-10° W., in the month of May during the years 1921-28. The result showed that of the 573 observations available 69 per cent were ordinary visibility, 9 per cent exceptional visibility, 8 per cent haze, 7 per cent mist and 7 per cent fog.

1. **Documents circulated.**—Minutes of the Fifth Meeting on Friday morning, 23rd August. (Minutes No. V).

2. **Ships Wireless Weather Telegraphy.**—The President called upon Capt. Brooke Smith to give an account of the proposals which were put forward.

Capt. BROOKE SMITH said that in formulating the proposals great care had been taken to get the views of shipping, seamen, and of the wireless authorities in the special questions involved. As an example of the utility of the reports from selected ships he referred to an account by a German Captain which would be published in the October number of the *Marine Observer*.

He referred to Article 34 of the Convention on the Safety of Life at Sea which dealt with reports from ships encountering tropical revolving storms, and said that full instructions as to the form of report had been laid down and would be published in the full report and reprinted in the *Marine Observer*. After ratification of the Convention it would be a matter of law that every ship knowing that she was encountering a dangerous tropical revolving storm should communicate the information to all ships in the vicinity and to the competent authorities on shore.

A routine was required in order to avoid unnecessary congestion and jamming in the transmission of weather reports from ships by wireless.

He said that the scheme put forward had been drawn up in consultation with the representatives of the big shipping companies; it had been submitted to a committee of representatives of the Marconi Company, the Honourable Company of Master Mariners and the Chamber of Shipping of the United Kingdom. The proposals for communication had been worked out in conjunction with Capt. Slee of the Marconi Company, and Capt. Loring, Inspector of Wireless Telegraphy, General Post Office; and the whole scheme put forward at the Paris Conference. After the conference the scheme had been modified in consultation with representatives of the Board of Trade and of the Post Office. The proposals therefore represented the views of experts in shipping and in wireless telegraphy; in particular he mentioned that it had been drawn up in conformity with the wireless watch zones.

The times of observation and transmission.—Capt. Brooke Smith laid particular stress on the fact that the wireless watches were fixed according to G.M.T., and that in view of the fact that both the observing ships and the meteorological phenomena observed were moving, no adequate picture of the conditions could be obtained unless the observations were synchronised according to G.M.T. He said errors would occur if there were ambiguities as to the standard of time used. In his opinion there was no alternative to that of using G.M.T. for both the observations and for the transmission of meteorological reports.

He reminded the conference that in many cases there was only one officer on watch in the smaller ships, and he said that such ships should not be asked to take observations during the night hours.

Capt. Brooke Smith proceeded to describe the two categories into which the selected ships were divided according to their wireless equipment. Details of the classification are set out in the memorandum (page 117). It was proposed that selected ships with long-range transmission (type A) should address their reports to the shore station, using the wave-length appropriate to that station, Berne being notified that the message might be intercepted. In places such as the trans-North Atlantic tracks, where congestion was probable, such selected ships could be called up every day by the shore station and informed as to the order in which the reports should be made. Such a proceeding would not be necessary, however, in most localities. Ships with short-wave spark transmission (type B) would transmit at certain hours, the hours stated being those at which the transmission should begin.

It was further proposed that areas where sufficient observations could be provided by ships of type A should be regarded as prohibited areas for transmission of routine meteorological reports by ships of type B.

The application of meteorological reports at sea.—Capt. Brooke Smith stated that reports were of value in many ways; they enabled a ship to make preparations for encountering bad weather, they assisted in the economy of coal consumption, and they were especially of importance in giving information as to the conditions of visibility and current.

The code.—Particulars of the code at present in use were briefly described (Appendix V, Annex B), and Capt. Brooke Smith set out what he regarded as the essential principles.

The code must be capable of giving the meteorologist at meteorological centres and the navigator in ships at sea the necessary information which they both desire in all parts of the world for the purposes of meteorology and safe navigation, both from ships and from *selected* stations. Therefore it must be capable of giving the ship's position with the customary accuracy of the sea. It must be capable of giving information of different elements on different occasions and in different places, and therefore certain groups must have identifications for otherwise they are not understandable in different parts of the world.

It must be simple but accurate and concise.

Committee on Ships' Wireless Weather Telegraphy.

The President suggested that as the discussion would necessarily be of a technical nature the Conference should go into Committee for the remainder of the morning. (See page 66.)

September 3, 1929.

(Signed) G. C. SIMPSON.

MINUTES No. IX.

Ninth Meeting, the 26th of August, 1929, at 2.30 p.m.

The following delegates were present: Dr. G. C. Simpson (Great Britain: *President*), in the Chair, Mr. A. J. Bamford (Ceylon), Lieut.-Col. D. C. Bates (New Zealand), Mr. T. F. Claxton (Hong Kong), Mr. H. H. Croucher (Leeward Islands), Mr. J. Dewar (Malaya), Capt. H. J. Feakes, R.A.N. (Australia), Mr. C. G. Hansford (Uganda), Dr. C. W. B. Normand (India), Mr. J. Patterson (Canada), Capt. A. B. Smith, R.N.R. (Trinidad), Mr. C. Stewart (South Africa), Mr. L. J. Sutton (Egypt), Dr. R. S. Taylor (Somaliland), Mr. R. Temple (Sierra Leone), Major E. E. Turner (Windward Islands), Mr. A. Walter (East Africa, Southern Rhodesia and Sudan), Capt. J. Calder Wood (Nigeria), Mr. E. J. Wortley (Nyasaland).

There were also present: Admiral H. P. Douglas (Hydrographer to the Navy), Capt. Ellery (Board of Trade), and the following members of the staff of the Meteorological Office: Col. E. Gold, Dr. F. J. W. Whipple, Mr. D. Brunt, Capt. F. Entwistle, Cmdr. L. G. Garbett, R.N.

1. **Documents circulated.**—(a) Minutes of the third, fifth, sixth and seventh meetings (Minutes No. III, V, VI and VII).

(b) The Meteorological Requirements of the Army within the British Empire (Appendix VI).

(c) Memorandum on Fleet Meteorology (Appendix VII).

The President reminded delegates that the memoranda (b) and (c) should be regarded as confidential.

2. **Sub-committees.**—The name of Col. Gold was added to the list of members of the sub-committee appointed to consider the meteorological organization on the Cairo-Cape Town air route.

3. **The Meteorological Requirements of the Army within the British Empire.**—Mr. D. BRUNT (Superintendent of Army Services, in the Meteorological Office) proceeded to give an account of his memorandum, Appendix VI. He emphasised the need for uniformity in the system of providing meteorological information to artillery units though he agreed that the rules which had been drawn up for England to meet the cases where observations of wind and temperature were lacking might possibly need slight modification abroad.

Mr. Brunt referred to a letter dated the 6th of June, 1929, which had been received from the Army Council with regard to the importance of obtaining records of wind direction and strength, temperature and humidity in the various parts of the Empire. He said that the directors of the meteorological services could assist in providing for the meteorological requirements of the army in three ways:—

(i) By studying the pamphlet M.O. 317 "The Supply of Meteor Reports to Artillery Units" and by using it as a basis for supplying meteorological information to gunners. He stated that the pamphlet should be regarded as confidential.

(ii) By the loan to the Meteorological Office in London, of a year's records of anemographs and hygrographs for at least one station in the region over which their service extended. In this connection he said that he would leave to the delegates the choice of the station for which records were sent, but he noted that he was especially interested in information from important base stations such as Hong Kong and Singapore, and from any station with a marked diurnal variation in wind. He pointed out that the anemometer records should, if possible, be records with a Dines pressure-tube instrument, though records from a Robinson cup anemometer would also be of interest.

On certain occasions a smoke screen was obtained by dropping a substance from an aeroplane, and success depended on an adequate supply of water-vapour and absence of turbulence in the wind. The hygrometer records, which should be for relative humidity, should cover the same period as those of the anemometer though humidity records alone would be welcome in cases where no record of wind was available. Records of the lapse of temperature in the surface layers would also be very valuable if there were any in existence. Mr. Brunt said he could assure the delegates that the records would be examined without delay, and that their loan would be required for a short period only.

(iii) By giving him in writing a statement of the number of professional meteorologists on their staff, and an indication as to the number which they estimated for 1940. This was required in order that a statement might be drawn up of the number of trained meteorologists who would be available to form the nucleus of a service in time of war in any locality. Mr. Brunt pointed out that the responsibilities of a meteorological officer in war time were very great and required a considerable period of training.

Some difficulty was expressed by the delegates as to the definition of the term professional meteorologist, in view of the fact that many of the services employed native assistants. It was understood that any statement of the strength of the staff of the various services with notes as to their rank and training would be acceptable.

At the request of the President, Mr. Brunt proceeded to give a brief sketch of the meteorological organization in the army in time of war. He said that the primary duty of the service was to give meteorological information to the general staff on the wider aspect of operations, to supply meteorological telegrams to artillery units and to supply information and forecasts to units of the Air Force. In the case of war over a small area the organization would consist of a central station where forecasts would be made. This would be located at army headquarters, and connected with it would be, first subsidiary pilot-balloon stations which would supply meteor telegrams to gunners and upper-air information to the Air Force, and secondly wind and weather posts which would take observations of surface conditions only. In the case of war over a wider area there would be central stations at general headquarters and at each army headquarters, at all of which charts would be drawn and forecasts issued for all types of operations; short and long-distance bombing raids and general operations.

Col. BATES added to the duties of a meteorologist in war time, which had been enumerated by Mr. Brunt, that of supplying information as to the climate of the country to which the troops were to be sent. He emphasised the importance of keeping a record of the forecasts issued.

Capt. CALDER WOOD reported that humidity records were available in Nigeria but no wind records.

Mr. CLAXTON said that the existing mast at Hong Kong would permit of observations of temperature up to 150 feet, and Mr. Brunt agreed that observations to that height would be sufficient for his purpose.

Mr. PATTERSON said that records of temperature by a differential method, together with wind records with cup anemometers were available for McGill University and Mount Royal about 300 feet higher. The records extended over a period of some years and would be available on loan if desired. Capt. Brunt said they would be of value.

4. **Fleet Meteorology.**—Cmdr. L. G. GARBETT, R.N., Superintendent of Navy Services in the Meteorological Office, gave an account of the meteorological requirements of the Fleet (Appendix VII). He pointed out that included in these requirements were marine meteorology for navigation and strategy, army meteorology for gunnery and smoke screens, and aviation meteorology for the Fleet Air Arm.

Not the least of the lessons of the war was the realization of the importance of meteorology in naval operations and he could say without hesitation, with the Hydrographer of the Navy present to support him, that the Admiralty was prepared to co-operate with the meteorological services of the Empire in investigating the meteorological conditions over the sea.

General organization.—Cmdr. Garbett proceeded to outline the present meteorological organization of the fleet, he referred especially to the arrangements made for the training of officers in meteorological duties, and said that courses were arranged both for navigating and surveying officers, and for selected naval observers of the Fleet Air Arm. He said that at present the aircraft carrier, where such exists, was the centre of the meteorological organization of the Fleet and was equipped with the most modern type of instruments; it was proposed in future to provide similar instruments on flagships where better exposure was available, and such ships would then be the centre of the organization.

Special requirements of the Fleet.—Foremost among these Cmdr. Garbett placed a knowledge of visibility, on which the fighting range depended. He said that at the request of the Admiralty a special investigation into visibility was being undertaken, and a Government committee was to consider the lines on which the investigation should proceed. Secondly a knowledge of the lapse-rate of temperature in the lowest layers was of importance for the successful operation of smoke screens, and a knowledge of upper winds was vital for carrier-borne aircraft. Cmdr. Garbett gave details of the numbers of ships equipped with pilot-balloon apparatus, one of the ships was in the African Navy and three in the Australian Navy, and the Squadron under the New Zealand Government had been asked to co-operate. He said that up to the present time about 600 observations had been received, and in future it was hoped to get 2,000 observations a year. Of course it would take a long time to obtain sufficient observations to prepare upper-air charts.

Mr. Giblett had suggested that a special ship should be equipped for the exploration of upper winds in the trade-wind region, and he wished to associate himself with that proposal and hoped it might receive official consideration.

With regard to upper-air temperatures he reported that some 50 observations from aeroplanes had been received, and he had also himself had some experience of obtaining records at sea with registering balloons.

A point on which he laid special emphasis was the importance to the Navy of a study of the problems of single-observer forecasting. An officer had been detailed by the Admiralty for this purpose, and the results so far obtained were encouraging.

Co-operation between the Navy and local services.—Cmdr. Garbett said that up to the present there was no official organization between the Fleet and the meteorological services abroad though there had in some cases been valuable personal liaison. Arrangements for official co-operation were in progress, and the Admiralty had recommended that commanders-in-chief should call conferences to discuss the organization and development of Fleet meteorology in their respective stations in peace and war. The first of these conferences would be held in Hong Kong in January, 1930, and in Trincomalee in February, 1930, and he himself hoped to attend. He said that it was of vital importance to have the assistance of the local services at the conferences, and he would be glad to know from the directors concerned, Dr. Normand, Mr. Bamford, Mr. Claxton, Mr. Dewar and Mr. Walter whether there was a prospect of their being able to attend. On the days preceding each conference he hoped to have an opportunity of discussing with the directors the memoranda on the proposed organization of the Fleet which he was preparing.

He said that the general nature of the co-operation between the Fleet and the meteorological services was set out on p. 128 of the memorandum (Appendix VII).

Co-operation with the Meteorological Office.—In this connection, Cmdr. Garbett referred to the service which the local meteorological services could render to seamen by assistance in the correction and revision of the Admiralty Sailing Directions in their own neighbourhood.

In conclusion Cmdr. Garbett emphasised the necessity for uniformity in general practice at all stations and for close co-operation both personal and official between the Fleet and the local meteorological services of the Empire. He asked for the support of the delegates in assisting to provide adequate organization for the Fleet both in peace and war throughout the British Empire.

The President asked for any experience of the delegates in co-operating with the Fleet in meteorological matters.

Mr. CLAXTON (Hong Kong) expressed his gratification at learning that so much had been done to perfect meteorology for the Fleet. He said he had had great difficulty in obtaining accurate barometer readings from ships though he might have had more success if he had requested the Admiralty to ask all ships to take observations for comparison as soon as they entered the harbour at Hong Kong. He congratulated the Meteorological Office on the production of Memo. 8/28 on "The Checking of H.M. Ships' Barometers", he thought it would do much to improve the accuracy of the readings, especially if even on the smaller ships meteorological observations became part of the routine duty of qualified persons. He understood that a new aneroid barometer was being devised which would give accurate readings—and though he was sceptical he hoped it might prove successful. He said he would be glad to co-operate as far as lay in his power, and pointed out that as the observations increased in accuracy so would the Hong Kong Observatory be able to extend the services it could perform. He thought there would be no difficulty in getting permission from the Hong Kong Government for his attendance at the Conference.

Capt. BAMFORD agreed that much turned on the provision of adequate liaison between the Fleet and the local services, and said he welcomed the arrangements that were being made.

Col. BATES said that he had on many occasions been brought into contact with ships, he referred to occasional errors in the barometer readings, but said that he was always ready to co-operate in the issue of reports. He emphasised the fact that New Zealanders were a maritime people and he thought the meteorologists owed a great debt to the Navy.

Dr. NORMAND said that up to the present there had been very little personal liaison between the Indian Meteorological Service and the Navy, he attributed this partly to the former small size of his service and partly to the location of the meteorological headquarters at Simla, 1,000 miles from a port. There had been, however, a certain amount of official correspondence, and at the request of the Navy, arrangements had been made for the transmission by wireless twice daily, from Aden and Matara, of a simple meteorological report. The Indian Service had also been glad to assist in the revision of the Admiralty Pilots. He had been interested to hear of the progress of the work and looked forward to receiving information from the Navy in future, especially observations of wind and temperature in the upper air. The transfer of the headquarters of his service to Poona offered greater opportunity for personal liaison especially in the event of the Fleet going to Bombay. With regard to his attendance at the proposed Conference at Trincomalee he did not anticipate any difficulty unless the time coincided with the arrival of the airship at Karachi; as the Conference was being held out of India a request from the Commander-in-Chief through the Indian Government would be necessary.

Mr. PATTERSON (Canada) said that the meteorological headquarters were also situated far inland, and consequently up to the present there had been no direct liaison. He was always glad to give any information that was asked for and when demands and opportunities for participation came he hoped to be able to do his part. He was interested in the arrangements for meteorological training of personnel and would be glad to have a syllabus of the courses that were organized.

Capt. H. J. FEAKES congratulated the Conference on the statements which Cmdr. Garbett had made. He was especially interested in the arrangements for meteorological education in the Navy and in the developments which were taking place, and he attached great importance to the principle of training the practical type of scientist in the meteorological service.

Mr. C. STEWART said he looked forward to closer liaison with the Navy. Up to the present there had been little communication, though the scheme in operation at present for the broadcast of wireless reports each morning had been drawn up by a naval officer in co-operation with a member of the staff of the meteorological service.

Mr. A. WALTER said that in Mauritius he had had little connection with the Navy as they usually visited the island at times when the weather conditions presented little interest, and at the time of which he spoke the possibility of wireless synoptic charts was unknown.

With regard to his work in East Africa he regarded liaison with the Navy as of the greatest importance, especially in the detailed survey of the SE. trade current. Though his headquarters were 350 miles from the sea he thought there would be little difficulty in organizing personal liaison as many officers of the Fleet visited Nairobi.

With regard to the Conference in 1930 he thought it was unlikely that he would be able to attend on account of his long absence from the Colony. An official request would be of value, but it would have to be sent not only to the Government of Kenya but to the six other Governments which he represented.

Mr. L. J. SUTTON said that not much information was supplied directly. The Egyptian synoptic broadcast message was received by Malta, and that station supplied most of the requirements of the Navy, he would be glad, however, to help in any way that was possible.

Mr. J. DEWAR (Malaya) also promised all the co-operation possible when the organization of the service was complete. He thought the Government would raise no objection to Mr. Stewart's attendance at the Conference.

The PRESIDENT referred to the close co-operation which existed between the Meteorological and Hydrographic Offices in Great Britain especially during Admiral Douglas's tenure of the office of Hydrographer, and he referred to the large developments in the meteorological organization in the Fleet during that period.

Admiral DOUGLAS (Hydrographer) in reply to the various speakers said he regretted the errors in the barometer readings from H.M. ships. He thought that the provision for meteorological courses in the navigation school and the arrangements that were being made by which all H.M. ships would carry mercurial barometers fitted with the Gold scale would make such errors unlikely in the future; he hoped that one of the many results of Cmdr. Garbett's visit would be to make arrangements for periodical testing of the (H.M. ships) barometers. He emphasised the importance of reports from the Navy and said that a recent Conference on the Safety of Life at Sea had made the reporting of dangerous tropical storms obligatory to all ships.

In reply to Dr. Normand he said he hoped it would be possible for him (Dr. Normand) or a representative of the Indian service to be present at the Conference at Trincomalee. He thought that any organization which might be developed after the Naval Conference would also be of benefit to the R.I. Navy, especially their surveying ships. He said that in co-operation with the Air Ministry it was proposed that at a later date Cmdr. Garbett should visit both the West Indies and South Africa, and he would welcome the co-operation of representatives of the services in Canada and South Africa.

The Hydrographer laid special stress on the importance to the Navy of single-observer forecasting and on the value of upper-air observations for aviation and gunnery. He expressed the hope that directors would not be unwilling to ask the Admiralty for any assistance they required and said that the Admiralty was very ready to co-operate with the meteorological services.

In reply to a question by Mr. Claxton as to the possibility of devising a barometer which would stand the vibration on a destroyer, Cmdr. GARBETT said that barometers were supplied to the destroyer leader which was a bigger ship than a destroyer and consequently inaccuracies arising from vibration from the discharge of torpedoes need not be considered.

Cmdr. Garbett concluded by thanking the delegates who had spoken, for their encouraging remarks and expressing his hope of establishing a close liaison between the Navy and the local meteorological services.

The Conference adjourned at 4.40 p.m.

September 3, 1929.

(Signed) G. C. SIMPSON.

MINUTES No. X.

Tenth Meeting, Tuesday, the 27th of August, 1929, at 10.50 a.m.

The following delegates were present: Dr. G. C. Simpson (Great Britain, *President*), in the chair, Mr. A. J. Bamford (Ceylon), Lieut.-Col. D. C. Bates (New Zealand), Mr. A. J. Brooks (Gambia), Mr. N. P. Chamney (Gold Coast), Mr. T. F. Claxton (Hong Kong), Mr. H. H. Croucher (Leeward Islands), Mr. J. Dewar (Malaya), Capt. H. J. Feakes, R.A.N. (Australia), Mr. C. G. Hansford (Uganda), Mr. S. M. Jacob (Nigeria), Dr. C. W. B. Normand (India), Mr. J. Patterson (Canada), Capt. A. B. Smith, R.N.R. (Trinidad), Mr. C. Stewart (South Africa), Mr. L. J. Sutton (Egypt), Mr. R. Temple (Sierra Leone), Mr. E. E. Turner (Windward Islands), Mr. A. Walter (East Africa, Southern Rhodesia and Sudan), Capt. J. Calder Wood (Nigeria), Mr. E. J. Wortley (Nyasaland).

There were also present: Capt. Ellery (Board of Trade), and the following members of the staff of the Meteorological Office: Col. Gold, Capt. Brooke Smith, R.N.R., Mr. J. S. Dines, Cmdr. L. G. Garbett, R.N.

An apology for absence from Mr. Eliassoff was received.

1. **Documents circulated.**—(i) Form of weather shipping bulletin and charts showing stations, forecast areas and districts.

(ii) Agenda for the meeting on Tuesday afternoon, August 27th.

(a) Meteorology in Polar Regions by Dr. G. C. Simpson. (See *London, Geographical Journal*, 74, 1929, p. 258).

(b) Copy of letter from Prof. W. Wiese to Dr. G. C. Simpson.

(c) Report of Sub-Committee on West African Meteorology.

(d) Proposed establishment of 13 new meteorological stations south of Hong Kong (Appendix VIII), by Mr. T. F. Claxton.

(e) Note on anemometers, by Mr. T. F. Claxton (Appendix IX).

(f) Minimum wet-bulb thermometers, Note by Mr. A. J. Bamford (Appendix X).

(iii) Agenda for the meetings on Wednesday, 28th August, 1929.

2. **Weather Shipping Bulletins, Wireless Gale and Hurricane Warnings, Visual Gale and Hurricane Warnings.**—(a) *Weather Shipping Bulletins.*—Capt. BROOKE SMITH related several experiences which, coupled with the wireless experience gained before and during the war, had led him to realise the importance of W/T in the issue of meteorological information.

He said that after the Admiralty service of weather bulletins ceased, requests were received from commanders for the issue of a shipping bulletin and in 1921 the Meteorological Office in London started a western-seaboard message giving the actual observations at five stations on the British coasts which, combined with their own observations and those from ships, enabled officers to visualise the weather conditions over a large area. The first weather chart made at sea was received from a young officer in the South African Mail Service.

After obtaining the views of experienced seamen a scheme had been drawn up in conjunction with Mr. J. S. Dines and Cmdr. Garbett; a chart before the meeting illustrated this. Information from 10 British stations, one in Iceland and one in the Faeroes was included in the bulletin; the region was divided into three forecast areas: western, eastern and southern and these were subdivided into districts because in these latitudes conditions may vary considerably within a small area. The area of the Thames was especially small on account both of the congestion of shipping and the differences of visibility at times. The area of the Clyde likewise. Forecasts for a period of twelve hours of two elements only, wind and visibility were made and were now issued twice daily.

The bulletins enabled the educated seamen either to use the forecast as issued or to verify it by his own deductions, and also to forecast for regions outside the areas; this increased confidence.

Capt. Brooke Smith said this broadcast bulletin was received as far as Madeira in the south and nearly as far as Belle Isle in the west. It included a general inference (which at present gave information over the land as well as over the sea), forecasts for areas and where necessary for districts, and coded reports from the stations.

In order to provide for ships that are unable to receive at long range the bulletin was divided into parts, and issued from two stations on the west coast, one on the east and one on the south. For fishermen, yachtsmen, and small craft without W/T the B.B.C. reported the forecasts for the three districts, by word of mouth. Capt. Brooke Smith pointed out that the extension of the use of the bulletin must be brought about in large measure through the influence of the more educated seamen. He said that the value of the forecast was not limited to safe navigation, but was useful in other ways such as enabling fishermen to know from which end to haul their herring nets.

(b) *Gale-warning service.*—Capt. Brooke Smith said that in Great Britain a message was issued giving warning of gales expected within a certain radius of the W/T station. The warning included both information of the wind and also the position of the depression and the direction of its travel. He emphasised the necessity of removing any ambiguities in the messages which were likely to mislead the mariner; in this connection he read the notes giving general principles set out in Appendix V, Annex A, which were for the tropics as well as middle and high latitudes in both hemispheres.

He emphasised the desirability of issuing reports of actual observation as a routine in all seasons when bad weather or bad visibility was possible. He said that seamen should have this opportunity of drawing their own conclusions.

(c) *Visual gale warnings.*—Capt. Brooke Smith emphasised the fact that a W/T signal was momentary and that visual signals were still necessary and would remain so.

He said that the visual signals were used by ships on long voyages as well as by local craft and urged the desirability of uniformity. He said that an expert forecaster in consultation with master mariners, with great experience of gales, hurricanes and signals in all parts of the world, and with fishing skippers, had drawn up a system of visual signals which he thought was suitable for general use. These signals would be demonstrated to any of the delegates who were interested.

In conclusion Capt. Brooke Smith thanked the delegates for the tolerance with which they had listened to him during the three days. He referred to the motto of Loyalty and Service which had been adopted by the Honourable Company of Master Mariners of which the Prince of Wales was Master, and he said that the Merchant Navy were not only working in the interest of safe navigation, but were furthering the interests of the British Empire and civilization in all parts of the world by the *voluntary* work of marine meteorology.

The PRESIDENT then asked the delegates for a discussion on the subjects put forward by Capt. Brooke Smith. He said that it was very desirable that the system of daily weather bulletins for shipping should be as far as possible uniform, though in view of the variety of needs in different parts of the world, he did not wish to press for rigid uniformity. With regard to the system of visual signals for gale warnings as distinct from hurricane warnings he said that up to the present the International Meteorological Committee had not found it practicable to put forward a scheme of world-wide application, though such a scheme for temperate latitudes was in operation. Great Britain had not yet found it possible to use the international signals.

Dr. NORMAND (India) said that in India in consideration of the fact that all wireless messages transmitted or received had to be paid for, they did not wish either to send out or to receive more information than was actually required. Two broadcasts from W/T stations were made daily, these were as brief as possible and aimed only at giving information about really disturbed weather, either to tell of the existence of conditions favourable for cyclone formation, or to give a description of the position and development of the cyclone where such existed, to differentiate between a strong and ordinary monsoon, or to describe strong winds in the North Arabian Sea or off the coast of Bengal during the passage in winter of a depression from Europe over northern India. On other occasions a bulletin "weather normal" was issued and this had met with criticism in some quarters. Apart from the question of finance it would be easy to give fuller information, but after discussion with port officers and with special committees appointed by the Chamber of Commerce at Calcutta, he thought the general feeling of the majority of ship-masters was that they did not desire more information at present, though he thought they would do so in future.

Dr. Normand referred to the minutes of a recent meeting of a committee in Calcutta in which it was stated that the expert opinion was divided, certain ship-masters were satisfied but others expressed the opinion that it was desirable to supplement the information with certain coastal details. He further stated that ship-masters in the Bay of Bengal had been asked two years ago for their opinion and apparently the general feeling then was that they did not wish for the broadcasting of synoptic weather information. He said that a scheme was in preparation as an experiment by which it was proposed to issue fuller bulletins supplemented by synoptic information for a limited number of coast stations during the cyclone periods of 1930 (April to May and after the monsoon); it was proposed that after the trial had been made ship-masters should be asked for an opinion as to whether they wished the bulletins to be continued. With regard to visual signals he said that India had developed its own methods and although it was desirable for all countries to come into line he did not think a proposal to that effect would prove practicable. He referred again to the meeting at Calcutta when ship-masters had expressed the view that the Indian system of visual signals was suited to their needs, that China and Japan both had their own systems which were excellent and well understood by ship-masters and that the subject of uniformity need not be raised at present.

Mr. CLAXTON (Hong Kong) said that a bulletin was sent out twice daily at noon and 8 p.m. based on observations at 6 a.m. and 2 p.m. In addition the observations at the stations were broadcast. The data included the barometric pressure (four figures) temperature of the air and of evaporation, wind direction and wind force on the Beaufort scale. The weather was given by Code 3 of the international code. The message was followed by a forecast for 24 hours of the direction and force of the wind, and of the weather. If there was an indication of a typhoon it was included in the forecast with information as to its position and direction of motion.

With regard to visual signals he said that warnings were exhibited visually by two codes, a local code and a non-local code. The local code was similar to the international code but differed from it in certain characteristics. The signals used were one red cone, two black cones, a black drum, a black ball, two black cones point to point and a black cross. The night signals were given by combinations of three vertical lamps, red, green and white.

Mr. Claxton said he thought the signals could be adapted for use internationally and asked that opportunity might be given for discussion as to the possibility of drawing up a uniform code as regards non-local codes. He thought some international agreement was desirable so that warnings of the position of typhoons could be issued. One of the advantages of the code used at Hong Kong was that it could be telegraphed by ten of Bentley's million cyphers, with an addendum of two letters.

Mr. BAMFORD said that Colombo sent out W/T signals at 11.30 a.m. and 10.30 p.m. quite apart from the messages from Matara. A change in method, from that formerly adopted at Colombo, and still used by India, was made a few years ago as the result of conversations with the captains of various ships. On occasions when there is nothing notable enough to be described as a "storm warning" an attempt is now made to give the actual conditions, especially near Colombo, instead of the mere phrase "weather normal." With regard to storm warnings the first and most useful indications are usually given by the up-country temperatures. Ceylon is too small for isobars across it to be sufficient to fix the position of storms, of a type common in the Bay, which do not pass over Ceylon, but pass near enough to it to have a distinct bearing on its weather. For this information we rely on the information kindly supplied by the Indian Dept. As regards visual signals, the Master Attendant is in close telephonic touch with the Observatory, and the methods of communicating information to ships in harbour, other than by the wireless broadcast, are a matter for him rather than for me.

Col. BATES (New Zealand) said that reports and forecasts were issued twice a day. He recalled the fact that fifty or sixty years ago a code of words had been adopted after consultation with Australia, and with slight amplification the same code was in use today. He said that ships in Australian waters sent out reports that could be picked up by wireless at stations in Australia, New Zealand, Samoa and Chatham Island. Changes agreed upon internationally could only be brought into operation in New Zealand after consultation with Australia. With regard to visual warnings he had proposed the subject for consideration at a meeting of the Maritime Committee fifteen years ago, as a result of the discussion he had been asked to collect notes of the systems in operation but the war intervened and he had been unable to do so. He

thought that it should be possible to come to some international agreement as to a code which would give information of the wind direction, using four points only, and of the changes expected. He expressed the hope that it would be possible to arrange a discussion so that the subject might be brought up for consideration internationally.

Mr. PATTERSON said that the Canadian code had to be used both on the coasts and in the Great Lakes. For the Atlantic coasts and the Great Lakes bulletins were issued twice daily based on observations at 8 a.m. and 8 p.m. 75th meridian time (01h. and 13h. G.M.T.). Bulletins were issued by wireless giving forecasts for the Grand Banks and for the Gulf of St. Lawrence. The bulletins were issued by wireless and broadcast about three hours after the observations. Storm warnings were also sent out by wireless and broadcast and visual signals were displayed at the storm signal stations affected. The visual signals used in the Canadian service were similar to those recommended internationally but made use of a cone and a drum instead of two cones; at night a red and a white light were used. He thought it would not be difficult for Canada to adopt the international system.

Capt. FEAKES confirmed Col. Bates's reference to the co-operation between Australia and New Zealand. He said that he had been in touch with the meteorological department in Australia for many years and was impressed by the efforts they were making towards the education of the farmer and the seaman by the publication of weather information and charts in the daily press. He thought the development of the sailor-scientist would do much to change the views by seamen and would give rise to a close liaison between the scientific and practical side of meteorology.

Mr. STEWART said that forecasting was comparatively young in South Africa and special problems arose out of the fact that the major part of the country was a plateau with only a narrow coastal strip at sea level. Forecasting storms was especially difficult when the isobars ran parallel to the coast and there was no information from the sea. Observations were broadcast by wireless at 08.30 (0630 G.M.T.) and special forecasts for coast stations at 09h. G.M.T. No special system of visual signals was in operation though some coast ports had their own system.

Mr. WALTER said that in Mauritius warnings were only issued during the cyclone season; until the actual development of the storm a simple signal was flown of the general conditions in the four quadrants, but after its development endeavour was made to keep in touch with ships in the neighbourhood by wireless. In East Africa there was no necessity for visual signals except for information of the current in the Mozambique channel. Dangerous storms only occurred at some distance from the coast and it was useless to issue warnings except by wireless. For weather messages he said he hoped to be able to adopt whatever form was recommended by international agreement.

Mr. SUTTON said that storm warnings were sent to Alexandria, Port Said, Rosetta and Damietta. The visual warnings used in Egypt are those of the international system. Warnings were issued to boats on the Nile by telephonic communication to the quays.

Mr. DEWAR said that the collection of weather information from various stations had been started and this was sent to the newspapers and to the Master Attendant, and to other services when required. Visual storm signals were not dealt with by the meteorological service.

Mr. WORTLEY said that a useful purpose would be served if arrangements could be made for the issue of forecasts of storms approaching the eastern coast of Central Africa.

The PRESIDENT in conclusion said he thought the discussion had served a useful purpose, though he did not think the Conference could come to any final decision. In his opinion a uniform system of visual signals was not necessary all the world over as such signals were intended chiefly for the use of local craft; he would, however, be glad if any directors who were interested would discuss the matter with Capt. Brooke Smith.

The meeting adjourned at 12.15.

September 3, 1929.

(Signed) G. C. SIMPSON.

MINUTES No. XI.

Eleventh Meeting, Tuesday, the 27th of August, 1929, at 3 p.m.

The following delegates were present: Dr. G. C. Simpson (Great Britain: *President*) in the Chair, Mr. A. J. Bamford (Ceylon), Lieut.-Col. D. C. Bates (New Zealand), Mr. N. P. Chamney (Gold Coast), Mr. T. F. Claxton (Hong Kong), Mr. H. H. Croucher (Leeward Islands), Mr. J. Dewar (Malaya), Mr. C. G. Hansford (Uganda), Mr. S. M. Jacob (Nigeria), Dr. C. W. B. Normand (India), Mr. J. Patterson (Canada), Capt. A. B. Smith, R.N.R. (Trinidad), Mr. C. Stewart (South Africa), Mr. L. J. Sutton (Egypt), Dr. R. S. Taylor (Somaliland), Mr. R. Temple (Sierra Leone), Mr. E. E. Turner (Windward Islands), Mr. A. Walter (East Africa, Southern Rhodesia and Sudan), Capt. J. Calder Wood (Nigeria), Mr. E. J. Wortley (Nyasaland).

The following members of the staff of the Meteorological Office were also present: Mr. R. G. K. Lempfert, Col. E. Gold, Dr. C. E. P. Brooks, Mr. D. Brunt, Mr. J. S. Dines, Capt. F. Entwistle, Cmdr. L. G. Garbett, Mr. F. J. W. Whipple.

An apology for absence from Mr. Eliassoff was received.

1. **Documents circulated.**—(a) Minutes of the fourth and ninth meetings (Minutes No. IV and IX).

(b) Addendum to Minutes No. VI.

2. **Minutes.**—The minutes of the fifth, sixth and seventh meetings were corrected and signed.

3. **The Polar Year.**—The PRESIDENT referred to his memorandum on Meteorology in Polar Regions, and to a copy of a letter from Professor W. Wiese, both of which had been circulated. He said that the question of organizing a polar year had arisen in connection with a scientific enterprise of 1882-3 when 14 expeditions had been sent to polar regions. On that occasion 12 countries (Austria, Canada, Denmark, England, Finland, France, Germany, Holland, Norway, Sweden, Russia and the United States) co-operated by sending expeditions to the Arctic; the United States and France also organized expeditions to the Antarctic. The results obtained were of outstanding importance in geophysics, and the enterprise formed a landmark both in international co-operation and polar exploration.

He said that Admiral Dominik, the President of Deutsche Seewarte, had suggested that the jubilee of the polar year should be celebrated by a repetition of the enterprise. The suggestion had been enthusiastically received and a small sub-committee of which he himself was President had been appointed to formulate proposals. This sub-committee had drawn up a report in which it was suggested that a number of small expeditions should be organized to take observations over the period of one year and that the main objects of the observers should be to investigate the polar atmosphere in the light of the new theories, to investigate terrestrial magnetism, and to investigate aurora. No large expedition was proposed but it was suggested that small parties should be sent to the most accessible of the inaccessible places of the polar regions.

Dr. Simpson referred to maps which had been circulated, one of which showed the stations for magnetic research from which it was hoped to obtain observations with self-recording magnetic instruments over a period of twelve months. The sub-committee suggested that the stations occupied during the polar year of 1882-83 should be re-opened and that in addition several new stations should be manned, the countries which were to be asked to undertake the work at the several stations were marked on the map.

It was suggested that meteorological observations should be made at all the magnetic stations, but the sub-committee realised that the meteorological conditions they required to study necessitated the establishment of stations at high level; it was proposed therefore that stations at high level should be chosen as close as possible to the magnetic observatories. The positions of such stations were shown on a second map on which were indicated the existing stations, the stations proposed, and additional stations which were desirable if the organization for their establishment could be made. It was considered that advantage should be taken of the occasion to endeavour to complete a daily synoptic map of the Northern Hemisphere by using the information from the Arctic regions; and the meteorological services of Canada

and the United States would be asked to take steps to get synoptic weather information from their northern stations. In this way it was hoped to get synoptic data from twelve stations extending into the Arctic circle.

With regard to the support to the project which had already been promised Dr. Simpson reported that Denmark was prepared to undertake all that was suggested as her part in the programme, i.e., the establishment and maintenance of three stations on the west coast of Greenland; Germany had undertaken to organize special observations from ships, to establish a station on the coast of Greenland, and to arrange the transport of expeditions by airship; the U.S.S.R. was prepared also to co-operate extensively in the work, a map showing the stations which that country was prepared to establish was referred to. The co-operation asked for from the British Empire, in the Northern Hemisphere was limited to the re-opening of the station at Fort Rae which Great Britain might undertake, and the establishment of a station on Hudson Bay which would fall to the part of the Canadian service.

With regard to the Southern Hemisphere the problem was slightly different, in view of the absence of any inhabited land areas; it was suggested, however, that by obtaining transport by whalers it might be possible to establish a station at Cape Adare where a hut was already in existence; stations at ocean islands such as Kerguelen and South Georgia might also be maintained.

In reply to a question by Mr. Dewar as to the difficulty of maintaining stations at high levels in the polar regions on account of the low temperatures, Dr. Simpson said that on many occasions the temperatures at high levels in those regions were greater than at the surface.

Col. BATES said that he regarded the establishment of stations at Kerguelen and Campbell Island as of great importance. He hoped that the occasion might be one in which all nations might work loyally together for the good of humanity and the extension of civilisation.

Mr. PATTERSON said that in respect of polar exploration Canada was fortunately situated, he had only recently learnt of the proposals and could not discuss them in detail, but the meteorological service in Canada would be willing to do its part to promote the success of the expeditions.

Mr. STEWART referred to a letter from Sydney which had been received by the Prime Minister in South Africa suggesting that the British services in the Southern Hemisphere should establish stations on the Antarctic continent in the belief that their establishment would lead to the possibility of the forecasting of droughts; evidence of the value of such stations was said to be based on forecasts issued in the Argentine, but the work seemed to him of problematical value in that respect.

Mr. Stewart said that while he was not prepared to support a scheme which involved the expenditure of a sum equivalent to his total annual budget, he would be glad to co-operate in the establishment of at least one station and he thought the South African Government would give their support to the proposal.

In reply to a question by Dr. WHIPPLE as to whether observations of atmospheric electricity were definitely excluded from the work, Dr. Simpson said that the final programme of observations had not been definitely agreed upon.

4. Sub-Committee on West African Meteorology.—The President called upon Mr. Jacob to give an account of the work of the sub-committee, a report of which had been circulated.

Mr. JACOB said that the formation of a sub-committee had been suggested because it was felt that, in view of the large demands for meteorological information that would shortly be made, some systematic meteorological organization in West Africa would be required. He wished to emphasise that such a desire involved no criticism of the existing organizations. The sub-committee had considered that the immediate requirements would be met by the appointment of a full-time meteorological officer in Nigeria; and though personally he had hoped for a more comprehensive scheme, he thought that co-ordination of the work of the West African colonies might be brought about if the officer appointed in Nigeria were able to visit the other colonies. The resolution which had been adopted by the sub-committee was proposed by Mr. Jacob and seconded by Mr. Temple.

After discussion in which Dr. Taylor, Col. Bates, Mr. Jacob and Mr. Chamney took part, it was proposed by Capt. SMITH and seconded by Mr. WALTER that in order to make the resolution appropriate as a resolution of the whole Conference the second paragraph should be omitted.

In view of the absence of two members of the sub-committee Mr. Auchinleck and Mr. Brooks it was decided to postpone the formal resolution until a later meeting.

5. The proposed establishment of thirteen new Meteorological Stations in the South China Sea (Appendix VIII).—Mr. T. F. CLAXTON submitted a map showing a proposed réseau of meteorological and aerological observing stations required by Hong Kong. Mr. DEWAR (Malaya) stated that of the 13 new stations required by Mr. Claxton three had recently been established in the Malay Peninsula and Dr. NORMAND (India) remarked that a station already existed at Bangkok and a second station in South Siam.

The Conference was of opinion that the establishment of additional stations in the regions south of Hong Kong would be of great value in connection with the requirements of aviation, fleet meteorology and forecasting.

In reply to Mr. Patterson (Canada) Mr. Claxton said that some of the new stations were foreign. To complete the scheme the co-operation of the Philippines, Indo-China, Siamese and Chinese Governments would be necessary. Some of the existing stations do not at present report to Hong Kong.

Capt. ENTWISTLE emphasised the value from the point of view of aviation of the distribution of stations suggested in Mr. Claxton's note.

6. Note on Anemometers (Appendix IX).—A note on anemometers by Mr. Claxton which had already been circulated was read.

Some discussion took place with regard to the proposal that the value of the mean wind velocity in the ten minutes ending at the hour could be supplied by measuring the ordinate at the 55th minute of the mean monthly curve.

The PRESIDENT agreed that the question would be looked into, and that a note on the subject would be included in the report of the meetings.

With regard to the comparison of records of the Dines anemometer with records from a cup anemometer, Mr. CLAXTON said that certain features had appeared in the values of wind velocity at Hong Kong which gave rise to the suspicion that they might be due to instrumental errors. He thought that any evidence that the records of the two instruments had been found to give satisfactory comparisons would be of value in restoring confidence.

Mr. J. S. DINES said that detailed comparisons between the records had been made many years ago, but he had been unable to trace any table giving a comparison of the monthly mean values, he thought that the absence of such a table was evidence that there were no unexplained discrepancies. He referred to a paper by Mr. R. H. Curtis on the comparison of a Robinson instrument with a pressure-tube instrument mounted at the top of a lighthouse. The results showed that the relative values obtained from the two instruments varied according to the direction of the wind, the differences amounting to about 10 per cent. He quoted a remark by W. H. Dines that it was well established that the records from the pressure-tube instrument agreed with those from the Kew pattern with the factor 2.2.

Mr. DINES and Dr. WHIPPLE cited instances of errors in the records of a pressure-tube anemometer arising from the breaking of one of the composition pipes, Dr. Whipple also emphasised the necessity of accurate testing of the water level. Dr. Whipple said that in normal circumstances the records of the two instruments were reasonably consistent, though discrepancies might arise from the fact that the factor 2.2 of the Robinson anemometer varied with the wind velocity.

Mr. PATTERSON said investigations of the characteristics of records from a cup anemometer had been carried out in Canada, it was found that the factor decreased with increase of wind velocity and with increase in the diameter of the cups and varied also with the length of the arm. He pointed out that the records from a Dines instrument were least accurate at low velocities (below 10 mi./hr.). A comparison of anemometers had been carried out at Mount Washington and showed that the three-cup anemometer with short arms and 5-in. cups gave a constant factor 2.5. In view of Mr. Claxton's suggestion he would endeavour to mount anemometers of the

two types in the same exposure and compare the records obtained. Such comparisons as he had carried out already showed that the values agreed to a fair degree of accuracy.

7. Note on Minimum Wet-bulb Thermometers (Appendix X).—Mr. BAMFORD referred to a note, which had already been circulated, as to the desirability of using a horizontal thermometer as the standard type of wet-bulb instrument in order that minimum values might be obtained.

The PRESIDENT pointed out that the minimum humidity at night could not be deduced from the minimum values of the dry and wet bulb readings as the minimum values were not necessarily synchronous.

Mr. SUTTON said that at the first-order station at Helwan records from separate dry-bulb thermographs and wet-bulb thermographs were available, but there was often some difficulty in keeping the wet bulb damp. From these a continuous record of humidity is deduced. Hygrographs at second-order stations did not always give satisfactory records owing to mechanical failure to record the large diurnal range encountered.

Mr. WALTER said that he thought it would be advantageous if the heads of services could meet to exchange experiences, with each other and with the experts of the Air Ministry, with regard to technical difficulties such as the exposure of instruments, the use of screens, the types of anemometer.

The PRESIDENT said that he would be glad to arrange such a meeting after the close of the conference.

8. Arrangements for Final Meeting.—The PRESIDENT said that the remaining meetings would be held in conjunction with the agriculturists. He hoped, however, to arrange for a final meeting for formal business such as obtaining approval of the minutes. If delegates who would be able to attend such a meeting during the ensuing week would inform him, he would circulate a notice of the arrangements made. He asked that all delegates would send in such corrections as they wished inserted in the minutes. The official corrected copy of the minutes would be available for consultation by any delegate who so desired.

The meeting adjourned at 5.15 p.m.

September 3, 1929.

(Signed) G. C. SIMPSON.

MINUTES No. XII.

Twelfth Meeting, Wednesday, the 28th of August, 1929, at 10.30 a.m.

The meeting was held in the Large Hall of the Civil Service Commission, Burlington House, W.1.

The following delegates were present: Dr. G. C. Simpson (Great Britain, *President*) in the Chair, Mr. G. Auchlinleck (Gold Coast), Mr. A. J. Bamford (Ceylon), Col. D. C. Bates (New Zealand), Mr. E. G. Bilham, Mr. A. J. Brooks (Gambia), Dr. C. E. P. Brooks, Mr. T. F. Claxton (Hong Kong), Mr. N. P. Chamney (Gold Coast), Mr. H. H. Croucher (Leeward Islands), Mr. J. Dewar (Malaya), Col. E. Gold, Mr. C. G. Hansford (Uganda), Mr. S. M. Jacob (Nigeria), Mr. R. G. K. Lempfert, Dr. C. W. B. Normand (India), Mr. J. M. Patterson (Canada and Newfoundland), Capt. A. B. Smith (Trinidad), Mr. C. Stewart (South Africa), Mr. L. J. Sutton (Egypt), Dr. R. S. Taylor (Somaliland), Mr. R. Temple (Sierra Leone), Major E. E. Turner (Windward Islands), Mr. A. Walter (East Africa, Southern Rhodesia and Sudan), Capt. J. Calder Wood (Nigeria), Mr. E. J. Wortley (Nyasaland).

The following agriculturists also attended: Sir Napier Shaw (*Chairman of the Agricultural Section*), Mr. W. R. G. Atkins, Dr. Lawrence Balls (Egypt), Mr. A. H. Bird, Mr. W. R. Black, Mr. J. I. Craig (Scotland), Dr. G. H. Cunningham (New Zealand), Mr. W. A. Davie (Sudan), Mr. A. S. Fitzpatrick (Australia), Mr. W. C. Grandi, Mr. H. Greene (Sudan), Mr. T. H. Holland (Ceylon), Capt. A. J. Hornby (Nyasaland), Mr. E. T. Huntingford, Mr. P. Inkpen, Mr. I. Jones (Wales), Mr. A. C. Mason, Mr. A. C. Miles (Gold Coast), Mr. H. Nicholas (Gold Coast), Mr. J. M. Ramsay (Scotland), Mr. A. Roebuck, Dr. J. Templeton (Egypt), Mr. G. W. Thomas, Mr. H. Tydeman.

I. The Empire in Relation to International Meteorology.—(a) *Réseau Mondial*, (b) *Colonial bluebooks* (Appendix XI). Mr. R. G. K. LEMPFERT (Assistant Director in the Meteorological Office) gave an account of the memorandum which had been circulated.

The PRESIDENT referred to the publication work of the *Réseau Mondial* which he regarded as the most valuable of its kind for the study of world meteorology. He asked that those who had stations under their control the values of which were published in the *Réseau Mondial* would take special care to ensure the accuracy, reliability and continuity of the data at such stations. He also asked directors to inform him of any changes which they considered desirable in the two stations chosen as representative in each 10-degree square, though on general principles he deprecated making unnecessary changes yet he would be glad to consult with directors as to any improvements that could be made in the representation especially with a view to filling any blanks in the réseau. He said that it was essential that meteorological factors should be given in a way suitable for correlation with agricultural data.

With regard to the publication of data in Colonial bluebooks he emphasised the advantages of the collection of all the meteorological data from isolated stations and asked for any suggestions from delegates as to the way in which the publications should be made.

He emphasised that the Meteorological Office was most desirous to help any representative of the meteorological services of the Empire, by discussing any technical points that arose, and by assisting in the supply of tested instruments. When placing orders for instruments delegates should instruct the Crown Agents for the Colonies to submit the indents to the Meteorological Office who would be glad to advise as to the placing of contracts, and the specification, and would be willing to inspect the instruments before despatch. In response to a request from various delegates that opportunity should be taken of their presence in London to arrange a meeting at which details of instruments and methods of observation might be discussed, he had arranged for such a meeting to be held at the Meteorological Office, South Kensington at 10.30 a.m. on Tuesday, September 3rd. At the close of that discussion the final meeting would be held for any formal matters that required attention.

He added that he would welcome suggestions for the improvement of, or additions to the "Observer's Primer."

Mr. A. J. BAMFORD (Ceylon) drew attention to the desirability of having some arrangement for keeping directors, who had in general to work through non-technical administrations in financial matters, more closely informed of changes contemplated in the arrangements for circulating the reprints from bluebooks.

He said that though he recognised the desirability of uniformity he thought that the conditions in the various parts differed so widely that it was essential that there should be some provision for flexibility, otherwise there was danger that factors which were of primary importance in certain parts might be omitted. He instanced the case of wet-bulb temperatures in Ceylon which were of special interest in that island, and data of which were in consequence published in detail.

Mr. JACOB (Nigeria) urged the desirability of having some check on the accuracy of the data published in the bluebooks, and gave an instance of the figures of the rainfall in Nigeria in which he had found a large number of errors some of considerable magnitude. He asked whether in cases where there was no expert meteorological officer in charge, the Meteorological Office could endeavour to make some check on the data.

Mr. CROUCHER in reply to a question from the President said that the service of the West Indies was small and he did not wish to draw general conclusions from his experience there.

Mr. CLAXTON (Hong Kong) said that he welcomed the decision to omit daily values from the bluebooks; he asked whether it would be possible to limit the data in the bluebooks to the standard form suggested by the Meteorological Office, and for the several observatories to issue their more detailed observations in their own publications. The President in reply said that the publication of data in the bluebooks was not intended in any way as a substitute for the publications of the separate observatories.

Col. D. C. BATES (New Zealand) said that on a recent voyage he had called at the island of Tahiti and seen there a publication of meteorological statistics by the French colony, he was not aware that this was made available for other services, and thought it would be of great advantage if other countries would arrange the distribution of their observations by some such method as had been done for the British colonies.

With regard to the *Réseau Mondial* he said that he had been asked by Dr. Kidson to inquire whether charts of departures from normal of temperature and pressure could be reproduced in that publication.

Referring to soil temperatures he said "The question is raised whether the depths in the English scheme viz., 4 in., 8 in., and 2 ft. have been chosen after sufficient consideration, and as to the way in which these depths compare with those used by other organisations. In New Zealand the depths of 1 ft. and 3 ft. have been used, following presumably British custom of some period. Standard depths should be very carefully chosen by the Conference. In the second place the Conference should give advice as to what are suitable soil thermometers and how they should be mounted. The form which has been widely used in New Zealand is most unsatisfactory. It has consisted of vertical iron tubes and thermometers encased in paraffin wax.

Col. Bates said that during his recent visit to Kew Observatory he had learned that the thermometers for soil temperatures were more satisfactory than he had believed. He thought however that as the diurnal change in soil temperature at 4 in. and 6 in. was considerable, more than one observation a day was required.

Sir NAPIER SHAW, in reference to the criticism of the ordinary ground thermometer, remarked that suggestions about instruments often came from persons who had no experience of practical work with them.

Mr. Lempfert had referred to Sir Norman Lockyer as an astronomer who took an interest in meteorology, personally he was so, but officially he was a meteorologist who needed a solar observatory in order to throw light on meteorology, and it was for that reason that Lockyer appealed for the creation of a commission. He wanted to study solar phenomena in order to get light on the famines of India, not use meteorology to help him in the study of the sky.

He thought that those who had spent time in dealing with the meteorology of the globe would agree that the most remarkable thing about the situation was that there was no office or organisation charged to deal with that subject. Many were charged to deal with certain portions of it but none had a world-wide parish, and when technical officers had to deal with non-technical financial officers the question arose on many occasions.

He thought the omission must be made good. It might be done by the League of Nations, but in the absence of that, he knew of no organisation more suited for the task than the British Empire which within its boundaries comprised all types of climate. He did not think that Mr. Bamford or Mr. Stewart could regard their information as complete without a knowledge of the meteorological conditions of Australia and South America; and he would he thought be forgiven for persuading the authorities in London to publish the *Réseau Mondial*; the publication would in the future be regarded as a valuable contribution to the prosperity of the whole world.

2. The collection, tabulation and publication of climatological data.—Dr. C. E. P. BROOKS (Superintendent of the General Climatology Division in the Meteorological Office) gave an account of his memorandum (Appendix XII) which had been circulated.

In reply to Mr. Jacob's request that the observations in the bluebooks should be checked, he said that such checking was performed in the Meteorological Office by all the means at its disposal; time did not always permit of any queries that arose being settled by communication with the station concerned, but when any doubt existed as to the accuracy of any observation a note was inserted in the introduction which was issued with the reprints of the tables. In reply to Mr. Jacob's suggestion that such corrections should be communicated to the Colonial Governments so that they might be inserted in the bluebook he said that a separate copy of the introduction was always sent to each Colony.

With regard to the forms, he referred to the space provided for corrections to the instruments and asked that these should be filled in especially in the case of new instruments. He said the Meteorological Office would be glad to receive notification when any changes were made at a station so that they might be included in the notes which accompanied the reprints from the bluebooks.

Mr. WALTER (East Africa) referred to his paper on the "Diurnal Variation of Meteorological Elements" (Appendix XIII) and gave a brief account of the conditions in the territories with which he had to deal. He said that it was given to few meteorologists to begin their career by the study of the conditions in one main air current and after twenty-five years be set to organise a complete new survey of conditions in another part of the same current. He said that the general organisation of the new service had been affected by the conditions over the South Indian Ocean. The area covered by the service was very considerable Kenya, Uganda, Northern Rhodesia, Tanganyika and Zanzibar were included; the region extended to a considerable distance north and south of the equator, and was about half the size of Europe (excluding Russia).

He referred to the fact that when the sun was at its most northerly point the SE. trade wind sweeps over the South Indian Ocean, swerves at the equator and forms the SW. monsoon over India. As the sun comes south the NE. monsoon approaches the West African coast and becomes NW. down as far as the northerly portion of Madagascar. In East Africa rains occurred as the line of discontinuity between the two currents swept over the country. Another peculiarity was the pulsation in the thickness of the current, this had been studied in a survey of the upper air over the South Indian Ocean which had been published as a *Geophysical Memoir* of the Meteorological Office, London.

He said that as he understood the problem there appeared to be three main factors affecting the climatology of the globe. In the first place there were two ridges of high pressure between 20° and 30° N. and S. with a trough of low pressure between, superimposed on these two ridges are the travelling anticyclones or perhaps the ridges were the representation of the travel of the high pressure areas; and superimposed again was the diurnal ripple which follows the sun round the earth.

He said that the data for any observatory were always represented in climatological tables by a monthly value, but in the regions to which he referred this method of averaging masked the main features. As an example he cited the case of rainfall which in the average hourly values showed a double maximum; this had no existence in nature: it arose from the fact that rain fell in the morning when it was of the monsoonal type but in the afternoon when it was of the instability type. In the case of temperature, likewise, on sunny days and in certain types of weather the range amounted in some cases to 30° or 40° F., but during the rains it was reduced practically to zero—the average of the two was something which did not exist in nature and was of no value to the meteorologist or to the research worker. Again in the case of wind there was a marked diurnal variation which differed according to the type of weather passing over the station. He did not think it would be possible to solve the problems which arose without more detailed values.

With regard to the diurnal ripple in the pressure he said the phenomenon was most marked in the tropics and disappeared entirely in polar regions.

The diurnal variation of the various elements was of importance in agriculture, aviation and medical research. Certain factors were present in the conditions in Nairobi which influenced human beings and animals in a peculiar way. The effect might be due to altitude or to the effect of the intense solar radiation but he thought the diurnal variation played a not unimportant part. A change of humidity from 95 to 15 per cent in the course of the day accompanied by large changes in temperature must have a notable effect.

With regard to agriculture it was of interest that in Kenya fruit and plants from temperate climates were found side by side with those of tropical regions, this might be due to the alternation of high values of the intensity of solar radiation with cool night temperatures but whatever its cause the inter-relation of crops and weather could only be studied if detailed observations were available.

He recognised the difficulty of printing and tabulating a large volume of data, but he thought the problem had been solved in Kenya where arrangements had been made by which it was possible to produce a bulletin within 15 or 20 days of the end of the month giving hourly values of each element during the month. The cost was only that of the paper and clerk's time for the Gestetner method of reproduction. The problem of tabulating the absolute hourly values of the different elements directly from the registers had also been solved.

Mr. Walter referred to Dr. Chapman's valuable work on lunar atmospheric tides and said that it had taken two or three years to put the data for Mauritius into a form suitable for Dr. Chapman to work with. To do the same for other elements would have been prohibitive, but he thought there would be a demand for such data and he pleaded for the presentation of the results in detail and their classification (possibly by Hollerith machines into different types of weather).

Mr. Walter endorsed Dr. Brooks's view as to the need of frequent inspection of stations; he suggested that in those cases where small services exist with no trained meteorologist, such services should invite an expert from a neighbouring colony to inspect its stations at intervals of one or two years. Such a scheme would he thought be of advantage not only to the service concerned but to the inspector also, in giving him a more detailed knowledge of conditions over other regions that those with which he has specially concerned.

Sir NAPIER SHAW said that Mr. Walter had raised a question which would become, in course of time, a subject of great importance namely the utility of mean values. So long as the purpose was the comparison with corresponding mean values at other places, there was no difficulty, but when it was for the application of the data to the variation of other quantities, mean values might have little value.

Dr. Brooks had described the best method of arriving at mean values; and as long as it was pure meteorology that was being dealt with mean values would give information that would enable a comparison to be made of conditions in different parts. Climate is what it is defined to be, and when once defined climates can be compared by mean values, but when the application to agriculture is being considered we must say whether what we have defined as climate will solve the problems represented by living things. He thought it was unlikely that it would; and that investigators into that subject would not find that mean values satisfied their requirements. He asked delegates from overseas to say in what way mean values misrepresented their climates. Meteorologists might work in mean values but nature does not do so; if the mean forces acting on the atmosphere were applied with mathematical accuracy they would not produce the mean circulation. He thought that meteorologists had extracted what was possible from mean values and it was necessary now to find the variations which underlie them.

With regard to the expression of pressure in millibars, Sir Napier Shaw said this did not necessitate a change in the barometer. It was the pressure that was required in millibars and not the barometric reading, and the adoption of the millibar involved not a change in instruments but simply a change in the table of reduction. He suggested that there should be separate columns in the register for "barometric reading" and "pressure", with the assurance that barometric readings were not pressure until they had been put through certain processes of reduction through which all such readings must go.

The President asked for a discussion as to the various points raised in Dr. Brooks's memorandum.

Mr. PATTERSON said he had listened to the papers with much interest and they raised important questions from the administrative point of view. Most services had established certain forms and it was not easy to make changes in those forms, nor did he think changes should be lightly made, though he was glad to keep in mind any methods of improvement that were suggested. With regard to the hours of observation, Mr. Patterson said that in countries stretching over a wide range of longitude this presented more difficulty than in the British Isles where one standard hour could be adopted for the whole country.

He said that in Canada he would like to see a first-order station in each province and he was working with that end in view. Stations other than first-order stations worked to an accuracy of 1° F. in temperature and this he thought was sufficient.

With regard to the forms; these were usually summarised by months; in western Canada where the growing season extended only over three months, the method was useless for the study of agricultural meteorology. He was strongly of opinion that the week should be the period chosen. Though the problem of choosing the weeks so that they would fit in with the proposed changes in the calendar had still to be solved, he thought the main point was to make a change from months to weeks. With regard to the unit of pressure, the inch was used at present in Canada, but he hoped to change to the millibar on the first opportunity.

Mr. WORTLEY (Nyasaland) said that he thought it would be of great advantage to the smaller colonies to invite a meteorological expert from time to time to visit and inspect their stations. He said that it would be a great help also to the smaller stations if officers on leave were invited to visit the Meteorological Office for advice and information. He recalled one instance of help which had been received from London when the height of the station at Zomba which was registered locally as 2,800 ft. had been corrected to 3,100 ft.

Col. GOLD said that in problems of climatology it should be remembered that it was an area and not a point which had to be dealt with. In the case of pressure the value obtained at a single station might represent the value over an area to a considerable degree of accuracy, and the same was true of temperature though not to the same extent, but the values of rainfall, cloud and sunshine were appropriate only to a small area; he thought the Conference should consider whether reports from stations were an adequate representation of the conditions over an area and whether some attempts should not be made to provide values for districts and not for stations. He suggested also that all rainfall stations should also be sunshine stations.

With regard to the exchange of information he would be glad of an expression of opinion as to the value of organizing some rapid method of exchange and suggested the possibility of the issue monthly by telegraph of a collective message of conditions in various parts of the Empire.

The PRESIDENT (a) *Notification of changes*. Speaking in reply to the questions raised by the delegates, the President said that the Meteorological Office was always desirous that any change introduced in the bluebooks should be communicated to the technical officers concerned, and he would endeavour to see that such a practice was always followed.

(b) *Checking of data*. In reply to Mr. Jacob's suggestion that the data published in the bluebooks should be critically examined in the Meteorological Office and that the colonies concerned should be communicated with if any errors were detected; he said he would gladly undertake the task if he thought it would not be resented by the observers.

The delegates were of opinion that the examination by the London Office of the data from colonies where there was no trained meteorologist would be welcomed.

(c) *Inspection of stations*. At the suggestion of the President the following minute was approved.

The Conference wishes the necessity of the frequent inspection of meteorological stations to be recognized and would be glad if meteorological services with trained meteorologists would give assistance to neighbouring services in this respect when desired to do so.

(d) *Visits to the Meteorological Office*. The President said that he wished it to be placed on record that the Meteorological Office would welcome visits from meteorological officers from the Colonies at all times, and was anxious to give to them such information and assistance as was within its power.

3. **A preliminary note on the rainfall of West Africa** (Appendix XIV). Mr. CHAMNEY gave a brief account of his paper which had been circulated. He referred especially to the diminution of rainfall described on p. 136 of Appendix XIV. Though the information available was insufficient to say whether this diminution extended over the whole of West Africa the records at Freetown and St. Louis seemed to indicate that it extended over a wide area. The deforestation of the agricultural areas combined with a diminution of rainfall would present a serious administrative problem in the future. In conclusion Mr. Chamney emphasised the importance from an agricultural point of view of information of the average rate of precipitation and of the average number of rain days in addition to figures for the total rainfall.

4. **Committee on West African Meteorology**.—The following resolution which had been postponed at the meeting on Monday, 26th August, was unanimously approved.

"In view of the urgent importance of full meteorological knowledge for the development of aviation, in addition to the value of meteorology to agriculture and medicine, it is recommended that Nigeria should have a full-time meteorological officer to be appointed on the advice of the Air Ministry.

The Conference is, of opinion that other West African Colonies should be invited to avail themselves of the services of the aforesaid Nigerian Officer, who should co-ordinate meteorological data in relation to aviation, agriculture, medicine, etc., for all West African Colonies".

The meeting adjourned at 1.5 p.m.

September 3, 1929.

(Signed) G. C. SIMPSON.

MINUTES No. XIII.

Thirteenth Meeting, Wednesday, the 28th of August, 1929, at 2.30 p.m.

The meeting was held in the Large Hall of the Civil Service Commission, Burlington House, W.1.

Present: Dr. G. C. Simpson (Great Britain: *President*) in the Chair, Mr. G. Auchinleck (Gold Coast), Mr. A. J. Bamford (Ceylon), Col. D. C. Bates (New Zealand), Dr. C. E. P. Brooks, Mr. D. Brunt, Mr. T. F. Claxton (Hong Kong), Mr. N. P. Chamney (Gold Coast), Mr. H. H. Croucher (Leeward Islands), Mr. J. Dewar (Malaya), Col. E. Gold, Mr. C. G. Hansford (Uganda), Mr. S. M. Jacob (Nigeria), Mr. R. G. K. Lempfert, Dr. C. W. B. Normand (India), Mr. J. M. Patterson (Canada and Newfoundland), Capt. A. B. Smith (Trinidad), Mr. C. Stewart (South Africa), Mr. L. J. Sutton (Egypt), Dr. R. S. Taylor (Somaliland), Mr. R. Temple (Sierra Leone), Major E. E. Turner (Windward Islands), Mr. A. Walter (East Africa, Southern Rhodesia and Sudan), Capt. J. Calder Wood (Nigeria), Mr. E. J. Wortley (Nyasaland).

The following agriculturists also attended: Sir Napier Shaw (*Chairman of the Agricultural Section*), Mr. W. R. G. Atkins, Dr. Lawrence Balls (Egypt), Mr. A. H. Bird, Mr. W. R. Black, Mr. J. I. Craig (Scotland), Dr. G. H. Cunningham (New Zealand), Mr. W. A. Davie (Sudan), Mr. W. C. Grandi, Mr. H. Greene (Sudan), Mr. T. H. Holland (Ceylon), Capt. A. J. Hornby (Nyasaland), Mr. E. T. Huntingford, Mr. P. Inkpen, Mr. T. O. Irwin, Mr. I. Jones (Wales), Mr. A. H. Lees, Dr. H. H. Mann, Mr. A. C. Mason, Mr. A. C. Miles (Gold Coast), Mr. A. E. Muskett, Mr. H. Nicholas (Gold Coast), Mr. J. M. Ramsay (Scotland), Mr. A. Roebuck, Mr. I. W. Seaton (North Ireland), Dr. J. Templeton (Egypt), Mr. G. W. Thomas, Mr. F. Tutin, Mr. H. Tydeman.

1. **Documents circulated.**—Minutes of the eighth and eleventh meetings (Minutes Nos. VIII and XI).

2. **On long-range forecasts.**—The *PRESIDENT* expressed his regret that Sir Gilbert Walker was unable to be present in person; he proceeded to give an account of Sir Gilbert Walker's memorandum (Appendix XV) which had been circulated. He said that one interesting point of the subject was that the correlations of temperature and sunspots were mainly negative, of 40 correlation coefficients that had been worked out 30 were negative, two zero and only eight positive. Abbot had found a simultaneous increase of solar radiation with sunspots, but the correlation coefficients showed that as the sunspots and consequently the solar radiation increased the temperature in all parts of the world decreased. No satisfactory explanation of the paradox was so far forthcoming.

In conclusion Dr. Simpson referred to the method of tabulating the data which Sir Gilbert Walker had adopted and said that Sir Gilbert had expressed his willingness to supply copies of the slips containing quarterly departures of the 32 world centres to any officers desirous of carrying out investigations in the subject; but in return he would like the officers to arrange to compute and publish similar data in the future as they become available.

3. **On forecasting by periodicity.**—Mr. D. BRUNT gave the following account of his investigations on the subject:—

PERIODICITY IN WEATHER.

Dr. Simpson has asked me to say a few words concerning the use of periodicity in weather for the purpose of forecasting. I will explain briefly the work which I carried out some years ago in an investigation of the periods in certain records at European stations. I took 12 records of 100 years' duration, consisting of the rainfall at 4 stations, Milan, Padua, London and Edinburgh, pressure at 2 stations, Edinburgh and Paris, and temperature at 6 stations, Edinburgh, Stockholm, London, Paris, Berlin and Vienna. Search was made for all periods between 1 and 50 years, and amplitudes were evaluated for a very large number of trial periods. It was found that each of the 12 records showed the presence of a very large number of periods, none of which had amplitudes of outstanding magnitude. This was a disappointing result as it would have been more hopeful to work with the results had there been a few outstanding periods.

The nature of the results can be quite simply shown by an example, viz., London temperature. The chief periods found in London temperature were:—

| | | | | Amp. | | | | | Amp. |
|------------------|--------|----|----|---------|------------------|--------|----|----|--------|
| 13 | months | .. | .. | 0.56°F. | 42 | months | .. | .. | .41°F. |
| 14 $\frac{2}{3}$ | " | .. | .. | .41 | 60-61 | " | .. | .. | .38 |
| 25 | " | .. | .. | .47 | 98 | " | .. | .. | .41 |
| 25 $\frac{1}{2}$ | " | .. | .. | .45 | 15 | years | .. | .. | .39 |
| 26 | " | .. | .. | .49 | 17 $\frac{1}{2}$ | " | .. | .. | .51 |
| 37 | " | .. | .. | .45 | 23 | " | .. | .. | .70 |
| | | | | | 30 | " | .. | .. | .41 |

The amplitudes were all round about $\frac{1}{2}$ °F. All of them considerably smaller than the standard deviation from the mean of the monthly temperature figures. I found, indeed, that only 1/7th of the variability of London temperatures could be accounted for by periodicities. For London rainfall and all other rainfall records, the fraction accounted for by periodicities was negligible, but it was about 1/6th to 1/7th for temperatures at London, Edinburgh, Stockholm and Vienna.

One of the most surprising results was that the sunspot period of 11 years only showed up in a marked way in Edinburgh temperatures, while the most important period in London temperatures was round about 23 years. There was another period over 30 years in London temperatures.

The records which I used when expressed as 5-yearly means of temperature or 5-yearly totals of rainfall, showed very marked variability, but when graphed they did not suggest the presence of periods of any marked importance. This was borne out by the result of drawing a graph of the superposed periods, and superposing on this the actual temperatures. The empirical curve shows much less variability than the actual temperature, and I should attach no importance to a forecast based on the superposition of all the periods.

The main defect of the method is that it assumes that nature works in sine curves. All the evidence points distinctly to this being incorrect. The complexity of the nature of the variations of meteorological elements, at least in Europe, does not suggest that they can be represented by the superposition of a number of simple sine curves. Take again the sunspot variation of 11 years. A similar period was found in Edinburgh temperatures, but there was no clearcut relation between the Edinburgh temperature and the phase of the sunspot variation. Very low temperatures were occasionally found associated with sunspot maxima, but on occasion also with sunspot minima.

In my view, therefore, the straightforward use of periodicities, mentioned by Sir Gilbert Walker under heading (b), is not likely to lead to results of value in forecasting, at least in Europe. I should hesitate to be didactic in extending this statement to other places. Kidson has given in Bulletin No. 17 of the Commonwealth Bureau of Meteorology, Australia, an account of an investigation into periods in Australian weather. His results are not in a form suitable for very direct comparison with my own work, but he appears to find far more direct relationships between the observations and his computed curves than I did. This is particularly true of the latitudes of anticyclones over the Australian continent.

Dr. NORMAND (India) said he thought his name appeared on the programme because he *happened* to be that very rare specimen—a perpetrator of official seasonal forecasts. If Dr. Simpson had not left India ten years ago, or Mr. Patterson 20 years ago either of them might be speaking in his place. He said that as he had only had notice of the subject after his arrival in Great Britain and consequently had no access to his papers he would deal only with the general question. He proposed to divide his remarks into three parts: (a) whether in the present state of our knowledge long-range forecasts should ever be issued, (b) whether a forecast of "normal or in excess" is ever justifiable, (c) the likely directions of progress in seasonal forecasts as far as India is concerned.

With regard to (a) he said that the prosperity of India depends to a large extent on the monsoon—as a finance minister once declared, his budget was a gamble in rainfall. The yearly arrival of the monsoon is a matter of tremendous interest throughout the country, and a forecast of the prospects is definitely forced on the meteorologist's attention. Sir John Eliot when he was Director of the Indian Service undertook the preparation every year of a memorandum discussing the prospects, and Sir Gilbert Walker on his arrival in India 25 years ago was faced with the same necessity. It was perhaps possible to justify the issue of seasonal forecasts by the fact that it was the necessity for their issue which had led Sir Gilbert Walker to undertake his important and very extensive investigations on the subject. As a result of his work a correlation coefficient of .76 had been derived between various factors and the rainfall of the succeeding monsoon. That correlation coefficient was calculated in 1924 and was based on a comparison of observations up to that year, and some assurance was desirable that the coefficient would retain that value as the years go on. Now Sir Gilbert was very cautious and critical in the selection of his factors. For instance, the correlation of .58 in his earlier monsoon prediction formula of 1908 had only altered to .56 when tested over the succeeding 20 years. He believed therefore that the coefficient of .76 will in the future be found almost to retain its value.

Dr. Normand said that a coefficient of $\cdot 76$ made it possible to give a forecast to the statistician, but it was more difficult to convey its meaning to the public. He said that the method adopted was to state briefly and simply that all the factors which governed the monsoon rainfall were not known but that sufficient was known to justify in most years the issue of forecasts with a reasonable chance of success. He invited delegates to examine both the published forecasts and the subsequently published comparisons of the forecasts with the event.

With regard to Sir Gilbert's suggestion that a forecast should be either "in excess" or "in defect" and that otherwise no forecast should be issued, he himself would prefer to divide the data into three sections: "in excess", "normal", "in defect", this has the advantage of enabling forecasts to be issued more often and there is also a certain practical value to the public in a forecast that the monsoon would be "normal or in excess", because the public, if they have to divide the monsoon data into two classes only, would do so into the classes "bad" and "not bad"; the latter is practically covered by the expression "normal or in excess".

With regard to future possibilities he agreed with Sir Gilbert Walker that so far solar physics, periodicity and surges had not led to hopeful results. The examples usually quoted in India were 1917 and 1918, the former of which gave the best monsoon on record, the latter, one of the worst. There had been no corresponding change in the sun to account for the difference and no combination of periods or surges was likely to lead to such large differences in successive years. He did not think that much progress in monsoon prediction would follow the further correlation of surface observations all over the globe. He thought Sir Gilbert had dealt exhaustively with that subject and further study would not lead to an increase of more than a few per cent in the correlation coefficient; he would like, however, to obtain a long series of values for the Antarctic regions.

Col. Gold had proposed that rainfall values should be given not only for single stations but also for large areas, e.g., districts or provinces, and he was in sympathy with that suggestion. Over North-West India a large excess of rainfall over a period of four months is a significant meteorological factor and similar information from other parts of the world would be of considerable assistance in investigations on seasonal forecasting.

He thought, however, that the primary need was for more data of winds and temperatures in the upper air. The initiation of upper-air observations in India had been largely due to the enthusiasm of Mr. Field, they were begun not to meet the needs of aviation but in the hope that they might lead to an increase in our knowledge of the general meteorology of the globe, and possibly also prove useful in seasonal forecasting. Agra was one of the first stations at which observations were taken, and one of the main features that emerged was the existence of strong west winds at heights of 20,000 to 30,000 feet during the winter months. The winds were not found in the summer and there is accordingly a period of transition which in some years takes place earlier than in others. Mr. Field noticed that the time of change had a close relationship with subsequent winter rains in North India. The results had not been published until recently (see page 20 of the Halley lecture, May, 1929, by Sir Gilbert Walker*), as only 16 years of data were available; after 12 or 14 years the correlation coefficient worked out at $\cdot 91$. He thought it was hardly to be expected that the coefficient would maintain its high value yet he thought the investigation was of interest as demonstrating the value of observations of upper winds at great heights. He thought that in obtaining information the meteorological services should not limit themselves merely to those required for aviation, and he hoped services would be able to obtain data at high levels in pilot-balloon work.

Mr. C. STEWART said that South Africa lying as it did between two anticyclones was peculiarly liable to droughts which were frequently of great intensity and long duration; in recent years he had been impressed with the desirability of obtaining seasonal forecasts as far ahead as possible.

He referred to an investigation into the rainfall at Cape Town made by his first assistant, which indicated a periodicity of 14 years. He recalled the fact that in 1897 when he first landed in South Africa one of the worst droughts on record was in progress. Fourteen years later (1911-12) there was another, and from 1925 to the present day a third, even more serious and prolonged, was in progress. It appeared to him that these droughts were associated with an increase of pressure of about one-fiftieth of an inch. Although certain major droughts could be identified as

* Oxford, Clarendon Press.

occurring at intervals of 14 years, others of practically equal severity and extent were met with in intervening years, as, for example, that of 1902-05. South Africa also suffered from more or less local droughts. It was an interesting feature that when the annual rainfall was plotted over a period of 50 years, and the departures computed, it was found that in no single year was the rainfall of the whole country in excess or in defect. No fourteen-year periodicity, however, had been traced in the case of years of abundant rainfall. The year 1891 was the best year, and copious rains occurred in 1917-18, but in 1919 severe drought occurred, particularly over the interior of the Cape Provinces. At the commencement of the 1928-29 season it was noted that there had been apparently a material change in the circulation of the middle layers. If the middle layers came from the NW. the supposition was that they would be warm, and this would preclude convection to great heights and would suggest a forecast of a series of light showers and if this direction of motion persisted would lead to a failure of the usual abundant heavy rains in November on which the success of agriculture was largely dependent. When the intermediate layers moved from some point between W. and S. South Africa was liable to heavy hailstorms. Agriculture was in consequence liable to suffer in either case, on the one hand from drought, on the other from hail. South Africa had therefore special interest in the success or failure of seasonal forecasts.

South Africa also suffered from more or less local droughts. It was an interesting feature that when the rainfall was plotted over a period of 50 years and the departures computed it was found that in no single year was the rainfall of the whole country in excess or in defect. In 1902-05 the drought was almost as severe and extensive as in 1897; 1891 was the best year, and 1917-18 gave exceptionally good rains.

Col. GOLD gave an account of a paper by Mr. H. A. Hunt, Commonwealth Meteorologist in Australia; the paper would shortly be published in the *Quarterly Journal of the Royal Meteorological Society*.† He said that Mr. Hunt looked upon the tropical rather than the polar regions as of most importance from the meteorological point of view; he regarded the weather as made by heat and looked therefore for information from the places where the heat was most intense—the relatively dry areas of the Sahara, the Kalahari and Central Australia.

He thought the central regions of Australia were responsible for the four-year period which had been found in Australian weather; this he attributed to the warmth of the sun. When the area has become dry the sun heats it and the moisture-carrying air from the ocean tends to flow in and finally produces rain; after the rain the area is still warm and the condition is favourable for the growth of rough grass. This diminishes the effect of the sun and also reduces evaporation, the central areas become relatively cooler, no more rain gets in and the cycle starts again, the whole period of the process being about four years. Mr. Hunt has worked out correlation coefficients which give support to his theory; the highest coefficient for the period 1917 to 1928 is derived from eight pairs of values, the correlation between the rainfall of July to December in one year and the rainfall of January to March, three and a half years later is $\cdot 94$; the coefficient is for a small number of values only, but some additional confirmation is given by the correlation coefficient between temperatures in the same month at intervals of two years, which is $-\cdot 73$.

Col. Gold described an experimental investigation made by Mr. Hunt on the effects produced on a glass tray with $\frac{1}{2}$ inch of water, by heating it at various points beneath. The results showed some points of similarity with those on the earth's surface although the conditions could not be regarded as strictly analogous.

Mr. JACOB (Nigeria) referred to some work of Dr. Simpson's in India many years ago which showed that the correlations of monthly rainfall figures *inter se* centred round zero, the results seemed to preclude the possibility of long-range forecasting by suggesting that there was no inertia in the weather at all. Mr. Jacob asked whether Sir Gilbert Walker's work included any further investigations along those lines. He said he had himself found a very marked correlation between the monsoon rainfall and the winter rainfall in North India. This correlation showed over a period of 20 years. When, however, longer periods were examined the correlation dropped to $\cdot 1$. These latter data were, however, for Madras and Sir Gilbert had himself found that that station gave unsatisfactory results from the point of view of correlation.

Mr. Jacob referred to a paper by Sir Gilbert Walker in which he had worked out the magnitude of the greatest correlation coefficient or harmonic amplitude that could be obtained from material substantively of zero correlation or of zero amplitude.

† Vol. 55, 1929, pp. 323-9.

He would like himself to see all the correlation coefficients worked out compared with the frequency curve for material of zero correlation for the particular length of time for which the data were calculated, as on the theory of chance distribution of correlation magnitudes, in a universe of zero correlation, large absolute values of the correlation coefficient were to be expected if a great number of coefficients were computed.

Mr. Jacob emphasised the desirability of the correlation coefficients being related to the physical facts; he would prefer to begin with a known physical cause and then calculate the correlation coefficient of that cause with its effect. Working from physical causes might suggest that the correlation should be worked out with some special function of meteorological data and not merely with the element for which the data were easily accessible.

With regard to Dr. Normand's statement of the change between 1917 and 1918 from the best monsoon to one of the worst, he pointed out that the correlation formula was unsatisfactory for the prediction of either very bad or very good values. The multiple correlation formula is equivalent to passing a plane through points in n dimensions; using the formula predicts that the variable is a point on the plane so that even with extremes of the independent variable the dependent variable will be in a plane and could not give the extreme values. This would be the case whether a linear or curvilinear correlation formula were used for prediction, and equations of this type, therefore, would never foretell extremes of climate.

Mr. BAMFORD (Ceylon) said that seasonal forecasts for the monsoon had been issued in Ceylon during the last few years, but the practical question was complicated by the fact that as much rain fell in that island in an inter-monsoon month, such as April, as in a typical monsoon month, such as June, while the public showed a strong desire to class all rain as monsoonal. Rainfall during the monsoon (May to September) showed a certain amount of periodicity, but not sufficient for a definite forecast to be made from periodicity alone. Other factors which show an appreciable correlation with the rainfall of the following monsoon are the inter-monsoon thunderstorms and the temperatures of February.

Reference had been made by a previous speaker to the dry Indian monsoon of 1918. In that year Ceylon monsoon rainfall was also low, and it is noteworthy that though the periodicity curve gave no hint of this, the February temperatures were so low as to lead Mr. Evans, who was then in charge at Colombo, to give a forecast which proved strikingly correct.

Mr. L. J. SUTTON (Egypt) said that Mr. Stewart had referred to periods of drought experienced with serious results in South Africa. Throughout most of Egypt and a great part of the Sudan there was a practically permanent drought and the great problem was that of forecasting the annual flood of the Nile. This duty was undertaken by the Hydrological Service of the Physical Department. A correlation was made before the war between the barometric pressure at St. Helena and the Nile flood; the results seemed to offer some encouragement, but when the question was resumed after some years and a longer series of observations was available, it was found that the correlation coefficient had fallen considerably. He referred also to the work of Mr. E. W. Bliss on the correlation of meteorological elements with the Nile flood. He agreed with Mr. Jacob that before attempting correlation it was advisable to investigate as far as possible probable physical causes. They were confronted with those problems in the Sudan. Most of the rain in the central and southern Sudan and on the western slopes of Abyssinia which resulted in the Nile flood was associated with the invasion of a broad south-westerly current of air which had its maximum effect on precipitation about July and August. There was insufficient information about this current, especially in the sparsely habited regions of the south-western Sudan and the Belgian Congo. Efforts were being made to increase the number of observations in that part of the Sudan, but facilities were scarce. It was advisable also to investigate this current above surface level more fully than had so far been possible, and it was hoped to do something in that direction.

There was an additional but smaller aspect of the question. Relatively cold air not infrequently invades the Sudan from the north, and cold fronts have been traced from Southern Russia, across the eastern Mediterranean Sea and Egypt to the extreme south of the Sudan. On a few such occasions it had been noticed that precipitation has occurred at localities in the Sudan, even in the far south before the south-westerly current has set in. The network of meteorological stations in the Sudan was not at present sufficiently close to make prediction of such rainfall anything

but hazardous, but investigation was proceeding. With the closer distribution of stations which was gradually being built up it may become possible to give short-period forecasts of that type of rainfall.

Dr. C. E. P. BROOKS said that Sir Gilbert Walker's systematic investigations into the relations between numerous action centres in all parts of the world had made long-range forecasts at certain seasons practicable for quite a number of countries. As an example he quoted his recent solution of the problem of forecasting droughts in Ceara, the dry north-east of Brazil. The method, as Sir Gilbert described it, appeared to him, however, to be too simple. He agreed with Mr. Jacob as to the desirability of studying physical causes before making wholesale correlations.

It could, he thought, be regarded as an axiom that there was some cause for the weather. There were two possible reasons for zero correlation. One possibility lay in the limitations of the machine; the cause of the variations might be outside Sir Gilbert's list of world centres. The second possibility was that the weather might have too many causes. The variations of weather in some temperate maritime countries certainly result from the interplay of a great number of different factors, and in that case it would follow that no single factor, no two or three or even four factors alone, would give a satisfactory prediction formula. A small correlation coefficient might represent a real but slight relationship or it might result from chance, the only method of differentiation was a careful examination of the physical processes involved. He pointed out that the whole science of day-to-day forecasting had been built up on the existence of a relationship between the synoptic charts for two successive days, but there was no record of any successful attempt to express that connection by means of a correlation coefficient. There were undoubtedly similar relationships in weather charts for longer periods, which were too complex for Sir Gilbert's machine, but which would reasonably be expected to yield to careful investigation along different lines. The deviations of pressure and temperature from normal, published month by month in the *Reseau Mondial*, offered a rich mine for such investigations, hitherto almost unworked. Another example of a factor outside the operation of the machine was the emission of large quantities of volcanic ash in major explosive eruptions such as that of Krakatoa. The effect of such eruptions was first indicated broadly by A. Defant; a closer investigation had recently indicated that the effect was probably real, but the phenomena were too spasmodic to be susceptible of analysis by the method of correlation.

In conclusion he pointed out that there did exist a few notable correlations between sunspots and terrestrial phenomena, for example $+0.92$ between the square root of the sunspot number and the number of thunderstorms in Siberia.

Mr. ROEBUCK said that the only agricultural problem which he had found to be susceptible to long-period forecasting was the growing of oats. Oats to be successful must be sown at the end of February or the beginning of March otherwise they went down in May with frit-fly. Sometimes, however, farmers could not get the ground prepared in order to enable them to sow by that time, and the question arose as to whether on those occasions they must forego their oat crop. In special weather conditions oats could be sown up to the end of April, and what the agriculturist required to know was whether the Meteorological Office could forecast the existence of favourable conditions (in this case two inches of rain) some months ahead.

Sir NAPIER SHAW said that before one could express an opinion on the methods which had been used one must examine the assumption from which the various methods started. In finding his centres of action Sir Gilbert Walker postulates twenty years as the minimum period over which the data must extend, but this implies that the centre of action will remain in action whatever period he takes up. Sir Napier thought there was no guarantee that such would be the case.

As an instance of the idiosyncrasy of nature he recalled Mr. Walter's remarks about the SE. and NE. winds which swept over the oceans towards Africa and turned away when they were within sight of their destination. Citing another example he said that a Canadian mathematician, with whom he has recently been discussing the possibility of some general mathematical solution to the problem of the general circulation, had reminded him of the fact that in South America parts of the coastal regions had had no rain for seventeen years and then a few years ago there was rainfall and plants began to grow after seventeen years of drought. Phenomena of that kind in the chronological sequence introduced items which had their effect on mean values and on departures from the mean; they should perhaps be eliminated before proceeding to the calculation of correlation coefficients but that would not,

he thought, commend itself to the mathematicians. In like manner a volcanic eruption might affect the data for any period but such phenomena could not be dealt with by the normal process of correlation which involved the assumption of some kind of continuity in the phenomena described.

The methods of periodicity in like manner, all rested on the assumption that there was continuity in the period throughout the whole length of time considered. He thought it more likely that periods were transient phenomena. As in the case of the correlation coefficients a single exceptional year would affect all the periods obtained. He thought the detection of periodicity required a special acuteness of sense. Nothing was so truly periodic as a gramophone record, but no numerical process would he thought, be able to detect the periods. The fluctuations in the atmosphere might possibly be regarded as a highly magnified gramophone record, but to disentangle the periods involved an acuter sense than meteorologists possessed at present. He thought the methods in use at present had failed to display any effective periodicity but he did not wish to regard the question as closed on that account.

In reply to Mr. Jacob's question he said he did not think Sir Gilbert Walker had traced the correlations to their physical causes. He agreed with Dr. Brooks as to the desirability of dealing with the atmospheric circulation by the process of maps and diagrams, which would show us the centres of action of the atmosphere from a point of view different from that which had been adopted by Sir Gilbert Walker. He thought that such information might show that the areas referred to as "centres of action" might not really be entitled to that name, such areas might be areas which were excluded from effects which influenced other parts. He said he was interested in the description of winds given by Mr. Sutton, he had always been inclined to think that the water of the Nile came not from the Indian Ocean but from the Atlantic, though possibly the rain was dropped and picked up again many times on its way across the Continent.

He welcomed Dr. Normand's remarks about the correlation between upper winds and the monsoon rainfall in North India, it was the first step in using the upper air conditions as a guide to surface weather and was one of the most encouraging features of the discussion. With regard to Mr. Stewart's fourteen-year period, it reminded him that periods may not be persistent—the music may change its key.

The PRESIDENT said Mr. Jacob had referred to his work on correlation in India to which he would reply personally. With regard to the possibility of the Meteorological Office being able to predict the probability of certain weather four or five months ahead he did not think that was possible at present, but anyone interested should consult with Dr. Brooks on the subject.

The meeting adjourned at 4.50 p.m.

September 3, 1929.

(Signed) G. C. SIMPSON.

Fourteenth Meeting, First Joint Session of the General Conference and the Agricultural Section, Thursday, the 29th of August, at 10.30 a.m.

The meeting was held in the Large Hall of the Civil Service Commission, Burlington House, W.1.

Sir Napier Shaw (*President of the Agricultural Section*) in the Chair.

The minutes of the fourteenth, fifteenth, sixteenth, seventeenth and nineteenth meetings have been published by the Ministry of Agriculture and Fisheries.

Fifteenth Meeting, Second Joint Session of the General Conference and the Agricultural Section, Thursday, the 29th of August, at 2.30 p.m.

The meeting was held in the Large Hall of the Civil Service Commission, Burlington House, W.1.

Sir Napier Shaw (*President of the Agricultural Section*) in the Chair.

Sixteenth Meeting, Third Joint Session of the General Conference and the Agricultural Section, Friday, the 30th of August, at 10.30 a.m.

The meeting was held in the Large Hall of the Civil Service Commission, Burlington House, W.1.

Sir Napier Shaw (*President of the Agricultural Section*) in the Chair.

Seventeenth Meeting, Fourth Joint Session of the General Conference and the Agricultural Section, Friday, the 30th of August, at 2.30 p.m.

The meeting was held in the Large Hall of the Civil Service Commission, Burlington House, W.1.

Sir Napier Shaw (*President of the Agricultural Section*) in the Chair.

MINUTES No. XIV.

Eighteenth Meeting on Tuesday, the 3rd of September, 1929, at 10.30 a.m.

The meeting was held at the Meteorological Office, South Kensington, S.W.7.

The following delegates were present: Dr. G. C. Simpson (Great Britain, *President*) in the Chair, Mr. A. J. Bamford (Ceylon), Lieut.-Col. D. C. Bates (New Zealand), Mr. T. F. Claxton (Hong Kong), Mr. S. M. Jacob (Nigeria), Mr. J. Patterson (Toronto), Mr. C. Stewart (South Africa), Dr. R. S. Taylor (Somaliland), Mr. A. Walter (East African Group, Southern Rhodesia and Sudan), Capt. J. Calder Wood (Nigeria), Mr. E. J. Wortley (Nyasaland). There were also present the following members of the staff of the Meteorological Office: Mr. R. C. K. Lempfert, Mr. E. G. Bilham, Dr. C. E. P. Brooks, Capt. F. Entwistle, Cmdr. L. G. Garbett, R.N., Mr. M. A. Giblett.

1. **Instruments.**—Mr. Bilham, Superintendent of the Instruments Division of the Meteorological Office, outlined the arrangements which had been made in the Meteorological Office in order to facilitate the supply of instruments to the Dominions and Colonies (Appendix XVI).

He emphasised the need of co-operation between the users of the instruments and the Meteorological Office, and said that the Office cordially welcomed criticisms of the instruments based on the experience of the users.

A discussion followed on technical details of certain meteorological instruments in which Mr. Walter, Mr. Patterson and Mr. Bamford took part.

2. **Minutes.**—In view of the difficulty of arranging for a meeting for the reading of the Minutes, the President asked delegates to forward any corrections they wished inserted, and authority was given for the signature of the Minutes when these corrections had been entered.

3. **Votes of thanks.**—The PRESIDENT in closing the Conference expressed his gratification at the work which had been accomplished, and emphasised the advantages which derived from personal contact between those responsible for meteorological work in the various countries of the Empire. He thanked the delegates for their presence at the meetings.

Dr. TAYLOR (Somaliland) said that at the opening meeting Mr. Patterson as representative of one of the largest Dominions had thanked Dr. Simpson for making the preliminary arrangements and had proposed his election as President; at this the final meeting he himself claimed the right to speak because of the smallness of the Colony which he represented, a Colony which on that account might be regarded as having perhaps the least claim to consideration; both on his own behalf and on behalf of all the members of the Conference he thanked Dr. Simpson for his work at the meetings and expressed the pleasure which delegates felt at being able to attend the Conference.

Mr. PATTERSON (Canada) also expressed his appreciation of the value of the Conference and referred especially to the advantage of coming into personal contact with members of the meteorological services of other countries and of being able to discuss common difficulties and methods of overcoming them. He reiterated the thanks which Dr. Taylor had expressed to the Director of the Meteorological Office, as President, and said he wished to thank also the Director and staff of the Meteorological Office for the help which they had given the delegates and for the proposals which they had put forward as a basis for the discussions; to Miss Austin for keeping the records of the meetings; to the staff at Croydon for the arrangements made for the visit to the aerodrome; to Imperial Airways for arranging for flights; and finally to the officials at Cardington for their kindness in organising the visit to the airship works.

The PRESIDENT again expressed his thanks to the delegates, and his personal thanks to the staff of the Office for their assistance in the work of the Conference.

The Conference rose at 12.15 p.m.

September 3, 1929.

(Signed) G. C. SIMPSON.

Informal Meeting.

At the close of the Conference an informal discussion on technical questions with regard to meteorological instruments continued in which Mr. BAMFORD, Mr. CLAXTON, Mr. WALTER, Mr. STEWART and Col. BATES took part.

The question of the ruling of forms for self-recording instruments was discussed with special reference to the possibility of using blank forms and determining the zero at certain intervals. Difficulties with regard to grass-minimum thermometers were described.

Future procedure.—Col. BATES asked what arrangements were being made for carrying on the work of liaison after the close of the Conference, especially with regard to the proposals about selected ships. The President replied that the subject of selected ships was on the agenda of the International Conference at Copenhagen and if it received the approval of the International Meteorological Organization a certain number of ships would be allotted to the British Empire as a whole. The various Dominions and Colonies would then be asked whether they were willing to take over the number of ships suggested as appropriate to them. The President emphasised the difficulties of international work and urged the desirability of the various countries of the Empire being represented at the international meteorological meetings.

Exchange of staff.—The PRESIDENT said that he had discussed informally with several of the delegates the possibility of arranging for the exchange of staff among the various meteorological services of the Empire, but the difficulties of arranging such an exchange in practice appeared very great and he had consequently not brought the matter up for general discussion. He wished however to record the fact that the Meteorological Office would be glad to receive for training, members of the staff of any of the meteorological services of the Empire.

Arrangements for future Conferences.—Col. BATES raised the question of the possibility of holding a conference in one of the larger Dominions. The PRESIDENT agreed as to the desirability but pointed out the practical difficulties of such a course.

Information on instrumental equipment.—The question of the dissemination of information as to modifications in instrumental equipment, the design of new instruments and the practice adopted for reducing the records was discussed; and the delegates agreed as to the desirability of maintaining a close liaison.

The various methods of circulating the information were suggested, including the possibility of adopting a system of inter-colonial progress reports or of including the information in the "Meteorological Observer's Handbook" or the *Meteorological Magazine*. Mr. WORTLEY remarked that at the suggestion of the Imperial Institute

the Colonial Office had instructed directors of agriculture to forward every six months brief notes on progress achieved in their areas and these notes were published by the Imperial Institute; he suggested that a similar method might be adopted by meteorologists.

It was agreed that as a trial a memorandum on the practice with regard to the tabulation of wind records should be drawn up in the Meteorological Office and circulated to the meteorological services of the various countries of the Empire inviting their comments, and remarks.

The desirability of including such information as far as possible in the "Meteorological Observer's Handbook" was emphasised.

The meeting rose at 1 p.m.

Nineteenth (Final) Meeting, Fifth Joint Session of the General Conference and the Agricultural Section, Wednesday, the 4th of September, at 2.30 p.m..

The meeting was held in the Large Hall of the Civil Service Commission, Burlington House, W.1.

Sir Napier Shaw (*President of the Agricultural Section*) in the Chair.

REPORTS OF THE MEETINGS OF THE SUB-COMMITTEES

SUB-COMMITTEE ON WEST AFRICAN METEOROLOGY.

A Sub-Committee on West African Meteorology met at 9.30 a.m. on Saturday, the 24th of August, at the Air Ministry.

Present : Mr. S. M. Jacob (Nigeria), *in the chair* ; Capt. J. Calder Wood (Deputy Surveyor-General, Nigeria), Mr. A. Walter (Director, British East African Meteorological Service), Mr. J. Dewar (Assistant Surveyor-General, Malaya), Mr. G. Auchinleck (Director of Agriculture, Gold Coast), Mr. A. J. Brooks (Director of Agriculture, Gambia), Mr. R. Temple (Lands Officer, Sierra Leone), Mr. N. P. Chamney (i/c Division of Publications and Meteorology, Gold Coast), Dr. C. E. P. Brooks (Superintendent, General Climatology Division, Meteorological Office, London).

Sub-Committee's proceedings.—Mr. A. WALTER said that the problem was different in West Africa as there was territorial discontinuity as against the continuity in East Africa where Governors' Conferences made for administrative unity.

Dr. BROOKS said that no real progress could be made in the application of meteorological observations to the problem either of agriculture or aviation until at least one first-order station had been established in West Africa.

Mr. AUCHINLECK held that there was a danger that a pure meteorologist would not handle the problem of agriculture.

Mr. WALTER said that a meteorological reporting officer would not deal with the problems. He suggested that Nigeria should have a special meteorological officer and he preferred a Nigerian officer who would inspect the meteorological work in other colonies.

Mr. DEWAR said that Malaya had both Federated and Unfederated States and for meteorological work it was treated as a unit.

Mr. WALTER suggested that Nigeria should have a special meteorological officer recommended by the Air Ministry, who would be available to advise the other West African colonies as to their meteorological work and observations ; each other West African colony retaining its present independent meteorological organization.

The following resolution was adopted :—

"In view of the urgent importance of full meteorological knowledge for the development of aviation, in addition to the value of meteorology to agriculture and medicine, it is recommended that Nigeria should have a full-time meteorological officer to be appointed on the advice of the Air Ministry.

The Colonies of the Gold Coast, Sierra Leone and the Gambia are not yet in a position to maintain separate local meteorological services.

The Committee is, however, of opinion that these Colonies should be invited to avail themselves of the services of the aforesaid Nigerian officer, who should co-ordinate meteorological data in relation to aviation, agriculture, medicine, etc., for all West African Colonies."

August 24, 1929.

(Signed) S. M. JACOB.

SUB-COMMITTEE ON WEST INDIAN HURRICANES.

Meeting on Monday, 26th of August, at 5 p.m.

Present : Dr. G. C. Simpson (Great Britain) *in the Chair*, Mr. H. H. Croucher (Leeward Islands), Rear-Admiral H. P. Douglas (Hydrographer of the Navy), Mr. J. Patterson (Canada), Capt. A. B. Smith (Trinidad), Major E. E. Turner (Windward Islands).

Mr. C. J. P. Cave (Barbados) was prevented from attending through illness.

The following papers had been circulated to the members of the Committee before the meeting :

Copy of despatch from Barbados (No. 197 dated 31.10.28) to the Colonial Office.

Copy of letter from the Air Ministry to the Colonial Office enclosing a memorandum by the Director of the Meteorological Office on the proposed establishment of a hurricane warning service in the West Indies.

Copy of despatch from Cuba (No. 46 dated 23.3.29) to the Foreign Office enclosing memorandum.

Dr. SIMPSON explained that on the receipt of the despatch from Cuba the Foreign Office had called a conference at which there were representatives of the Foreign Office, Colonial Office, Board of Trade, Admiralty and the Air Ministry (Meteorological Office). At that meeting he had pointed out that, so far as he could see, there were two subjects for discussion at the Conference in Cuba, the first dealing with purely local warnings of the nature of police and relief measures, and the second dealing with meteorological warnings. Great Britain was not directly concerned with the former, for which satisfactory codes had been evolved, but was very much interested in the latter. The hurricane warning in the West Indies was undertaken by the United States at their own expense and for Cuba, or any other West Indian Island to attempt to issue warnings would simply be duplicating work. Further no Island could possibly have the resources and the information which were available to the United States. So long as it was recognised that this important public work was being carried out by a foreign government, it was not necessary to take any further steps regarding the hurricane warnings. On the other hand if the Islands commenced to collect observations from ships, then they would interfere with the international organization for meteorological reporting at sea, and it was very important that nothing should be decided at the Conference in Cuba which would interfere with these international arrangements. The Foreign Office Committee had recommended that he (Dr. Simpson) should attend the Conference if it were held, mainly with the object of advising on the wider international and imperial aspects of the meteorological problems involved. The Foreign Office Committee also considered that it was desirable that the British Dependencies in the West Indies should have an opportunity of sending delegates to the Conference and the various governments had already been asked whether they wished to do so.

Mr. CROUCHER asked whether the Foreign Office Committee had come to any decision as to whether shipping lines should be asked to take part in the Conference. Dr. Simpson replied that in the opinion of the Committee only those countries having territory in the West Indian area should be invited, since if shipping interests were invited, almost every country in the world would be involved.

Mr. Croucher was of the opinion that observations from ships were of paramount importance since the weather of the West Indian Islands came largely from the eastward, that is, the Atlantic area in which regular observations were unobtainable.

The HYDROGRAPHER considered that the weak point in the existing scheme was the fact that though the Leeward and Windward Islands were able to send reports of hurricanes to the United States in time for her to make adequate preparations, the Islands themselves were often not warned in time to make preparations for their own safety. He thought that more reports from ships would remedy this defect.

Dr. SIMPSON called attention to the recently signed Convention on Safety of Life at Sea by which captains of ships were bound, under penalty, to report to all ships and also to the shore, when they encountered a hurricane. This regulation, he thought, would improve matters.

Capt. SMITH said that the first intimation of the hurricane which did so much damage in the West Indies in September, 1928, was received from a ship 150 miles east of Barbados at 6 o'clock in the evening, and the hurricane struck Dominica at 9 o'clock next morning, and was at its zenith between noon and 1 p.m. There had been a certain amount of damage in St. Lucia during the night although that Island was some distance from the main line of the storm. There was room for improving the information available to detect and locate hurricanes, and Capt. Smith thought that making it obligatory on ships to report these storms would help in this, but it was more important to have means of issuing warnings when storms were located. Most of the wireless and cable offices closed down at 6 p.m. daily and possibly all day on Sundays and holidays.

Major TURNER considered that communication to the smaller islands ought to be improved, the wireless and cable services were very meagre. He expressed the opinion that when a hurricane warning had been issued, the staff at the wireless and cable stations should remain on duty to receive and send out further reports of the course of the hurricane until it had passed over that area. Capt. SMITH thought that the various wireless and cable companies might agree to co-operate in this way.

Capt. SMITH suggested to Dr. Simpson that if he went to the Conference in Cuba he should call at Trinidad and then at the various West Indian Islands with a view to gaining a knowledge of the schemes for hurricane warning now existing. Dr. SIMPSON said that he would be glad to do so if it were at all possible but he reiterated the fact that he would not attend the Conference to represent local interests.

Mr. PATTERSON agreed that the United States of America was the only country in the position to undertake the hurricane warning service in the West Indies and pointed out that she spent large sums of money annually on reports from ships and from the Islands.

As the result of the discussion the Committee considered that it was undesirable to make any change in the present arrangement by which the United States Government undertook all hurricane warning in the West Indies.

It was also of opinion that at the Conference in Cuba the desirability that local governments should provide meteorological observing stations which could co-operate with the United States in the improvement of their warning service, should be stressed.

Arrangements should also be made by local governments to extend telegraphic facilities during the hurricane season.

The Committee was agreed that Dr. Simpson's help would be useful in informing the Conference of international arrangements regarding meteorology.

August 26, 1929.

(Signed) G. C. SIMPSON.

SUB-COMMITTEE ON THE METEOROLOGICAL ORGANIZATION ON THE CAIRO-DURBAN AIRSHIP ROUTE AND THE CAIRO-CAPE TOWN AIR ROUTE.

Meeting on the 26th of August, 1929, at 5 p.m.

The following were present: Mr. C. Stewart (South Africa) *in the Chair*, Mr. L. J. Sutton (Egypt), Mr. A. Walter (East Africa), Mr. C. G. Hansford (Uganda), Mr. E. J. Wortley (Nyasaland), Lieut.-Col. E. Gold (Assistant Director, Meteorological Office), Capt. F. Entwistle (Superintendent, Aviation Services Division, Meteorological Office), Mr. M. A. Giblett (Superintendent, Airships Services Division, Meteorological Office), Mr. F. Tymms (Directorate of Civil Aviation), Squadron-Leader J. H. Simpson and Flight-Lieut. R. F. Durrant (Signals Branch) and Flight-Lieut. S. Nixon (Royal Airships Works).

Cairo-Durban Airship Route.

1. **Position of boundary between East Africa and South Africa.**—Mr. WALTER said that Southern Rhodesia at present reported to the South African Service and to the East African Service, whilst Northern Rhodesia definitely came within the East African Group. The line of demarcation should follow the northern boundary of Southern Rhodesia and then along the 20° S. parallel. Portuguese East Africa and Madagascar possessed properly equipped services and he believed both would be willing to co-operate.

Mr. STEWART said that Antananarivo also reported to South Africa.

Mr. GIBLETT suggested that the question of Madagascar would probably be solved by a wireless issue and that the question of regional telegrams would be solved by each service intercepting the wireless reports of the other service.

Mr. WALTER agreed to Lieut.-Col. GOLD's suggestion that the 15° S. parallel should be the dividing line for forecast purposes and for wireless issues. The weather charts for each service would inevitably overlap but the responsibility of each could be defined by the 15° parallel.

It was agreed that the line of demarcation between the East and South African Services both for the responsibility of the issue of forecasts and for the collection of data should lie along the 15° S. parallel to the Loangwe River and thence along the northern boundary of Southern Rhodesia.

2. **Communications between ground stations.**—Mr. GIBLETT said that there were meteorological centres at Ismailia, Aden, Mombasa and Durban, and it was necessary to have a chain of communications so that each station could exchange data with the next and could also operate with the airship in flight.

Mr. WALTER said that Mombasa only had a range of 300 miles and was not sufficiently powerful to be of use. There was a short-wave set at Beira. He would prefer to use Nairobi as the short-wave set as this would be at the same station as the first-order station; this set could work with Mombasa.

Mr. GIBLETT said that the first flight would be direct from Ismailia to Durban, but that subsequent flights would stop at Mombasa and that would transfer the centre of forecasting to that station.

Squadron-Leader SIMPSON said that it was necessary to have a wireless station intermediate between Mombasa and Durban. The new station at Salisbury was reported to be a beam station and would presumably only be able to work from point to point.

Mr. GIBLETT suggested that a short-wave station at Nairobi would be able to work with Durban through a relay at Salisbury.

Mr. WALTER said that Salisbury would be the best relay station and should be open this year. There was a cable but communication over this was *very slow*.

3. **Communication between ground and airship in flight.**—At the suggestion of Flight-Lieut. DURRANT, it was agreed that short-wave transmitters were essential for communication between ground stations and the airship in flight owing to the distances to be covered and the intensity of atmospherics.

4. **Network of meteorological stations required on the route.**—It was agreed that the question of the network of meteorological stations be left over for subsequent discussion between the representatives of the services concerned.

5. **Reports from Madagascar.**—At the suggestion of Lieut.-Col. GOLD, it was agreed that Mr. Walter and Mr. Stewart should discuss the question of reports required from Madagascar and that, following agreement between the two services, the Director of the Meteorological Office, London, should ask through the appropriate channels, for authority for Mr. Walter to discuss the requirements directly with the Governor General of Madagascar.

Cairo-Cape Town Air Route.

6. **Position of meteorological stations on the route.**—Capt. ENTWISTLE said that the provisional arrangements for landing grounds and wireless stations on the route had been circulated to the delegates. It was desired to discuss the positions of the meteorological stations along the route and the general meteorological organization for the service. Before doing so, however, he suggested that the delegates should be made familiar with the provisional heads of agreement which had been drawn up relative to the meteorological services for this route.

Mr. TYMMS explained that the services to be provided on the route were based on the agreement between the governments concerned and the operating company, Imperial Airways, Ltd. The list of wireless stations had been strengthened after consideration of local conditions but further additions might be required owing to the distances to be covered. The heads of agreement relating to meteorological services were as follows:—

“ Clause 10—

(1) The President shall at all times communicate to the Company, free of charge, such of the weather reports of stations under the control of His Majesty's Government as may be reasonably necessary for the proper operation of the Company's services.

(2) The President shall provide, free of charge to the Company, all reasonable facilities for the transmission by wireless telegraphy or telephony from such stations at may from time to time be available or under his control to the aircraft of the Company of all available meteorological reports and information as far as may be necessary for the purpose of air navigation of the said Service, and will use his best endeavours to obtain similar facilities for the Company from other governments, dominion, colonial or foreign, provided that the President shall not incur any liability be reason of any accidental failure to issue any such information or by reason of the inaccuracy thereof.

(3) If reasonable meteorological facilities are not available, the President will supply to the Company such instruments and apparatus as may be considered necessary by the President, under the conditions of clause 8 (3) (a) hereof.”

“ Clause 8—

(3) (a) If at any of the stations on the route wireless facilities, as set forth in the fourth column of the First Schedule hereto and/or reasonable meteorological services are not available, the President will arrange with the respective governments concerned for the provision of the facilities necessary for the Service and the Company shall, if so requested by the President, work and maintain them to the reasonable satisfaction of the President and shall furnish and pay such personnel, as may be so necessary in connection therewith.”

On the proposal of Capt. ENTWISTLE the route was then discussed section by section.

A.—EGYPT AND THE SUDAN.

Mr. SUTTON outlined the position in these areas. The Air Ministry have a meteorological staff in Heliopolis who prepare the aviation forecasts on data which include reports supplied by the stations under the control of the Egyptian Physical Department. Stations exist at present at all places on the route from Cairo as far as Mongalla with the exception of Luxor, Abu Hamed, Kosti and possibly Shambe, and there are also additional meteorological stations at intervening places on the route not mentioned in the list. A station could be arranged at Luxor. At stations in the Sudan the observers are provided by the Sudan Government, the instruments are supplied by the Egyptian Physical Department and the observations are forwarded to the Physical Department in Cairo for computation, etc. Selected Sudanese stations telegraph their observations daily to Cairo, although the reports from the southern Sudan are sometimes received late, but there is no central collecting or forecasting station in that area. The observations at Khartoum are taken by an English official of Gordon College.

Capt. ENTWISTLE suggested that the air route wireless system could be used for collecting these reports and communications would be thereby accelerated.

Mr. SUTTON said that morning observations could easily be arranged but there would probably be some difficulty in the communication of evening reports. It was impossible for a forecaster in Cairo to predict haboobs in the Sudan and he agreed with Lieut.-Col. Gold that special reports of this nature would be required.

It was agreed that a communication, to be agreed to by Mr. Sutton before dispatch, should be addressed to the Egyptian Government through the Foreign Office regarding the need for communication to suit the schedule of the air service.

With regard to pilot-balloon stations in this sector, Mr. SUTTON said that it was proposed to instal stations at Sollum and Assuan and possibly Assuit. He would also try to arrange stations at Khartoum, Malakal and Mongalla, but the probability of doing so at an early date was small.

It was agreed that it was essential to have a forecast centre in the Sudan, preferably at Khartoum.

B.—EAST AFRICA.

Mr. WALTER said that he had not selected any stations yet in Uganda, but was waiting for a decision as to the location of the wireless stations there. Four or five European assistants would be necessary for the whole East African Service and he wished to place his first-order stations at places where Europeans could live and work in comfort. It would be necessary to have a wireless station at Port Bell for the issue of warnings. This station should be in addition to Butiaba where a reporting station appeared to be essential.

It was agreed that it was necessary for a wireless station to be erected at Port Bell in addition to that at Butiaba.

Mr. WALTER said that his first-order station in Tanganyika was at Tabora. The main forecasting centre would be at Nairobi and the best position for the central wireless station in Tanganyika would be at Tabora. He would issue all reports and forecasts for the route down to Livingstone. The central station in Northern Rhodesia is at Mazabuka. A wireless reporting station at Mwanza would be very helpful. If the aerodrome was at Arusha it would be necessary to have a direct communication between this station and Tabora.

Mr. TYMMS explained that Mwanza was only a temporary station and that the air route would not pass over Tabora.

It was agreed that the wireless station at Arusha might be made a collecting centre from which the reports could be transmitted to the meteorological centre at Tabora by telegraph.

C.—SOUTHERN RHODESIA AND THE BECHUANALAND PROTECTORATE.

Mr. WALTER outlined the position in this area. Southern Rhodesia now has a meteorological service centred at Salisbury which could collect reports from the surrounding area.

Capt. ENTWISTLE said that it was essential that there should be an aircraft wireless station in this area.

It was agreed that it was necessary to erect a wireless station at Bulawayo which could communicate direct with aircraft.

D.—SOUTH AFRICA.

Mr. STEWART said that there were already reporting stations along the route, but the only station with a professional meteorologist and which made upper air observations was at Victoria West. There was no forecasting centre at Cape Town, the only forecasting centre being at Pretoria. There was also a pilot-balloon station at Pretoria. He considered that there would be no difficulty in the provision of equipment but the provision of personnel might be difficult.

Mr. TYMMS said that the ground staff of Imperial Airways were capable of making observations, including pilot-balloon ascents, provided they were given training.

It was agreed that, from the point of view of this air service, it was very desirable that a forecast service should be established on the terminal aerodrome at Cape Town.

It was also agreed that it was desirable that pilot-balloon stations should be established at Beaufort West and Cape Town.

7. **Skeleton organization for the whole route.**—It was agreed that Capt. ENTWISTLE, in consultation with the representatives of the services concerned, should prepare a skeleton organization of meteorological stations on this route.

The meeting terminated at 7.5 p.m.

August 26, 1929.

(Signed) C. STEWART.

SUB-COMMITTEE ON SHIP'S WIRELESS WEATHER TELEGRAPHY.

Meeting on Monday, the 26th of August.

The following delegates were present: Dr. G. C. Simpson (Great Britain) *in the Chair*, Messrs. Auchinleck (Gold Coast), Bamford (Ceylon), Bates (New Zealand), Claxton (Hong Kong), Feakes (Australia), Normand (India), Patterson (Canada), Smith (Trinidad), Stewart (South Africa), Sutton (Egypt), Walter (East Africa, Southern Rhodesia and Sudan). There were also present Capt. Brooke Smith and Col. E. Gold.

The President stated that the discussion would centre round four main subjects; the time of observations by selected ships, the time of wireless issues, the coast stations which should receive the reports, the code.

The times of observation and transmission.—The PRESIDENT referred to the chart accompanying the memorandum (Appendix V, Chart II) and said that the times suggested by the International Commission were 0000, 0600, 1200, 1800, G.M.T. In view of the difficulty of obtaining reports from ships where only one officer was on watch, it was proposed to ask such ships for observations only during the daylight hours, and such hours were marked by a star on the chart. The times of transmission of observations by ships of the various types was set out on page 119 of the memorandum (Appendix V), in cases where the time of transmission would not coincide with the time at which single-operator ships would be keeping wireless watch a second time was entered.

The President asked for the opinions of the delegates as to whether the adoption of the principle of taking observations during daylight hours was regarded as satisfactory, and whether the times set out were convenient.

Dr. NORMAND (India) said that the main difficulty in accepting the proposal was that according to the scheme the earliest observation made each day off the west coast of India would be at 11h. local time. According to the practice in operation at present ships were asked to take observations at 7h. local time, and this fitted in with the observations on land which were only made once a day; in addition special observations were asked for in disturbed weather, and for four months of the year observations were only sent when the weather showed signs of disturbance. In accordance with the new scheme the ships' data along the west coast would only be available for use on the day following the observation. In the region of the Bay of Bengal the observations would be a little earlier than was convenient but they could be utilised. He said that the Indian Service depends for its observations chiefly on smaller ships trading in Indian waters, such ships carry only one wireless operator and transmit by spark. Evidence of the success of the present practice was given by the increase in observations from 900 a year in 1922 to 5,000 at the present time.

Dr. Normand said that in view of these facts he did not feel himself able to accept the hours set out in the scheme for the region of the Arabian Sea. Mr. BAMFORD associated himself with that opinion.

In reply Capt. BROOKE SMITH pointed out that many of the ships of the Orient, P. and O., and B.I. and other lines carried two officers on watch, and there would be no difficulty in making arrangements with such ships to transmit reports at all four hours of observation. He further pointed out that it was probable that in future years observations might be made every three hours, and such hours would fit in with the times required by the Indian service.

Capt. FEAKES emphasised the fact that the convention dealt only with the *safety* of life at sea, and was not concerned with the regular transmission of meteorological information but only with reports of weather conditions likely to prove dangerous to shipping.

The possibility of the adoption of local time in place of G.M.T. was discussed.

Col. BATES asked whether since ships themselves kept local time it would be practicable for them to continue to take observations by local time and that these observations should be transmitted at such hours as was convenient from the point of view of W/T. He said that by using observations of the barometric tendency it was possible to utilize data from ships which were not absolutely synchronous with those of the land area. He read a note from Dr. Kidson, pointing out that the times suggested, viz., 0530, 1130, 1730, 2330 New Zealand standard time were inconvenient for use with observations at 0900.

From his own experience he realized the unnecessary amount of labour which devolved upon the ship's officers in meeting the present requirements of the various meteorological services.

Mr. PATTERSON using information received from the Union Steamship Co. of New Zealand gave instances of the unnecessary duplication of reports, among others he mentioned that on the route from Vancouver to Australia the officer was required to observe for the British M.O. and ships' log at 2026 G.M.T. and to transmit by radio four different sets of data at 2030, 2100, 2126 and 2130 G.M.T. Officers in the Canadian Pacific Line from Vancouver to Hong Kong suffered from similar duplication, their time-table included:

the transmission of weather reports at 0800, 1200 and 2000 ship's local time in accordance with a general custom.

at 0000 and 1200 G.M.T. when in W. longitude coded reports for American meteorological service.

at 0100 and 1300 G.M.T. when in W. longitude broadcast to all ships as required by the British Air Ministry.

at 2100 G.M.T. between 180th meridian and Japan, as required by the British Air Ministry.

at 2200 in China Seas, as required by the British Air Ministry.

at 0300, 0600, 0900 and 2200 to Zi-ka-Wei, Hong Kong or Manila.

the transmissions at 0100, 1300 and 2100 were regarded as without value.

Col. GOLD said that the possibility of adopting local time for observations at sea had not been considered by the Synoptic Commission in full session. The Sub-Committee had reported in favour of adopting G.M.T. for such observations and as this was in accordance with the desires of the main Commission the question had not been further explored. The Synoptic Commission was willing to allow a latitude of two hours in the time of observations on land; his impression was that they would be willing to accept the nearest four-hourly observation from the sea.

Capt. BROOKE SMITH stated that especially in view of the opinions expressed at the Conference in Paris he was convinced that the adoption of local time in place of G.M.T. would be contrary to the principles of sound navigation and would bring about the failure of the whole scheme. He was strongly of the opinion that all signals especially long-distance signals must be timed G.M.T. He mentioned that support to the scheme had been received from three of the leading officers in the New Zealand service.

Capt. FEAKES also supported the necessity of using G.M.T. and said that unless that practice was adopted it would be impossible to obtain a synchronous picture of the conditions.

In view of these opinions the Committee proceeded to discuss *the possibility of utilising the observations made at the standard hours.*

On the proposal of Mr. WALTER the possibility of advancing the midnight observation by two or three hours in certain zones was considered. After some discussion, however, such a change was found to be impracticable and there was general agreement that the lack of synchronisation of the land and sea observations by a maximum of three hours did not materially detract from the value of the observations over the sea.

Mr. CLAXTON expressed himself as unwilling to destroy the elaborate fabric which had been built up, simply in order to fit in with the local requirements of any particular service. He suggested that if the local services in any longitude would come to some agreement as to the additional requirements of their services these requirements could be met without either placing an unnecessary burden on the ships' officers or breaking down the scheme at present proposed.

Dr. NORMAND agreed that the Indian service could utilise the observations at 0000 G.M.T. if arrangements could be made, in practice if not in theory, for such observations to be transmitted.

Mr. BAMFORD inquired as to the possibility of obtaining special data in addition to those provided for in the main structure for the scheme; he said that such data were required as soon as conditions became suspicious, which might be considerably ahead of the time when a storm had become so definite that shipmasters volunteered information about it.

Col. BATES agreed as to the need for providing for additional observations, but said that on normal occasions New Zealand would only require observations at one of the four standard hours, viz., 18 h. G.M.T.

Mr. WALTER was of the opinion that the six-hourly observations would be sufficient for most purposes.

The Committee was finally in agreement with the suggestion that observations from selected ships should be taken at 0000, 0600, 1200 and 1800 G.M.T. It was understood that there would be no difficulty in the several services making arrangements with the ships on their register to provide for their special requirements, but that in doing so they should bear in mind the general arrangements that were in operation.

Wireless stations.—The President referred to the chart of wireless stations which had been circulated. The directors of the various services were asked to consider which stations would be most suitable, bearing in mind the fact that the long-range stations should be continuous-wave stations using the wave-lengths laid down by the Washington Convention.

Codes.—It was agreed that a meeting should be held at 9.30 a.m. on Tuesday, August 27th, to consider the question of codes; and the President agreed that notes on the codes proposed should be circulated.

The meeting adjourned at 1 p.m.

August 26, 1929.

(Signed) G. C. SIMPSON.

Meeting on Tuesday, the 27th of August, 1929, at 9.30 a.m. and 12.15 p.m.

The following delegates were present: Dr. G. C. Simpson *in the Chair*, Mr. A. J. Bamford, Col. D. C. Bates, Mr. T. F. Claxton, Dr. C. W. B. Normand, Mr. J. Patterson, Capt. A. B. Smith, R.N.R., Mr. C. Stewart, Mr. L. J. Sutton, Mr. A. Walter. There were also present: Capt. Ellery, Col. E. Gold, Capt. Brooke Smith, R.N.R., Mr. J. S. Dines, Cmdr. L. G. Garbett.

Codes.—In opening the discussion the PRESIDENT said that the International Commission for Synoptic Weather Information had made proposals for a new code for use by ships. The proposed code had been circulated to the directors of all meteorological services for consideration and a final decision would be taken at Copenhagen. It is highly desirable that the code finally adopted should be suitable for use in all parts of the world and he had spent much time in considering the problem and discussing it with those concerned. In the early part of the year he had had the advantage of discussing the question very thoroughly with Mr. Calvert of the U.S.A. Weather Bureau and they had reached agreement on a form of code which appeared to meet the needs both of the ships themselves and of the various meteorological services.

The President then set out the codes under discussion, namely:*

(a) The code at present in use on British Ships (omitting check figures)
PQLLL IIIIGG BBDDF wwVKd CNWU TTtt

(b) The code proposed by the International Commission for Synoptic Weather Information.

PQLLL IIIGV BBDDF wwNKd CCTTd_i C_iWIII d_scbN_hh

(c) The codes proposed by himself after discussion with Mr. Calvert.

I PQLLL IIIIGG BBDDF wwVTT { ZKdCN d_sWd_scb
ZCCC_iN d_iWd_scb KdN_hh
Z_____

The President explained that he proposed that all ships' messages should have the first four groups in common, but that there should be a choice of later groups. This would necessitate some method of indicating what code was being used for the final groups and he proposed that the first figure of the fifth group should give this information. For this purpose he introduced the letter Z to indicate a figure which would specify the code used for the subsequent groups.

* For the meanings of the symbols see Appendix V, Annex B, p. 120.

He proposed two codes at the moment but other codes based on the same principle could be formulated as required.

The first of the two new codes which he now proposed (PQLLL IIIIGG BBDDF wwVTT ZKdCN d_iWd_scb) would be suitable for ordinary selected ships and he believed that it gave all the information which could be usefully used by ships at sea and meteorological services in tropical regions, such as India, Hong Kong and the West Indies. If a selected ship did not carry sea-temperature thermometers and a barograph the last group could be omitted leaving the first five groups which contain practically all the information desired.

The second code proposed (PQLLL IIIIGG BBDDF wwVTT ZCCC_iN d_iWd_scb KdN_hh) contains all the observations included in the code proposed by the Synoptic Commission and would be used by those ships able to make the amplified observations. If his proposals were adopted by the International Meteorological Organization, a figure for Z would be allotted for each code and similar figures allotted to subsequent codes as they are approved. The method gives facilities for developing new codes without at the same time abolishing those already in use.

Dr. NORMAND (India) said that the form suggested for selected ships would be generally acceptable, but he pointed out that in the Indian service the information included in the fourth group was of less importance than that in the fifth. The information under ww would be useful if the code could be modified to meet the needs of tropical countries as had been already suggested. He pointed out that neither V nor TT was of much importance in India whereas observations of swell Kd would be required. It would also be slightly more convenient in India to have three figures for the barometer readings so that these might be reported in inches, though the conversion to millibars could if necessary be arranged.

Mr. PATTERSON (Canada) said that the first four groups were required both by the U.S. and Canadian services, the fifth group was not necessary, though the sixth might be required. He would prefer interchanging N and V. He was prepared to accept the code and regarded the introduction of Z as an ingenious way of providing for the various international requirements.

Mr. CLAXTON (Hong Kong) thought it impossible to come to an agreement as to what should be given in the first four groups and suggested that it would be more convenient if five groups could be made uniform throughout so that the smaller services could limit themselves to those five groups; he proposed therefore that Z of Dr. Simpson's code should be transferred from the fifth to the sixth group. He thought that the barometric tendency was not of sufficient value to warrant the use of three figures; observers were not always in a position to give useful information as regards barometric tendency, on account of diurnal variation, and short negative or positive waves of pressure which masked the general tendency; and also on account of the speed of the ship. He emphasised however the increasing importance of visibility and of the difference of sea and air temperatures.

Mr. WALTER (East Africa) said that the fifth group included important information for tropical countries otherwise he would suggest putting N in the fourth group. He would like to transfer Z from the fifth to the sixth group. He was of opinion that the code would meet most difficulties.

Col. BATES (New Zealand) referred to the difficulty of units and said he was prepared to accept the millibar. He expressed the hope that some agreement could be reached.

Capt. SMITH (Trinidad) referred to the desirability of getting the code included in the International Code of Signals for ships which was at present under revision. He emphasised the need of brevity in the messages.

Capt. BROOKE SMITH referred again to the general principles on which he considered the choice of a code should be based. He read a resolution of a departmental committee to consider the British proposals for the Safety of Life at Sea regarding the reporting of position in W/T weather reports, and emphasised the need for giving position correctly; he further pointed out the value of including information on the set and drift of currents, and that it was necessary that clear identification of groups should be insisted upon.

Mr. WALTER endorsed Capt. Brooke Smith's opinion as to the importance of current observations and said that in the Mozambique channel visual signals embodying the information had been asked for.

Cmdr. GARBETT emphasised the importance of including information of barometric tendency and said that naval officers regarded it as of essential importance.

In reply the PRESIDENT said that the choice of a uniform pressure unit was essential and he thought conversion to millibars would present no difficulty. With regard to the position of Z it was desirable that it should be placed as far from the beginning as possible. The first four groups were those required by the American service and he thought it might be possible to come to a general agreement about those four groups. He thought that information of V and TT would be of increasing importance. To transfer the Z beyond the fifth group would not he thought be possible in view of differences of opinion as to the necessity for detailed observations of cloud. With regard to observations of current, these could be added by any ships that desired to do so provided that the information was disconnected from the meteorological information. In reply to Capt. Smith he said that every effort would be made to include information about the code in the new edition of the International Code of Signals.

The President called on Col. Gold to speak on the international aspect of the subject, and on the reasons which had led to the proposals for the code put forward by the Synoptic Weather Commission (Appendix V, Annex B).

The form of code is :—PQ LLL III GV BB DDF ww NKd CCTTd_t C_i WIII d_s cb N_h h.

Col. GOLD said it was important that no decision should be reached without the consideration of all aspects of the problem.

At the meeting of the International Organization at Utrecht in 1923 proposals had been put forward for drastic changes in the codes, and the Commission for Synoptic Weather Information had appointed a Sub-Commission to consider the proposals and to effect some compromise between the proposals and the existing practice. In considering the code the Sub-Commission had in mind certain leading principles : (a) that no unnecessary figures should be included, (b) that nothing should be included which would impose on all ships the necessity for carrying other instruments in addition to the barometer (c) that unnecessary changes in the existing code should be avoided, (d) that the information which was regarded as essential to all services should be included in the first four groups. This accounted for the item V being included in Group 2 ; it was regarded as essential by many services that all ships should report visibility.

At this point the meeting was adjourned to allow for the session of the full Conference.

At the resumed meeting at 12.15 p.m. Col. GOLD continued :—

The reason for providing only one figure G for time was that, if observations were made on the basis of four standard hours, only one figure was necessary, and it was worthy of consideration whether occasional observations at other than standard hours could not be indicated independently in the message, without imposing an unnecessary figure on the preponderating mass of standard reports : (with 1,000 selected ships, half of which are reporting at any particular time the cost of one figure is about £4,000 per annum at the rate paid for reports from British Ships). He pointed out that the combination of P and G would enable more accurate information of time to be given. The Commission had proposed that the first six groups of the code should be for all selected ships, and that the last group which included data of barometric tendency and cloud height involving certain difficulties of observation, should be optional.

He pointed out that it was the intention of the Commission that the code should be submitted to the Maritime Commission and to all services which had to deal with marine meteorology, so that they might consider it from the point of view of its adoption by a service of voluntary observers. He emphasised the fact that if the code was voluntary it was very desirable, both from the point of view of the ships themselves and of the meteorological services, that the code should be the same everywhere.

Col. Gold said that two points had to be borne in mind : first that in order to get co-operation in the code it was necessary that all the services concerned should have a hand in making it, and secondly that the representatives of other nations might be able to contribute ideas and suggestions of real value and such ideas ought to be capable of incorporation in the final proposal.

With regard to the figures for CC he thought meteorologists could learn a great deal from the ideas which were expressed in the code but it was recognised that some education was required before the information could be incorporated with advantage in the code for ships, and until the time for its incorporation arrived it had been suggested that the figures should be used for information of low and middle cloud. Col. Gold emphasised the need of being conversant with all the factors involved if a really acceptable code was to be evolved.

The PRESIDENT emphasised the need of the representatives of the Empire coming to some general agreement before the general discussion of the code at Copenhagen.

The President asked Dr. Normand whether it would be possible to use the code proposed by the International Commission in the Indian service.

Dr. NORMAND in reply said that the Indian service would depend largely on information from non-selected ships, for these the first four groups contained the information required, except that only one figure was given for time, and no information of the type of predominant cloud was included ; he would not be prepared to accept groups beyond the fourth on account of the inclusion of CC. He did not regard his objection to the omission of two figures for time as entirely insuperable. In comparing the two codes he said that as far as the first four groups were concerned the international code was more suited to the requirements of the Indian service on account of the substitution of NKd for VTT, but knowing the requirements of Great Britain and America he would be prepared to support the proposals put forward by the President. He did not think it possible to devise one code that would be suitable for the whole world and he recognised that the provision for two alternative codes in the latter part of the message offered opportunities for elasticity.

Mr. PATTERSON said that for the Canadian service one figure would suffice for G if standard hours were used, TT was needed but probably not Kd or CC and the last two groups might be omitted. He asked for information as to how many of the services regarded the information in the first four groups of the President's code as fundamental.

Col. BATES said that a code of words was in use in Australasian waters and would have to be considered in the case of local ships trading in those waters ; he regarded P as essential in order to avoid all ambiguity in identifying a message.

The PRESIDENT emphasised the fact that the needs of the American service would be met by the code which he had put forward, the first four groups agreed with those used in that service at present. He said that he had been asked to reduce as far as possible the length of messages re-transmitted from United States to England, and the four groups gave what information was required. The United States Weather Bureau regarded two figures for time as essential and did not desire information of swell. He expressed the opinion that the adoption of the code suggested by the Synoptic Commission would hinder the development of the ships' code ; and he emphasised the difficulties caused by the lack of permanence in the codes. He thought that in view of the difficult circumstances under which ships' reports had sometimes to be coded it was undesirable to try to compensate for the omission of a second figure for time by the use of a complicated code combining P and G, in his opinion each figure should have one simple meaning.

The first four groups.—The President then asked the delegates for information in reply to Mr. Patterson's question. The following opinions were expressed.

Great Britain. J. S. DINES speaking from the point of view of the synoptic service said that information of d_t was preferable to V ; P was required for observations from the further side of the Atlantic. Cmdr. Garbett however said that the Navy required V. Capt. Brooke Smith said that the fundamental meteorological data were wind direction and force, and visibility from shore stations ; he emphasised the need for two figures for time and said that it was essential that information of the position, date and time should be beyond question.

Mr. SUTTON (Egypt) agreed with Great Britain's point of view.

Mr. CLAXTON (Hong Kong) said he liked the elasticity provided by the use of Z in the code, and he would be willing to accept the first four groups if his requirements as to the fifth could be satisfied.

Mr. BAMFORD (Ceylon) expressed himself in favour of two figures for time.

Col. BATES (New Zealand) expressed his satisfaction with the scheme. As a practical meteorologist he emphasised the importance of visibility in forecasting, and though he regarded the difference of sea and air temperature d_t as important he did not think it should have precedence over V especially in view of the possible inaccuracy of the observations.

Capt. SMITH (Trinidad) said that from the point of view of accuracy observations of V were likely to be more satisfactory than those of d_t .

General agreement was given to the first four groups of the code suggested by the President.

The fifth group. ZKdCN.—Mr. CLAXTON said he wished to confine the messages to five groups and in view of the importance of information of d_t in forecasting fogs he would prefer that element included in place of either C or N.

Dr. NORMAND, Mr. WALTER, Mr. BAMFORD and Capt. SMITH all expressed their preference for the group in its present form.

The PRESIDENT pointed out that the number of groups which were included in the report of a ship and the decision as to which of the two codes should be used for the supplementary groups would rest with the service which issued the instructions. In the English service it was probable that all selected ships would use the first type of code, whereas naval ships might use the second.

Capt. BROOKE SMITH pointed out that from the point of view of the forecast service there would always be more selected ships available than were required and the control system which had already been described would provide for a certain choice as to the data received, those ships being called on to report which could provide data of the type required. He thought that the capacities of the officers with regard to observations had been underestimated.

The meeting adjourned at 1.30 p.m.

August 27, 1929.

(Signed) G. C. SIMPSON.

SUB-COMMITTEE ON THE METEOROLOGICAL REQUIREMENTS AT ADEN.

Meeting on the 27th of August, 1929, at 5.15 p.m.

The following were present: Dr. G. C. Simpson (Director, Meteorological Office) *in the Chair*, Dr. C. W. B. Normand (India), Mr. A. Walter (East Africa), Dr. R. S. Taylor (Somaliland), Mr. L. J. Sutton (Egypt) Mr. A. J. Bamford (Ceylon), Mr. D. Brunt (Superintendent, Army Services Division, Meteorological Office) and Capt. F. Entwistle (Superintendent, Aviation Services Division, Meteorological Office).

1. Capt. ENTWISTLE outlined the points for discussion. There were three points of view to be considered: (a) Airships, (b) the Royal Air Force, and (c) the Army. Dealing first with (a) he said that Aden lies on a possible alternative airship route to India via the Red Sea and also on the route to South Africa via the east coast of Africa. For this reason it was desirable to have a meteorological station at Aden for collection of the data required for meteorological investigations for airships, including upper winds and observations of upper air temperatures. Further, if and when airships fly along these routes, a distributing centre would be required at Aden.

With regard to (b), Aden was at present a Royal Air Force Command and there was a bomber squadron stationed there. In addition to local flying there was a considerable amount of flying between Aden and other Commands, but there was no meteorologist or system of meteorological reports. The Royal Air Force required a meteorological station and, in particular, observations of upper winds.

There was a further point for consideration. The provision of reports from the Aden area would probably be found of value for forecasting purposes over other areas e.g. Iraq and the Persian Gulf.

The first question to consider was which Government should assume responsibility for meteorological work at Aden on the lines visualised.

Dr. NORMAND said that the Indian Meteorological Department had maintained a third-class observing station at Aden for the past 40 years or so. Observations were made once daily in the morning. A Robinson anemometer was maintained there but its records were of doubtful value. A difficulty in maintaining the station in efficient condition had been the lack of inspection. A scheme for a pilot-balloon station had been sanctioned by the Indian Government. Two observers had been posted to Aden and the station would shortly be working. He had inquired from the Royal Air Force Headquarters, India, regarding observations of upper air temperature at Aden but they had not found it possible to make any arrangements for such observations.

2. Establishment of a pilot-balloon station in Somaliland.—In reply to Dr. Simpson, Dr. TAYLOR said that there was a weekly mail service between Aden and Berbera and there would be no difficulty in Dr. Normand's observer visiting Berbera for the purpose of training his clerks in pilot-balloon work. He might promise one station at Berbera where already he had one clerk employed part time on meteorological observations.

Dr. NORMAND said that he had been in correspondence with the Italian Government who had promised to instal a pilot-balloon station at Cape Guardafui. With this station working, one station at Berbera would be sufficient. If the Berbera staff were trained in Indian methods, two full-time clerks would be needed to maintain the station.

Dr. TAYLOR said that two clerks were available but not for full-time meteorological work. The question of the staff required would have to be taken up with his Government.

On the proposal of Dr. SIMPSON, it was agreed that a letter, drafted by himself in conjunction with Dr. NORMAND, should be sent to the Somaliland Government requesting the establishment of a pilot-balloon station at Berbera; the instruments to be provided by the Meteorological Office, London, and the staff by the Somaliland Government.

3. Meteorological requirements at Aden.—Dr. SIMPSON said that there would be four pilot-balloon stations in this area, viz., Kamarun Island, Aden, Berbera and Cape Guardafui. Was it necessary to have more than a pilot-balloon station at Aden?

Mr. BRUNT said that so far as the Army requirements were concerned, the artillery would need meteor reports. Dr. Normand's station could supply the upper winds and arrangements should be made with the Royal Air Force for upper air temperatures. The present personnel at Aden would meet all requirements of the Army.

Capt. ENTWISTLE said that owing to the number of long-distance aeroplane flights which were likely to increase in the future, and the fact that Aden came within the airship scheme as a forecast centre, it would be necessary to station a professional meteorologist there.

Dr. NORMAND replied that, although occasional storm warnings to shipping were issued by his staff, he could not assume forecasting responsibility for that area and, if a distributive station were required, it would have to be provided by the Air Ministry.

Dr. SIMPSON said that if the Royal Air Force needed a distributive station at Aden they should initiate the request and that the need for a forecast centre for airships could be left over until the airship route was definitely fixed.

It was agreed that apart from any request made by the Royal Air Force, the pilot-balloon station at Aden under the control of the Indian Meteorological Department would meet present requirements and that Mr. Brunt should initiate a request that observations of upper air temperature should be made by Royal Air Force machines at that station as frequently as possible.

4. Generators for hydrogen.—Mr. WALTER said that both at his station and in Ceylon hydrogen generators were used successfully and he suggested that such a machine would solve transport difficulties to Berbera.

Dr. SIMPSON replied that although there was now no difficulty in the transport of hydrogen to Egypt and Kamarun Island, the question of generators would soon have to be solved.

It was agreed that Dr. Simpson, Dr. Normand and Mr. Bamford should discuss the question of hydrogen generators on their return from the Conference of Directors at Copenhagen.

5. **Anemometer at Aden.**—In reply to Mr. Brunt, Dr. NORMAND said that he was not considering the installation of a pressure-tube anemograph at Aden.

Mr. BRUNT said that he hoped Dr. Normand would consider the desirability of such an instrument as the records would be of great interest.

6. **Boundaries of areas of responsibility for issue of reports and forecasts to airships.**—It was agreed that this question should be left for discussion between Mr. Giblett, Dr. Normand and Mr. Walter.

The meeting terminated at 6.5 p.m.

August 27, 1929.

(Signed) G. C. SIMPSON.

SUB-COMMITTEE ON CHARTS AND CODES (AVIATION).

Meeting on the 29th of August, 1929, at 5 p.m.

The following were present: Dr. C. W. B. Normand (India) *in the Chair*, Dr. G. C. Simpson (Director, Meteorological Office), Col. D. C. Bates (New Zealand), Mr. J. Patterson (Canada), Mr. L. J. Sutton (Egypt), Mr. A. Walter (East Africa), Mr. C. Stewart (South Africa), Mr. A. J. Bamford (Ceylon), Lieut.-Col. Gold (Assistant Director, Meteorological Office), and Capt. F. Entwistle (Superintendent, Aviation Services Division, Meteorological Office).

Charts.

1. Capt. ENTWISTLE outlined the points for discussion. There appeared to be a general desire for uniformity in the working charts used by the various Empire meteorological services, particularly those to be used at aerodromes and airship bases. It would be desirable to discuss the following points in order:—scale, projection, colour, contours and method of showing position of stations. In reply to Mr. Patterson he said that in this country agreement had been reached between the aviation and airship divisions and the same charts were used by both services. Form 2213 (scale 1 : 5,000,000) was used for the preparation of detailed forecasts for aviation in this country and along the adjacent Continental air routes, and Form 2205 (scale 1 : 20,000,000) for forecasts for flights beyond the area covered by Form 2213.

2. **Scale.**—Lieut.-Col. GOLD stated that, prior to the war, the International Meteorological Organization, recommended that standard charts for forecasts should be on the scale 1 : 10,000,000 and that other charts should be on one of the scales in the series 1 : 5,000,000, 1 : 20,000,000, 1 : 30,000,000 and 1 : 40,000,000. In selecting a chart for use by a particular meteorological service it would be advisable to adopt one of these scales.

Mr. PATTERSON said that in Canada they had not got maps corresponding to those used in England but he could use Form 2205 at the airship base for the initial flights. In preparing new charts he would keep the need for uniformity in view. No scale under 1 : 10,000,000 would be of use normally in America but a chart similar to Form 2213 could be used as a secondary map at airship bases.

Dr. SIMPSON said that the attempt to secure uniformity should be done in moderation. It was not desirable for a forecaster to work on charts with which he was not familiar.

In reply to Mr. Walter, Capt. ENTWISTLE said that charts on the scale 1 : 10,000,000 were used for general forecast work in England.

Dr. NORMAND said that in India the ordinary charts were on a scale of about 1 : 15,000,000.

Mr. SUTTON said that in Egypt the scale was 1 : 7,500,000.

Dr. SIMPSON pointed out that it would be misleading to use charts on the same scale and not to use the same intervals of pressure for isobars.

Mr. PATTERSON said in Canada inches were used at present. He would prefer to introduce millibars but the change must be made in Canada and the United States at the same time.

In reply to Dr. Normand, Capt. ENTWISTLE said that at Cardington, there would be two scales used. 1 : 5,000,000 would be used for the more detailed forecasts and for landing and base operations; 1 : 20,000,000 would be used for forecasts for the more distant parts of the routes. In general it might be stated that the scale to be used in any particular country would depend largely upon the intensity of the network of stations available for the charts.

On the proposition of Dr. NORMAND, it was agreed that it was desirable to use charts on the scales 1 : 5,000,000, 1 : 10,000,000 or 1 : 20,000,000 according to the particular needs for which the maps were prepared.

3. **Projection.**—Capt. ENTWISTLE explained that Form 2213 was on a conical orthomorphic projection with two standard parallels at 60° N. and 45° N., and Form 2205 was on a similar projection with standard parallels at 50° N. and 20° N.

Dr. NORMAND said that the real question was the projection to be used in the tropics. He was willing to accept the English projection in India for the Cairo-Karachi air route but he doubted if it were suitable for example in East Africa.

Lieut.-Col. GOLD suggested that 20° N. and 20° S. should be taken as standard parallels and any projection which was orthomorphic with one of these as a standard parallel would be suitable.

Dr. SIMPSON said that at the meeting of the Conference of Directors at Paris in 1919, Professor V. Bjerknes had submitted the following proposals regarding charts:—

“(i) *General principles.*—The projection adopted for meteorological charts should satisfy the following requirements:—

(a) The meridians should be rectilinear.

(b) The projection should be conformable.

(c) The distortion of the scale should be as small as possible in relation to the extent of the area represented.

(ii) *Special projections.*—In conformity with these general principles the three following projections are recommended:—

(a) For Polar regions: projection on a plane intersecting the parallel of 75°.

(b) For temperate latitudes: projection on a cone intersecting the parallels of 30° and 60°.

(c) For Equatorial regions: projection on a cylinder intersecting the parallels of $\pm 15^\circ$.

(iii) *Scale.*—The use of scale 1 : 10,000,000 is recommended whenever possible.

For work covering a wide area the scale 1 : 20,000,000 might also be used. For detailed work the scales 1 : 5,000,000 and 1 : 2,500,000 are recommended.

Meteorological services should be urged to apply these principles whenever an opportunity offers for revising the form of their charts.”

Dr. SIMPSON explained that these proposals were never actually accepted by the Conference of Directors and were not binding but in England they had tried to conform to them when designing charts.

It was agreed that, as such maps were already in existence in several services, it was desirable to follow the general principles proposed by Professor Bjerknes.

4. **Contours.**—In reply to Dr. Normand, Lieut.-Col. GOLD said that it was desirable to indicate contours at 1,000, 2,000 and 3,000 metres, as they were the international heights for upper winds and reduction of barometer readings.

It was agreed that it was desirable to show contours at 200, 1,000, 2,000 and 3,000 metres.

5. **Colours.**—Dr. NORMAND said that in his experience the green shading on land over 3,000 metres interfered with the blue and green ink used in India, and that there was no interference with any ink used on a brown chart.

Mr. PATTERSON said that only one colour of ink was used in Canada and that the sea was coloured blue on their charts.

Col. BATES, Mr. WALTER and Mr. SUTTON said that blue charts were used in their services.

Lieut.-Col. GOLD suggested that information was required regarding the experience of the use of different colours. At present no decision regarding the suitability of green or brown had been reached in England.

Capt. ENTWISTLE said that both he and Mr. GIBLETT wished to stress the need for uniformity in colour as it would add to the ease with which aeroplane pilots and airship commanders could understand the charts of different services. He could see no disadvantage in green but would not express a strong preference for that colour. It might be a question of the suitability of the natural background, e.g., green in England and brown in the tropics.

Lieut.-Col. GOLD said that it was not uncommon to have charts with the sea coloured blue. This was very confusing if other services chose blue for contours on land.

It was agreed that there would be advantages in a common colour scheme but at the present time there was not sufficient information to determine what the common colour scheme should be.

6. **Method of plotting of charts.**—Dr. SIMPSON drew the attention of the members to Form 2458 (Preparation of Weather Maps) and asked them to consider the methods outlined therein.

Mr. PATTERSON said that these methods would mean a change in Canada where only one colour ink is used. He desired to conform as nearly as possible to the symbols to which the airship staff were used.

Mr. WALTER suggested that the desire for uniformity was clear but he doubted if we could arrive at a scheme immediately.

On the proposition of Dr. SIMPSON, it was agreed that he should circulate to the director of each service a working chart prepared on the lines set out in Form 2458, together with a copy of that form. The directors should consider these charts and forward any suggestions to Dr. Simpson who should circulate them for information and comments to the other directors concerned.

7. **Method of showing positions of stations.**—Lieut.-Col. GOLD said that dots were normally used on charts in England but that an experimental chart with circles had been printed. The experiment had not yet been in progress for sufficient time to enable a definite decision to be reached.

It was stated that in India, Canada, Egypt and New Zealand circles, are used to show cloud amount.

Mr. WALTER said he preferred circles to dots.

In reply to Capt. Entwistle, Mr. PATTERSON said that the circles on their charts were clear and the forecaster shaded the requisite amount to denote the cloud amount. The wind arrows ran across the circles and the velocity was shown not by feathers but by a figure underneath the arrow.

Mr. SUTTON said that on his charts a small circle denoted the position of the station and the head of the wind arrow was on this circle. A separate circle placed in a conveniently adjacent position was used for depicting cloud amount.

On the proposition of Dr. SIMPSON it was agreed that, at the conclusion of the experiment in England, he should prepare a memorandum on the method of showing the position of stations on charts and should circulate it to the other services for their comments.

Codes.

Mr. WALTER said that at the present time there were some elements included in the code which rarely show appreciable change in his area, such as barometric tendency, and he would prefer to use these figures for reporting past conditions of wind and weather. Otherwise he would have to draw another chart and there would probably be difficulty in obtaining reports in the afternoon. His difficulty was that internationally he had to deal with the Belgian Congo and Portuguese East Africa, and, if he used the international code, he must either leave out useful information or add another group with a consequent increase in telegraphic charges.

Mr. SUTTON said that it would be necessary shortly to draw a midday map.

Dr. SIMPSON said that they could not devise a code which would contain all data and reduce the cost of telegraphy at the same time. These services were now coming into the meteorological family and should bring their ideas and problems before the Conference of Directors at Copenhagen.

Mr. WALTER suggested that a code like the ship's code with alternative groups for tropical and temperate zones was required.

Mr. BAMFORD strongly supported this suggestion.

Lieut.-Col. GOLD said that the international code was based on observations taken three or four times a day and it was difficult to fit in the question of observations taken only once a day. The answer would probably be the addition of groups at the end of the message. There was a possibility of arranging for elasticity in the land code to suit conditions in polar, temperate and tropical regions and the International Meteorological Organization should take this into consideration.

It was agreed that it was desirable to devise a code with flexibility at the end of the message on the lines of Dr. Simpson's proposed code for selected ships.

The meeting terminated at 6.50 p.m.

August 29, 1929.

(Signed) C. W. B. NORMAND.

NOTE.—Specimen copies of any of the Forms referred to in these appendices may be obtained from the Meteorological Office, Air Ministry, London, W.C.2.

APPENDICES

C.E.M. 8/1929.

APPENDIX I.—MEMORANDUM ON METEOROLOGY AND AVIATION IN THE BRITISH EMPIRE.

By F. ENTWISTLE,
Superintendent, Aviation Services Division, Meteorological Office.

I. THE DEVELOPMENT OF IMPERIAL AIR ROUTES.

1. Introductory.
2. Preliminary meteorological investigations.
3. Organization of meteorological reporting and forecasting service.
 - A. The London—Continental routes.
 - B. The principles of the organization of meteorological services.
 - C. The England—India—Australia route.
 - D. The Cairo—Cape Town route.
 - E. Other air routes.

II. THE METEOROLOGICAL REQUIREMENTS OF THE ROYAL AIR FORCE AND OF DOMINION AIR SERVICES.

III. METEOROLOGICAL ARRANGEMENTS FOR LONG-DISTANCE NON-STOP FLIGHTS.

I.—The Development of Imperial Air Routes.

1. **Introductory.**—When commercial aviation was inaugurated in Europe ten years ago it was recognized that the safe and regular operation of an air route must depend not only on efficient aircraft and skilled pilots, but also on a technically developed and soundly administered ground organization, the latter including an adequate meteorological service and a system of wireless communication both between ground stations, and between ground stations and aircraft. The important increase in civil flying which has taken place since the first commercial aeroplane flew across the English Channel in 1919 has been accompanied, accordingly, by a corresponding development in these ancillary services. In north-west Europe where the weather is difficult from the point of view of flying, owing largely to the prevalence of fog and low cloud, and to the fact that there is no well-marked seasonal variation of weather, an intensive weather reporting system has been found necessary for safeguarding the air routes and for ensuring as far as possible the regularity of the air services.

While it may be argued that a highly developed meteorological organization is unnecessary in the case of air routes which lie in tropical and sub-tropical regions, where the seasonal variations of weather are relatively well marked, there can be no question that an air route which does not include a meteorological service in its ground organization must suffer in the long run as compared with a route which is so equipped. The persistence of adverse weather as frequently experienced in temperate latitudes may be rare in the tropics, but the bad weather that does occur is usually more violent in character, and provision must be made for warnings of dangerous phenomena if an air route is to be operated with safety.

There is, however, another aspect of the application of meteorology to aviation, apart from the questions of safety and regularity. A knowledge of the direction and speed of the wind currents at different levels is of considerable economic importance in the operation of a commercial air route. By selecting a particular height for flying it is frequently possible for an air pilot to effect an appreciable saving both in fuel and in time. Cases are on record where, with the certain knowledge that there was a favourable wind ahead, it has been possible to increase the paying load of a commercial aircraft by reducing the amount of fuel carried. This aspect of the application of meteorology to aviation is of considerable importance, particularly in certain parts of the tropics, where there are marked variations of wind with height.

2. **Preliminary meteorological investigations.**—It will be obvious that the decision to proceed with the development of a particular air route is governed primarily by other than meteorological considerations. Nevertheless it is of importance to those concerned with the development of the route to have before them the results of a preliminary investigation into the meteorological conditions from the point of view of flying over the area through which the route will pass. The value of such an investigation would be to indicate, among other factors,

(a) the frequency of occurrence of conditions likely to cause interruption of the service at different seasons.

(b) the diurnal variation of such conditions and hence the best period of the day to operate any given portion of the route.

(c) the prevalence of winds from different directions at various heights and hence the probability of securing a following wind at an economical height in either direction along the route. This information would also indicate the distances at which it would be necessary to place intermediate landing grounds between the main aerodromes where the latter were too far apart for the route to be flown without landing. It would also assist the operating company in preparing the time tables of the service.

(d) the best route, from the point of view of weather conditions, between any two aerodromes. The information would also indicate whether it was desirable to lay down alternative routes along any section.

The data which would be required from a given area to form a basis for the discussion of the meteorological conditions along a projected route may be summarised as follows:—

(a) A climatological summary giving for a period of years the monthly means and extremes of the normal meteorological elements, and the frequencies of occurrence of rain, hail, gales, thunderstorms, etc. The form of summary recommended in the memorandum of the "Collection, Tabulation and Publication of Climatological Data" (Appendix XII) would be suitable for this purpose.

(b) A summary giving the monthly frequencies of different amounts of cloud at selected hours of the day, if this information is not included in the general climatological summary.

(c) A summary giving the monthly frequencies of different degrees of horizontal visibility at selected hours.

(d) A summary giving the monthly frequencies of different heights of base of low cloud at selected hours.

(e) A summary giving the monthly frequencies of winds from different directions and of different speeds at the surface and at selected heights up to and including 10,000 feet.

(f) For flying boat routes, a summary giving the frequencies of different degrees of sea disturbance, particularly in regard to the nature and amount of the swell.

The stations for which the summaries are prepared should be selected to give the best representation of the meteorological conditions over the area concerned, but localities subject to exceptional conditions should be included whenever possible. For the climatological summaries and the statistics of cloud and visibility the network of stations should be as close as possible.

The method of preparation of the summaries is a matter of some importance. It has to be borne in mind that there are likely to be few Imperial air routes which will not pass at some stage through foreign countries where landings will be made, or which will not link up at various points with foreign air routes. It is desirable, therefore, that the data should be prepared in such a form that they are comparable with those published by foreign countries. The system recommended for the summaries of horizontal visibility, height of base of low cloud and surface and upper winds is that adopted by the International Commission for Air Navigation and described in Annex G to the "Convention relating to the Regulation of Aerial Navigation dated 13th October, 1919". A specimen of the summaries prepared for one month for stations in Great Britain and Northern Ireland is attached (Annex A). Details of the method of preparing wind summaries are given in the memorandum dealing with Meteorology and Airships (Appendix II) and need not be repeated here. The following notes may be of use in connection with the preparation of the remaining summaries.

Visibility.—The standard method of measuring horizontal visibility at meteorological stations is to select a number of well-defined objects at certain distances according to the International scale and to observe the most distant of these objects which is clearly visible. For each hour of observation selected the number of observations between the various limits are extracted for each month and a frequency table prepared.

Height of base of low cloud above ground level.—For these summaries only observations from stations where reliable measurements or estimates of the height of base of cloud are made should be included. The observations should be made in accordance with the international scale and the number of observations between the various limits extracted and the summaries prepared as in the case of visibility. It is desirable that a second frequency summary should be prepared, in the same form, giving observations of height of base of low cloud for those occasions when the total amount of low cloud is greater than three-quarters of sky covered, that is, when the amount is 8, 9 or 10 tenths.

The frequency summaries of visibility and of height of base of low cloud covering a period of years should be prepared in the form of percentages of the total number of observations for each month, this number being shown in the tables.

Wherever possible, separate summaries should be prepared for at least three different hours of observation, preferably one in the morning, one near mid-day and one in the late afternoon or evening.

While the summaries described in the preceding paragraphs would form a suitable basis for a discussion of the meteorological conditions along a projected air route, provided that they covered an adequate network of stations, it would be necessary to supplement the data by further information in the form of a route guide, giving details regarding special phenomena such as sandstorms, tornadoes, tropical revolving storms, etc., the frequency with which they occur, the areas affected, and, when possible, the average vertical extent of the disturbance. The guide would also include any additional information not covered by the summaries but important from the point of view of aviation, e.g., information regarding areas where marked vertical currents are experienced, the diurnal changes of surface winds, and the frequency with which high ground which has to be crossed is enveloped in cloud. Such information would be based largely on a study of the day to day changes by means of synoptic charts and would be prepared by the appropriate meteorological service. Where, as not infrequently happens, flights have already taken place over the route under discussion, a consideration of the pilot's reports on the meteorological conditions experienced would assist materially in the preparation of the route guide. In the case of dangerous phenomena an indication should be included of the amount of warning that could be given by the meteorological service.

The sites proposed for aerodromes and seaplane bases along the routes should be subject to special investigation from the meteorological point of view. The positions of aerodromes are determined, primarily, by such considerations as access to capitals or important centres, freedom from obstructions, nature of soil, etc., but any local meteorological conditions likely to affect the regularity of the air service should also be taken into account. The data prepared for any route should include a table giving the monthly mean and minimum values of air density at ground level at the various aerodromes, this factor affecting the load which can be carried by an aircraft without unduly increasing the length of take-off run.

3. Organization of meteorological reporting and forecasting service.—A. *The London-Continental routes.*—An historical account of the development of meteorological services for aviation in Europe from 1919 to 1926 was given in Appendix D to "The Approach towards a System of Imperial Air Communications," a memorandum by the Secretary of State for Air laid before the Imperial Conference, 1926. The present organization is described in chapter III of the "Air Pilot of Great Britain."

The essential features of the organization, which is based on the meteorological arrangements for an international airway as outlined in Annex G to the "Convention relating to the Regulation of Aerial Navigation" may be summarised as follows, in so far as the British portion of the routes is concerned.

(i) The supply to the pilot, *before leaving the terminal aerodrome at Croydon*, of:

(a) recent reports of the existing weather conditions at stations on or near the route up to the next aerodrome of call, including upper wind observations from selected stations.

(b) a detailed short-period forecast covering the flight and, in the event of the pilot continuing the flight beyond the next aerodrome of call, an indication of the probable conditions along the next stage of the route.

(c) on days when there is a large horizontal pressure gradient over the area to be traversed, and the weather is adverse, an altimeter correction chart indicating the approximate error in the readings of the altimeter at various points along the route.

(d) on days when the weather is bad along the main route between Croydon and the Channel, reports from stations on the alternative routes.

(ii) Notification to the pilot *when in flight* of,

(a) warnings of the subsequent occurrence at any station of weather phenomena which may be regarded as threatening the safety of aircraft on the route, such as fog, low cloud, thunderstorms or squalls.

| | | |
|--|--|--|
| * FWP FWP Cherbourg Brest | * GFB PIM London De Bilt | DDM DDX DDW Hamburg Berlin Königsberg |
| FWR FWB FWO Rochefort Carouba Cuers | FNB OPO DDK Le Bourget Brussels Cologne | DDL DDO DDU Leipzig Hof Breslau |
| * FNX * Bordeaux | FND FNC FNS Dijon Nancy Strasbourg | DDF UOA * Frankfurt Vienna |
| * FNT FYG Toulouse Tours | FNL HBW HBZ Lyon Geneva Zurich | OKB OKM * Brünn Prague |
| * * * | FOM * * Marianne | * * * |
| * * * | FNJ * * Ajaccio | * * * |
| * FOR FOA Oran Algiers | * * * | * * * |
| * FON FOU Bône Tunis | * * * | * * * |

* Not yet allocated

The boundaries for the different regions indicate the wave-lengths as follows:—

| | | |
|-------|----------|---------------|
| ----- | 238 kc/s | (1260 metres) |
| ===== | 233 kc/s | (1288 ") |
| ===== | 228 kc/s | (1316 ") |

The transmitting stations in the region enclosed by diagonal stripes use the wave length 124 kc/s (2425 metres), as the transmissions are also employed for shipping.

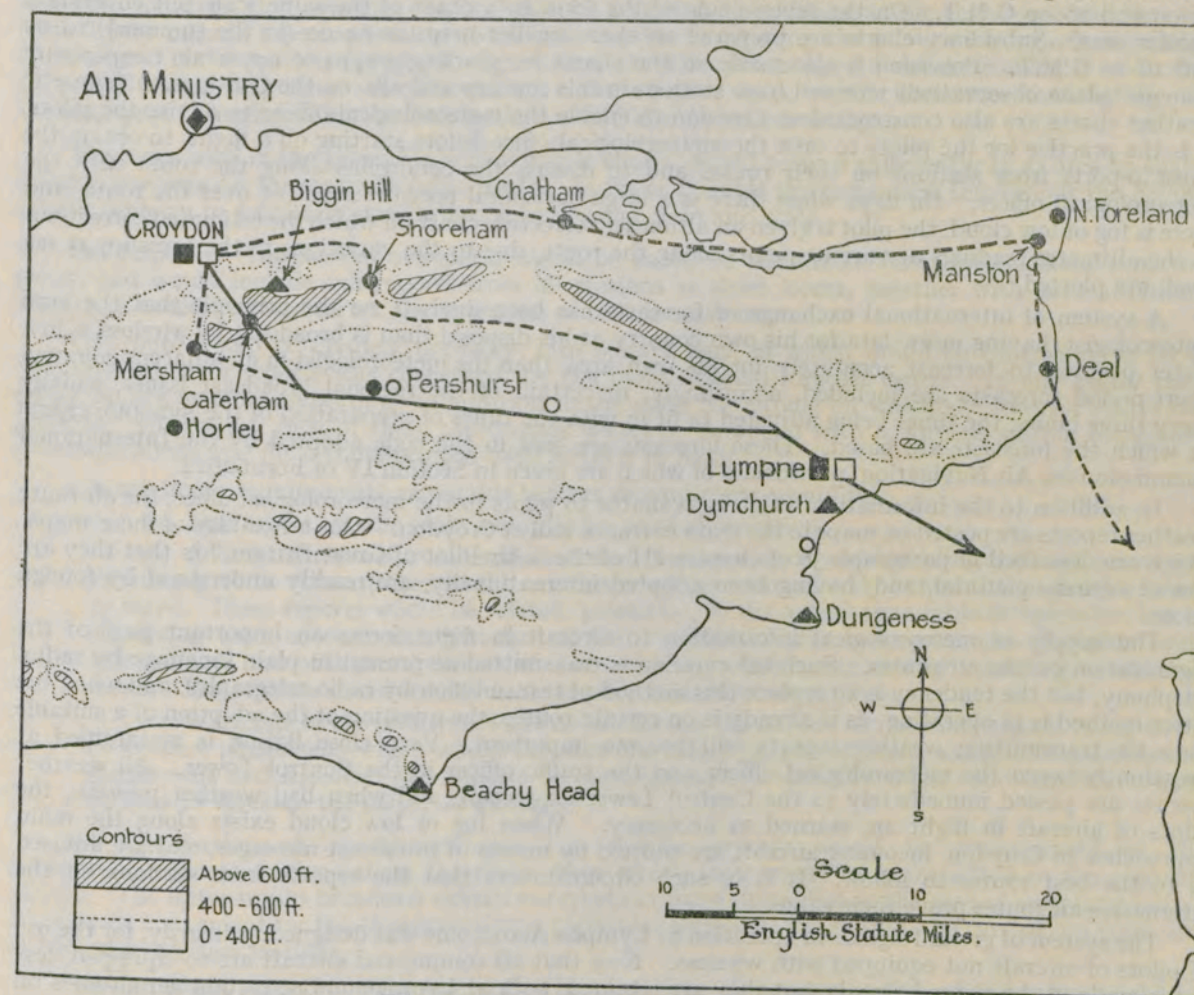
FIG. 1.—Regional system of collective weather reports for aviation transmitted in Europe and North Africa.

(b) in the case of incoming aircraft, on days when there is fog or low cloud in the neighbourhood of Croydon, special warnings, including information regarding weather conditions along the alternative routes leading in to the terminal aerodrome. These warnings are broadcast to all aircraft within range of Croydon.

The system of reports, which is described in detail in chapter III of the "Air Pilot of Great Britain," is based on observations made at the international times for synoptic observations, viz.: 07.00, 13.00 and 18.00 G.M.T. (The 01.00 observations are not utilised as there is not, as yet, regular night flying.) At these times, and also midway between them, that is, at 04.00 (in summer), 07.00, 10.00, 13.00, 16.00 and 18.00 G.M.T. observations are made regularly at all air route reporting stations. During the intermediate hours, regular observations are limited to stations on the more important aerodromes, but all stations report immediately any important change in weather conditions that may occur since the last regular observation. These special reports are sent according to the system detailed in paragraph 34, any such report being included in the next collective message broadcast from the regional wireless station.

The system of exchange of route meteorological information by means of regional broadcast messages, which is described in paragraph 31, is in operation throughout several of the countries of western Europe. The distribution of regions and sub-regions, and the wave-lengths used, are shown in the diagram in Fig. 1. The system is particularly advantageous in a country possessing a large network of air routes, since it enables any one region to intercept the maximum number of reports from other areas without interference. In the case of aircraft equipped with wireless telegraphy apparatus, it is possible for the aircraft to intercept the messages and so limit the amount of direct wireless communication with ground stations. The frequency with which the reports are transmitted ensures that the information is up-to-date.

A map showing the meteorological stations reporting in connection with civil aviation in south-east England is given in Fig. 2. The main stations on the air route, e.g., Croydon and Lympne, which are



EXPLANATION

The Map shows the routes followed by Aeroplanes flying between Croydon and the Continent, thus:—
 ——— MAIN ROUTE
 - - - - - ALTERNATIVE ROUTES, Used when the weather on Main Route is bad.

The Meteorological Stations are shown thus:—

- CENTRAL METEOROLOGICAL STATION.
- MAIN STATION
- ▲ SECONDARY STATION
- AUXILIARY REPORTING STATION
- AERODROME
- LANDING GROUND

FIG. 2.—Aeroplane routes between Croydon and the Continent.

staffed with trained meteorological personnel, are equipped as first-order meteorological stations and the three-hourly observations from these stations are transmitted in the full international code for synoptic reports. They can be utilised, thus, in the preparation of synoptic charts for forecasting purposes. These stations also make regular pilot balloon observations, usually near the times of the three-hourly observations. When a pilot balloon ascent is impossible owing to low cloud, the direction and speed of the cloud are observed by means of a Besson nephoscope. All regular reports other than the three-hourly reports from synoptic stations are sent in the abbreviated code for aviation reports. Particulars of this code, and also of the codes for special reports, are given in Sections I and II of Form 2612, "Weather Reports and Forecasts for Aviation," which is published by the Meteorological Office.

The auxiliary reporting stations are manned by coastguards, lighthouse-keepers or officials of other departments of the public service whose duties necessitate a more or less continuous watch. In some cases the observations are made by private observers. A small payment is made for the observations except in the case of two stations on the route, where the observations are made voluntarily by public-spirited private observers. It is found that after training, the observers are efficient and find no difficulty in using the abbreviated code. Their greatest difficulty is in making accurate estimates of the height of base of cloud. For this reason, the more important stations are supplied with small balloons and hydrogen. By inflating the balloon to rise at a predetermined rate, and using a stop watch, the height of the base of low cloud can be determined quickly and accurately. All auxiliary stations are visited regularly, to ensure that the correct procedure is being followed with regard to the observations.

The forecasts for the air routes emanating from Croydon are prepared by the Aviation Forecast Service at the Air Ministry. They are based on synoptic weather charts prepared several times daily. The chart used for this purpose is on conical orthomorphic projection with two standard parallels 60°N. and 45°N. where the scale is 1 in 5,000,000. The area covered by the chart includes Greenland to the north-west, the Azores to the south-west, Finland to the north-east and Italy to the south-east. Four of these large charts are prepared daily from observations at the four standard hours, 01.00, 07.00, 13.00 and 19.00 G.M.T. On the reverse side of the form is a chart of the same scale but covering a smaller area. Subsidiary charts are prepared on these smaller maps at 04.00 (in the summer), 10.00 and 16.00 G.M.T. Provision is also made on the charts for plotting graphs of upper air temperature from aeroplane observations received from stations in this country and also on the Continent. Synoptic weather charts are also constructed at Croydon to enable the meteorological officer to advise the pilots. It is the practice for the pilots to visit the meteorological office before starting on a flight, to obtain the latest reports from stations on their routes and to discuss the conditions along the route with the meteorological officer. On days when there is a large horizontal pressure gradient over the route, and there is fog or low cloud, the pilot is given an altimeter correction chart on which the estimated corrections to the altimeter readings at various points along the route, due to the variations in the pressure at sea level, are plotted.

A system of international exchange of forecasts has been devised, on the principle that the local meteorologist, having more data for his own country at his disposal than is broadcast by wireless, is in a better position to forecast accurately for his own area than the meteorologist in an adjacent country. Short-period forecasts are included, accordingly, in certain of the regional broadcast issues, usually every three hours, the times being adjusted to fit in with the times of preparation of the synoptic charts on which the forecasts are based. These forecasts are sent in the code adopted by the International Commission for Air Navigation, particulars of which are given in Section IV of Form 2612.

In addition to the information which is available to pilots in the meteorological office, the air route weather reports are posted on maps in the main entrance hall at Croydon. One advantage of these maps, which are described in paragraph 36 of chapter III of the "Air Pilot of Great Britain," is that they are almost entirely pictorial, and, having been adopted internationally, are readily understood by foreign pilots.

The supply of meteorological information to aircraft in flight forms an important part of the organization on the air routes. Such information is transmitted at present in plain language by radio-telephony, but the tendency is to replace this method of transmission by radio-telegraphy, and when the latter method is in operation, as it already is on certain routes, the question of the adoption of a suitable code for transmitting weather reports will become important. Very close liaison is maintained at Croydon between the meteorological officer and the traffic officer in the Control Tower. All weather reports are passed immediately to the Control Tower on receipt, and when bad weather prevails, the pilots of aircraft in flight are warned as necessary. When fog or low cloud exists along the main approaches to Croydon, incoming aircraft are warned by means of broadcast messages, and are advised as to the best routes to follow. It is in such circumstances that the reports from stations on the alternative air routes prove their value.

The system of ground signals in operation at Lympne Aerodrome was designed, primarily, for the use of pilots of aircraft not equipped with wireless. Now that all commercial aircraft are so equipped, less use is made of the ground signals, but they are retained, both at Lympne and at certain aerodromes on the Continent, owing to the increasing number of privately owned aircraft which fly on the routes.

It remains to add a word regarding the arrangements for ensuring co-operation between the various meteorological services responsible for the organization on the air routes. Such co-operation is secured by periodical conferences between representatives of the services concerned, at which the various questions arising in connection with the operation of the services are discussed, and as a result of which the organization is improved in detail from time to time. Conferences between representatives of the Official administrative and wireless services are held at the same times, usually twice a year.

B. The principals of the organization of meteorological services.—Before proceeding to discuss the meteorological organization on the individual Imperial air routes, it may not be out of place to consider briefly the general principles of such an organization as deduced from the existing arrangements on the London-Continental routes, which are based on ten years' experience. Along many sections of Imperial air routes which will lie over sparsely populated territory or over regions which enjoy fine settled weather for a considerable period of the year, such a close network of stations or intensive system of weather reporting will be neither possible nor necessary, but the general principles will remain unchanged.

(i) Distribution of stations.—There will sometimes exist already a network of stations adequate for general forecast purposes, and the equipment, in addition, of the main aerodromes along the route, i.e., aerodromes where regular landings are made, as first order meteorological stations will usually, in such cases, complete the network and provide an adequate distribution of synoptic stations for forecasting for the air services. Where a network of stations is not already in existence, it may be necessary to establish additional synoptic stations over the area through which the route passes. The number and distribution of such stations would depend on the particular meteorological conditions to which the area is subject.

A sufficient number of stations should be equipped for making pilot balloon ascents to give an adequate representation of the upper wind distribution along the route. In general, this condition would be met by equipping the stations at main aerodromes as pilot balloon stations. Additional upper wind stations, not lying on the route, may, however, be required for forecasting purposes.

In addition to the synoptic stations, auxiliary reporting stations should be established as necessary both along the route and also, when necessary, on either side of the route. In particular, arrangements should be made to obtain reports from any place on or near the route which is subject to exceptional meteorological conditions. Where the route is affected by travelling disturbances such as line-squalls, a selection of warning stations is desirable on the side of the route from which the disturbances usually approach the route.

(ii) Forecast centres.—In principle a forecast centre should be established at each main aerodrome along the route. In many cases this will not be practicable, but arrangements should then be made for the air route forecasts to be prepared at the regional centre and transmitted to the other aerodromes for the information of the pilots. In any case, forecast centres should be established at the terminal aerodromes of a route and at aerodromes which form a junction between two or more routes. When the main aerodrome lies near the capital of a country where the headquarters of the meteorological service are situated, it may be found more convenient to have the forecast centre at the main headquarters. It is desirable, however, that synoptic charts should be prepared, in addition, at the aerodrome and that the staff should include a professional meteorologist capable of advising the pilots with regard to weather conditions. If the route is used by foreign aircraft, it is an advantage for the meteorologist to be able to speak foreign languages. A pictorial air route weather map, on the lines recommended by the International Commission for Air Navigation, would also be an advantage.

The maps used in the preparation of synoptic charts should cover a sufficiently large area to enable reliable forecasts for the air route to be made. As far as possible the maps used throughout the Empire should conform to a uniform standard as regards projection and scale.

(iii) Reports.—The system of reports would be based on the fundamental international reporting hours, and would include full reports from all stations at these hours, together with such additional reports as would be required for the operation of the air services.

The route would be divided, normally, into sectors, each of which would be controlled, as far as the distribution of reports was concerned, by the main regional forecast centre. In any sector there might be one or more aerodromes in addition to the main aerodrome on which the forecast centre was situated. In general, each of these aerodromes would be equipped with a wireless station for ground communications and for communication with aircraft in flight.

The minimum requirements as regards reports on any route would be:

(a) Full reports at the main synoptic hours of observation.

(b) Additional reports from each section of the route up to and including the next aerodrome of landing, to be concentrated at the aerodrome of departure shortly before the air service is due to leave. These reports would be related, primarily, to the actual time-table in operation but in organising them account also be taken of the possibility of the commencement of flights being delayed, and also of flights commenced, but not always continuing strictly according to schedule times. The reports would usually include pilot balloon observations.

(c) Warnings of the occurrence at any station on the section of the route that is being flown of weather phenomena which would threaten the safety of aircraft, such as fogs, thunderstorms, sandstorms and squalls; and reports of improvements of weather when conditions have been such as to threaten the safety of aircraft.

(iv) Organisation of communications.—The routine reports would be concentrated at the appropriate wireless stations along the route, from which they would be transmitted to the regional centres. The latter would broadcast collective reports at fixed times, but in the case of very long routes it might be convenient for the broadcasts for a particular section of the route to be carried out from one of the other wireless stations.

The additional reports for the air service from stations along any section of the route would be concentrated at the aerodrome of departure, the reports from the remote half of the section being collected at the next aerodrome and transmitted to the aerodrome of departure by wireless.

During the period that the air service was in operation, each station along a particular section of the route would maintain a continuous watch from the time the aircraft left the aerodrome at the beginning of that section until it landed at the next aerodrome along the route. During this period reports of sudden changes in the weather conditions would be concentrated at the two wireless stations and passed to the aircraft by W/T as required.

A typical communications organisation is illustrated by the diagram in Fig. 3.

(v) Codes for reports.—The question of codes is a difficult one. Many of the reports which form part of an air route organisation have to serve two purposes. In the first place they have to convey to the meteorologist, who is responsible for the supply of data to the flying personnel, sufficient information to enable him to form an accurate mental picture of the weather conditions at remote stations and to

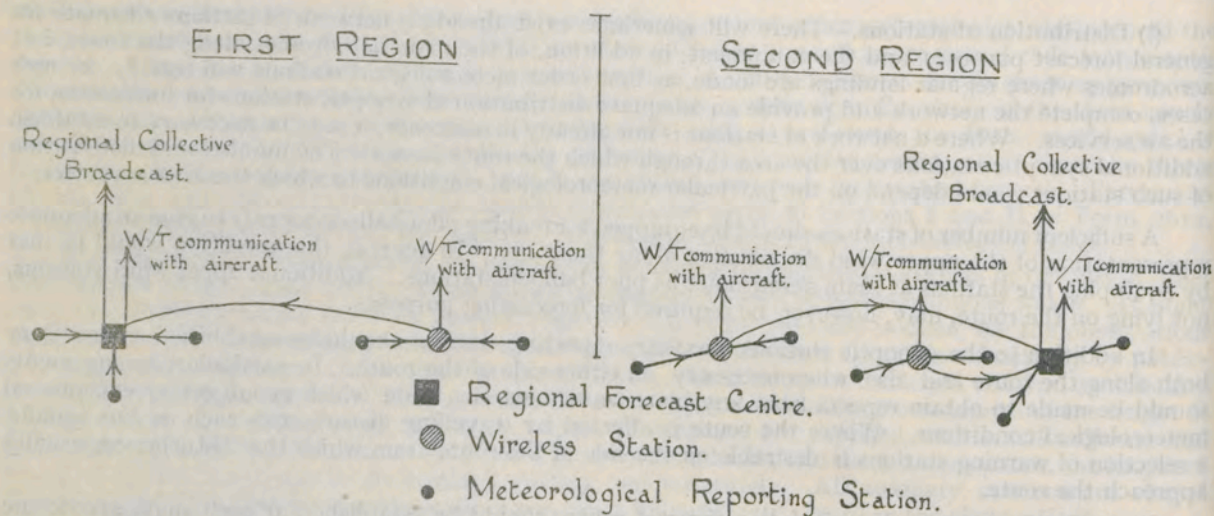


FIG. 3.—Organization for transmission of meteorological reports on an air route.

serve as a basis for forecasting. Secondly they are required to provide the air pilot with essential information regarding the weather conditions ahead. If the meteorologist were the only one concerned with the codes, the complexity which must characterise them to some extent would not be a matter of great import, since dealing with codes forms part of his daily routine. In practice, however, it is frequently necessary to employ a non-technical observer to make and encode the observations for transmission and it is also necessary to pass certain information to pilots in coded form. It is imperative, therefore, that the codes in use in aviation work should be as simple as possible, and that they should be of such a character that they can be employed on air routes in all countries. This ideal is being slowly but steadily attained, although it is not always easy to keep the codes in a simple form, in view of the nature of the information which has to be transmitted. The essential thing is that a pilot, wherever he may be, should always know what meteorological information he may expect to receive and the form in which he is likely to receive it.

It is recommended, therefore, that on Imperial air routes, the codes of Annex G of the Convention relating to Aerial Navigation should be employed whenever possible. Certain of these codes do not at present cover all the phenomena likely to be encountered in tropical or sub-tropical countries. Until the codes can be completed in this respect, the difficulty can be overcome by adding to the messages in plain language any information which is necessary owing to conditions which are not covered by the code.

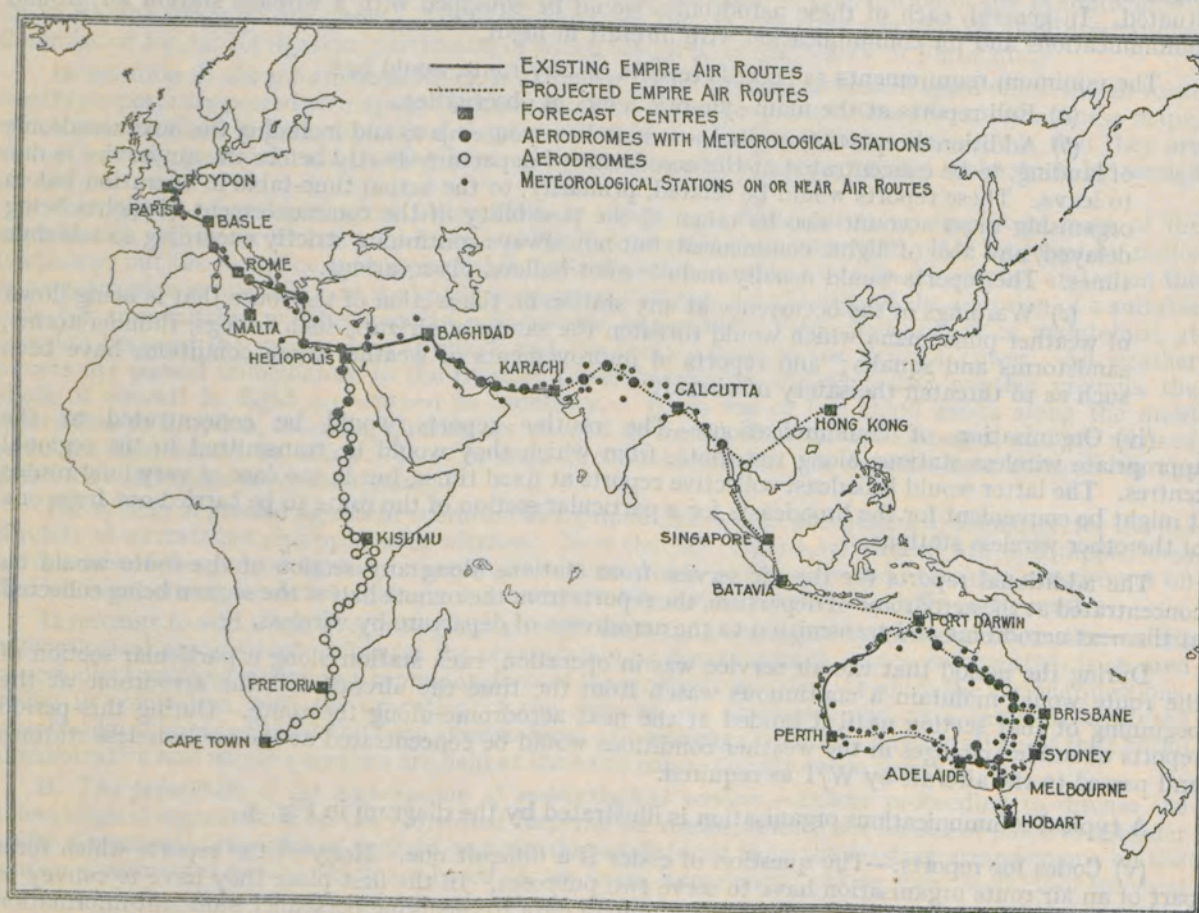


FIG. 4.—Empire air routes.

The main codes which are used on air routes at the present time are:

- the international code for synoptic reports,
- the abbreviated code for aviation reports (Form 2612, section I),
- Codes for special reports of sudden changes in meteorological conditions (Form 2612 section II),
- Code for short-period weather forecasts for aviation (Form 2612, section IV).

(vi) Co-operation between the meteorological services.—Where an air route passes through different countries and various meteorological services are concerned with the organization of weather reports, it is essential for the smooth running of the route, that there should be continuous and full co-operation between the services concerned. Such co-operation is best secured by periodical conferences, similar to those which are held in north-west Europe. In the case of long-distance air routes, however, this procedure is not likely to be practicable, and correspondence will usually have to take the place of the more intimate personal conversations. Whether the co-operation is ensured by personal contact or by correspondence, it is desirable that the necessity for it should not be overlooked.

In the case of the main Imperial air routes it is desirable that the Meteorological Office, London, should be kept informed of the progress of the organization and of changes in procedure. In the case of the England-India route which is now in operation, this liaison is affected by means of monthly progress reports. As further routes are developed similar reports from the Empire meteorological services concerned would be welcome.

C. *The England-India-Australia route.*—This route together with other projected Empire air routes is shown on the map in Fig. 4 on which the main forecast centres and meteorological stations, as known to exist at present or to be in view, are indicated.

The first section of the route, between Cairo and Basra, was opened in January, 1927, and in April of this year the service was extended in both directions forming a complete link between England and India. At present a weekly service in each direction between Croydon and Karachi is operated, the journey occupying eight days. The time table is as follows:—

| Local standard time. | | | G.M.T. Day. | | | Local standard time. | | | G.M.T. Day. | | |
|-------------------------------|------------|------------|-------------|--------|--|------------------------------|----|----|-------------|-------|--------|
| London (Airways House) | dep. 09.40 | 08.40 | Sat. | | | Karachi | .. | .. | arr. 17.15 | 11.45 | Sat. |
| " (Croydon Aero-drome) | dep. 10.30 | 09.30 | " | | | Karachi | .. | .. | dep. 10.00 | 04.30 | Sun. |
| Paris (Le Bourget Aerodrome) | arr. 13.00 | 12.00 | " | | | Gwadar.. | .. | .. | arr. 13.40 | 08.10 | " |
| " | dep. 14.00 | 13.00 | " | | | " | .. | .. | dep. 14.40 | 09.10 | " |
| Basle (Birsfelden Aero-drome) | arr. 17.00 | 16.00 | " | | | Jask .. | .. | .. | arr. 15.35 | 11.40 | " |
| " (Central Station) | dep. 21.35 | — | " | | | " | .. | .. | dep. 06.30 | 02.35 | Mon. |
| Genoa (P. Principe Station) | arr. 09.13 | 2 | Sun. | | | Lingeh .. | .. | .. | arr. 08.50 | 04.55 | " |
| " (Air Port) | .. | dep. 10.30 | 09.30 | " | | " | .. | .. | dep. 09.35 | 05.40 | " |
| Rome—Ostia .. | .. | arr. 13.30 | 12.30 | " | | Bushire.. | .. | .. | arr. 12.50 | 09.30 | " |
| Naples .. | .. | dep. 14.30 | 13.30 | " | | " | .. | .. | dep. 13.35 | 10.15 | " |
| " | .. | arr. 15.45 | 14.45 | " | | Basra .. | .. | .. | arr. 15.55 | 12.35 | " |
| Corfu .. | .. | dep. 07.45 | 06.45 | Mon. | | " | .. | .. | dep. 05.00 | 02.00 | Tues. |
| " | .. | arr. 13.15 | 11.15 | " | | Baghdad .. | .. | .. | arr. 08.30 | 05.30 | " |
| Athens .. | .. | dep. 14.15 | 12.15 | " | | " | .. | .. | dep. 09.15 | 06.15 | " |
| " | .. | arr. 17.30 | 15.30 | " | | Gaza .. | .. | .. | arr. 16.45 | 14.45 | " |
| Suda Bay .. | .. | dep. 10.30 | 08.30 | Tues. | | " | .. | .. | dep. 08.00 | 06.00 | Wed. |
| Tobruk .. | .. | arr. 12.45 | 10.45 | " | | Alexandria (Aboukir) .. | .. | .. | arr. 11.25 | 09.25 | " |
| " | .. | dep. 13.45 | 11.45 | " | | " (Harbour) .. | .. | .. | dep. 13.30 | 11.30 | " |
| Alexandria (Harbour) .. | .. | arr. 16.00 | 15.00 | " | | Tobruk .. | .. | .. | arr. 17.00 | 16.00 | " |
| " (Aboukir) .. | .. | dep. 06.00 | 05.00 | Wed. | | " | .. | .. | dep. 09.30 | 08.30 | Thurs. |
| Gaza .. | .. | arr. 11.30 | 09.30 | " | | Suda Bay .. | .. | .. | arr. 13.45 | 11.45 | " |
| " | .. | dep. 14.05 | 12.05 | " | | " | .. | .. | dep. 14.45 | 12.45 | " |
| Baghdad .. | .. | arr. 17.30 | 15.30 | " | | Athens .. | .. | .. | arr. 17.00 | 15.00 | " |
| " | .. | dep. 06.30 | 04.30 | Thurs. | | " | .. | .. | dep. 08.45 | 16.45 | Fri. |
| Basra .. | .. | arr. 15.00 | 12.00 | " | | Corfu .. | .. | .. | arr. 12.00 | 10.00 | " |
| " | .. | dep. 15.45 | 12.45 | " | | " | .. | .. | dep. 13.00 | 11.00 | " |
| Bushire.. | .. | arr. 18.45 | 15.45 | " | | Naples .. | .. | .. | arr. 16.30 | 15.30 | " |
| " | .. | dep. 06.00 | 03.00 | Fri. | | " | .. | .. | dep. 10.45 | 09.45 | Sat. |
| Lingeh .. | .. | arr. 09.00 | 05.40 | " | | Rome—Ostia .. | .. | .. | arr. 12.30 | 11.30 | " |
| Jask .. | .. | dep. 09.45 | 06.25 | " | | " | .. | .. | dep. 13.30 | 12.30 | " |
| " | .. | arr. 14.10 | 10.15 | " | | Genoa (Air Port) .. | .. | .. | arr. 16.30 | 15.30 | " |
| Gwadar .. | .. | dep. 14.55 | 11.00 | " | | Genoa (P. Principe) .. | .. | .. | arr. 19.00 | — | Sun. |
| " | .. | arr. 17.15 | 13.20 | " | | Basle (Central Station) .. | .. | .. | arr. 06.16 | — | Sun. |
| " | .. | dep. 07.30 | 03.35 | Sat. | | " (Birsfelden Aero-drome) | .. | .. | dep. 09.30 | 08.30 | " |
| " | .. | arr. 12.35 | 07.05 | " | | Paris (Le Bourget Aerodrome) | .. | .. | arr. 12.45 | 11.45 | " |
| " | .. | dep. 13.35 | 08.05 | " | | " | .. | .. | dep. 14.15 | 13.15 | " |
| | | | | | | London (Croydon Aero-drome) | .. | .. | arr. 16.45 | 15.45 | " |
| | | | | | | " (Airways House) | .. | .. | arr. 17.30 | 16.30 | " |

The meteorological arrangements between Croydon and Basle form part of the organization of meteorological services in north-west Europe, which has already been described. Between Basle and Genoa the passengers are conveyed by train, this part of the journey being made by night.

The section of the route from Genoa to Alexandria is a flying boat route operated by Imperial Airways Ltd. in conjunction with an Italian Company. The meteorological organization along this section of the route is not yet complete. Up to the present the Italian Meteorological Service has arranged for the supply of information between Genoa and Athens and the Air Ministry Meteorological Section, Middle East Area, for reports between Athens and Alexandria. The reports from Suda Bay are obtained from an Imperial Airways Depot Ship. Route forecasts are prepared at Heliopolis and issued by W/T in code to Athens, Suda Bay, Tobruk and Aboukir.

Between Aboukir and Basra, the meteorological organization is working satisfactorily. Reports are obtained from the Air Ministry meteorological stations at Aboukir, Ismailia, Ramleh and Amman, from the Royal Air Force meteorological stations at Baghdad and Basra, from Gaza where observations are made by Imperial Airways wireless operators, the Air Ministry having supplied the necessary instruments and from Rutbah and Diwanija where the observations are made by arrangement with the Iraq Government. Aboukir, Ismailia, Ramleh, Amman, Rutbah, Baghdad, Diwanija and Basra are pilot-balloon stations. Forecasts are issued from Heliopolis and Baghdad to aerodromes as required. All stations make regular synoptic observations at dawn (the time varying throughout the year), 0600, 1200 and 1800 G.M.T. and also additional reports for the air service. The reports and forecasts are concentrated as required at Aboukir (for Alexandria), Gaza, Baghdad and Basra, and additional reports are sent from these stations and from Rutbah to the aircraft in flight as necessary.

The arrangements for the supply of information between Bushire and Karachi are made by the India Meteorological Department. Reports are obtained from Bushire, Lingeh, Jask, Charbar, Gwadar, Pasni, Ormara and Karachi, while pilot observations are made at Bahrein, Muscat, Gwadar and Karachi. Forecasts are issued from Karachi to Basra and Jask as required. Regular reports are issued for the eastbound and westbound services and are concentrated at Basra, Jask and Karachi. In addition special reports of disturbed weather on the route are issued to the aircraft by wireless. Collective reports containing observations at 0400 G.M.T. and 1700 G.M.T. from stations west of Karachi are broadcast regularly from Karachi.

It is too early to discuss in detail the meteorological organization between Karachi and Australia. There is little doubt that between Calcutta and Port Darwin the route will be operated by flying boats, and by land machines from Port Darwin southwards where the route will link up, at Camooweal, with the existing route. The meteorological organization will be shared between India, the Federated Malay States, the Dutch East Indies and Australia. The immediate need is to collect meteorological data relating particularly to the section of the route between Burma and Northern Australia.

D. The Cairo-Cape Town route.—It is proposed to proceed with the establishment of this route in 1930 and the discussion of the details of the meteorological organization has thus become a matter of some urgency. It is not proposed to go into detail in the present memorandum but it is hoped, during the course of the Conference, to discuss the question with the representatives of the services concerned and with representatives of the Director of Civil Aviation and the Air Ministry Signals Branch.

E. Other air routes.—There is a possibility that air routes will be established in the future

- (i) Between Canada and South America via Florida and the West Indies.
- (ii) Between the West African Colonies and Dakar, linking up with the French West African service.
- (iii) Between Rangoon and Hong Kong via Bangkok.

In the event of services being established, information would be required from the areas affected as outlined in section I, sub-section 2 of this memorandum, and subsequently arrangements would have to be made for adequate meteorological services.

II.—The Meteorological Requirements of the Royal Air Force and of Dominion Air Services.

In connection with the requirements of Dominion Air Services, it may be of interest to give a brief resumé of the organization which exists in this country for supplying meteorological information to the Royal Air Force.

At the Air Ministry there is a special forecast service for aviation which forms part of the Aviation Services Division. This service issues regular forecasts to all Royal Air Force aerodromes.

- (a) in the early morning—for the period of daylight.
- (b) in the afternoon—for the following day.
- (c) in the afternoon—for night flying (to certain units only).

The forecast service is in operation throughout the twenty-four hours and any Royal Air Force unit can apply at any time for a special forecast for cross-country flying or for special operations. In addition warnings of line-squalls and thunderstorms are issued to all aerodromes, when they are likely to be affected by these phenomena. In addition to the aviation forecast service, meteorological stations are maintained at twelve Royal Air Force Aerodromes. Ten of these are in charge of professional meteorologists who issue reports and forecasts to meet the special requirements of the units to which they are attached. At the Royal Air Force Cadet College, Training Bases and Flying Training Schools, the meteorological officers give courses of instruction in meteorology in addition to carrying out their other duties. Arrangements are also made from time to time to meet special Royal Air Force requirements.

The main meteorological requirements of the Royal Air Force overseas are in connection with flights along the strategic air routes between various parts of the Empire. Several such flights have already taken place, of which may be mentioned the Far East Flight to India, Singapore, Hong Kong and Australia and the Cairo-Cape Town and Cairo-Nigeria flights. These flights have been either pioneering

flights to try out flying conditions for forces of aircraft, or service exercises for training. But their object is to work towards a chain of routes, linking up the overseas commands, along which air units can be moved rapidly for reinforcement wherever required. An instance of such use of service aircraft was the recent movement of a squadron of troop carriers from Iraq to the North-West Frontier of India to evacuate the Legations from Kabul.

The mobility of air power is absolutely dependent upon well organized routes with adequate meteorological services. Without such routes air units are tied down as garrisons within their commands. The full use of their mobility means a reduction in the total number of units that has to be maintained.

In connection with the development of such flights there are two main requirements:—

- (a) information regarding the average meteorological conditions over the areas within which future flights are likely to take place,
- (b) provision for weather reporting and forecasting facilities during the course of the flights and
- (c) the provision of meteorological facilities in certain parts of the Empire where Royal Air Force units are stationed.

With regard to (a) the information required is similar to that outlined in section I, sub-section 2 of this memorandum. Information regarding wind currents at different levels is of considerable importance, since in particular cases a following wind may be essential in order to enable aircraft of certain types to reach their destinations. There is, at the present time, a definite tendency towards an increase in the development and utility of flying boat squadrons, and in addition to the overland air routes, maritime routes have to be developed to meet the requirements of this arm of the Service. Information regarding the meteorological conditions over sea areas must be added, thus, to the data required.

It may be stated therefore, that air service requirements necessitate a comprehensive survey of the meteorological conditions from the point of view of aviation not only over the various parts of the Empire but also over the adjacent seas.

With regard to (b), when service flights take place along existing air routes, there is no difficulty with regard to the supply of reports and forecasts. Along other routes, however, special arrangements may have to be made. The organization required includes the supply of route weather reports and forecasts at each port of call for the next stage of the flight and additional reports by wireless to the aircraft when in flight. In connection with such flights accurate upper wind data are important.

With regard to (c), this question will be discussed by a sub-committee during the course of the Conference.

III.—Meteorological Arrangements for Long-Distance Non-Stop Flights.

In the course of the work of the Aviation Forecast Service at the Air Ministry, requests are sometimes made for forecasts for special flights up to distances of 1,000 miles. Such requests can be met with existing facilities, no special organization being necessary.

During the last few years, however, a somewhat larger problem has presented itself in connection with non-stop flights up to considerable distances. In order to supply adequate meteorological information for such flights special arrangements have been made. As further flights are contemplated, it is proposed to give a brief outline of the organization necessary, and an indication of the assistance which is required from other parts of the Empire.

The meteorological organization which is required may be summarized as follows:—

- (a) A study of the average meteorological conditions over the route to be flown in order to select the best month or months for the flight.
- (b) An examination, as far as possible, of the day to day conditions along the route in order to ascertain the average number of days or periods of days in each of the months selected during which the desired conditions hold.
- (c) Arrangements with the appropriate meteorological services for the supply of weather reports and forecasts for the different sections of the route. The co-ordination of these reports and supply of the necessary information to the Air Staff and pilots.

With regard to (a) and (b), the fullest possible meteorological information is necessary. A flight of this kind is normally carried out by the shortest, i.e., the great circle, route and conditions of the flight are such that only slight deviations from the route can be allowed. With a heavily loaded aircraft and a flight lasting for two days or more it is essential that the pilot should not have to encounter unduly adverse weather. In this connection information regarding the period of the day when the best weather conditions would be experienced along the different sections of the route would be useful. A following wind along the greater part of the route is usually essential to the complete success of the flight. For this reason full information regarding the winds at different heights along the route is necessary.

With regard to (c), suggestions are being put forward in the memorandum on Meteorology and Airship (Appendix II) for the delimitation of areas in which the various Empire meteorological services will make themselves responsible for giving information to airships. In drawing up these proposals the requirements of long distance aeroplane flights have been considered. In fact, these provisional arrangements have been used already on the occasions of certain long distance flights. In the case of the Royal Air Force non-stop flight from England to India in April of this year, reports and forecasts were received in London by wireless twice daily from the Meteorological Section Heliopolis, for the section Constantinople to Bushire, and from the India Meteorological Department for the section Bushire to Karachi. The information from these services was based in each case on their latest weather charts and included a statement of the weather conditions and winds at different heights along the route and a forecast of the probable conditions as far ahead as possible. Actual observations from Iraq, the Persian Gulf, Baluchistan and Karachi were relayed by wireless from Egypt and it was thus possible to prepare complete synoptic

charts for the route at the Air Ministry. This was exceedingly useful as it enabled the forecaster to interpret the forecasts received from Egypt and India. From a consideration of all the data received, a consolidated statement of the conditions along the entire route was prepared and a forecast for the flight issued to the pilots.

The working chart used for the study of meteorological conditions in relation to flights of this kind covers the area from North America in the west to Japan and India in the east, and to central Africa in the south. This chart is prepared twice daily, as a matter of routine, by the Aviation Forecast Service for the study of day-to-day changes over a wide area and for forecasts of the general tendency for some days ahead.

Information on somewhat similar lines to those described has been supplied occasionally during the last few years for civilian non-stop flights between Europe and North America. In such cases longitude 40° W. forms the boundary between the forecast areas, and agreement has been reached with the Canadian Meteorological Service and the United States Weather Bureau regarding the provisional organization to be brought into operation on the occasions of such flights.

MONTHLY FREQUENCY TABLES

being

Summaries of Observations of Horizontal Visibility, Height of Base of Low Cloud and Speed and Direction of Surface and Upper Winds in the form approved by the International Commission for Air Navigation.

No. 3.—March, 1930.

Tables 1 to 3: Frequency of Observations of Horizontal Visibility at 0700 h., 1300 h. and 1800 h. G.M.T.

TABLE 1.—Observations of Visibility at 0700 h. G.M.T.

| Station. | Latitude. | Longitude. | Height. Metres. | Number of Observations Between the Following Limits. | | | | | | | | | |
|-------------------|---------------------|--------------------|--------------------|--|----------------|-----------------|------------------|-------------------|-------------------|--------------------|---------------------|---------------------|--------------------|
| | | | | Less than 50m. | 50 to 200m. | 200 to 500m. | 500 to 1000m. | 1000 to 2000m. | 2000 to 4000m. | 4000 to 10000m. | 10000 to 20000m. | 20000 to 50000m. | More than 50km. |
| Aberdeen .. | N. $57^{\circ} 10'$ | $2^{\circ} 6' W$ | 14 | — | — | 1 | — | 1 | 2 | 7 | 10 | 10 | — |
| Renfrew .. | $55^{\circ} 52'$ | $4^{\circ} 24' W$ | 11 | 1 | — | 2 | — | 2 | 4 | 12 | 4 | 3 | 1 |
| Leuchars .. | $56^{\circ} 23'$ | $2^{\circ} 53' W$ | 12 | — | — | — | 1 | 2 | 2 | 7 | 8 | 7 | 4 |
| Eskdalemuir .. | $55^{\circ} 19'$ | $3^{\circ} 12' W$ | 237 | — | 3 | — | — | 1 | 7 | 3 | 8 | 9 | — |
| Holyhead .. | $53^{\circ} 18'$ | $4^{\circ} 37' W$ | 8 | — | — | 2 | — | 2 | 2 | 12 | 3 | 10 | — |
| Aldergrove .. | $54^{\circ} 39'$ | $6^{\circ} 13' W$ | 73 | — | 1 | — | 1 | — | 3 | 6 | 6 | 14 | — |
| Sealand .. | $53^{\circ} 13'$ | $3^{\circ} 0' W$ | 5 | 1 | — | 1 | 3 | 2 | 7 | 6 | 5 | 6 | — |
| Cranwell .. | $53^{\circ} 1'$ | $0^{\circ} 30' W$ | 72 | — | — | 1 | 4 | 2 | 8 | 7 | 8 | 1 | — |
| Valentia .. | $51^{\circ} 56'$ | $10^{\circ} 15' W$ | 9 | — | — | 2 | — | — | 1 | 2 | 6 | 17 | 3 |
| Worthy Down .. | $51^{\circ} 7'$ | $1^{\circ} 19' W$ | 83 | — | 2 | — | 1 | 2 | 2 | 7 | 10 | 7 | — |
| S. Farnborough .. | $51^{\circ} 17'$ | $0^{\circ} 45' W$ | 70 | — | 1 | — | 2 | 3 | 8 | 4 | 7 | 5 | 1 |
| Croydon .. | $51^{\circ} 21'$ | $0^{\circ} 7' W$ | 74 | — | — | — | 1 | 4 | 9 | 10 | 6 | 1 | — |
| Shoeburyness .. | $51^{\circ} 32'$ | $0^{\circ} 47' E$ | 3 | — | — | — | 1 | 3 | 5 | 4 | 11 | 7 | — |
| Felixstowe .. | $51^{\circ} 57'$ | $1^{\circ} 20' E$ | 5 | — | 2 | — | — | 4 | 7 | 6 | 6 | 6 | — |
| Biggin Hill .. | $51^{\circ} 19'$ | $0^{\circ} 2' E$ | 183 | 1 | 1 | 3 | 3 | 3 | 1 | 8 | 10 | 1 | — |
| Lympne .. | $51^{\circ} 5'$ | $1^{\circ} 1' E$ | 107 | — | 3 | 2 | 1 | 6 | 6 | 7 | 5 | 1 | — |
| Mount Batten .. | $50^{\circ} 22'$ | $4^{\circ} 8' W$ | 25 | — | — | — | — | 3 | — | 6 | 12 | 7 | 3 |
| Calshot .. | $50^{\circ} 49'$ | $1^{\circ} 18' W$ | 2 | — | — | 2 | — | — | 3 | 13 | 7 | 6 | — |
| Upper Heyford .. | $51^{\circ} 56'$ | $1^{\circ} 15' W$ | 123 | — | 3 | — | — | 6 | 4 | 8 | 2 | 8 | — |
| Lerwick .. | $60^{\circ} 9'$ | $1^{\circ} 8' W$ | 17 | — | — | — | — | — | 1 | 4 | 17 | 9 | — |
| Stornoway .. | $58^{\circ} 11'$ | $6^{\circ} 22' W$ | 9 | — | 1 | — | 1 | 2 | 3 | 5 | 18 | 1 | — |
| Scilly .. | $49^{\circ} 56'$ | $6^{\circ} 18' W$ | 39 | — | — | 1 | — | — | — | 6 | 11 | 13 | — |
| Tynemouth .. | $55^{\circ} 1'$ | $1^{\circ} 25' W$ | 21 | 1 | — | 1 | 2 | 2 | 2 | 9 | 13 | 1 | — |
| Pembroke .. | $51^{\circ} 41'$ | $5^{\circ} 10' W$ | 46 | — | 1 | — | — | — | 2 | 10 | 8 | 10 | — |
| Leafeld .. | $51^{\circ} 50'$ | $1^{\circ} 35' W$ | 187 | — | 2 | — | — | 6 | 1 | 4 | 5 | 8 | 3 |
| Cardington .. | $52^{\circ} 6'$ | $0^{\circ} 25' W$ | 30 | — | 1 | — | — | 4 | 5 | 14 | 3 | 4 | — |
| Manston .. | $51^{\circ} 21'$ | $1^{\circ} 21' E$ | 43 | — | 1 | 1 | 1 | 1 | 4 | 8 | 6 | 9 | — |

Meteorological Office, London.

8th May, 1930.

MONTHLY FREQUENCY TABLES: MARCH, 1930.

TABLE 2.—Observations of Visibility at 1300 h. G.M.T.

| Station. | Latitude. | Longitude. | Height. Metres. | Number of Observations Between the Following Limits. | | | | | | | | | | More than 5000m. |
|-------------------|-----------|------------|--------------------|--|----------------|-----------------|------------------|-------------------|-------------------|--------------------|---------------------|---------------------|---|---------------------|
| | | | | Less than 50m. | 50 to 200m. | 200 to 500m. | 500 to 1000m. | 1000 to 2000m. | 2000 to 4000m. | 4000 to 10000m. | 10000 to 20000m. | 20000 to 50000m. | | |
| | N. | | | | | | | | | | | | | |
| Aberdeen | 57° 10' | 2° 6' W | 14 | — | — | — | — | 3 | 1 | 7 | 5 | 15 | — | |
| Renfrew | 55° 52' | 4° 24' W | 11 | — | 1 | — | 2 | 1 | 4 | 6 | 7 | 10 | — | |
| Leuchars | 56° 23' | 2° 53' W | 12 | — | — | — | — | 1 | 1 | 6 | 4 | 12 | — | |
| Eskdalemuir .. | 55° 19' | 3° 12' W | 237 | — | — | — | — | — | 2 | 11 | 7 | 11 | — | |
| Holyhead | 53° 18' | 4° 37' W | 8 | — | — | — | — | 1 | 1 | 10 | 6 | 11 | — | |
| Aldergrove | 54° 39' | 6° 13' W | 73 | — | — | — | — | — | 4 | 5 | 5 | 14 | — | |
| Sealand | 53° 13' | 3° 0' W | 5 | — | — | — | — | — | 4 | 7 | 5 | 14 | — | |
| Cranwell | 53° 1' | 0° 30' W | 72 | — | — | — | 1 | 3 | 1 | 2 | 13 | 6 | 8 | |
| Valentia | 51° 56' | 10° 15' W | 9 | — | — | — | 1 | 1 | — | 4 | 4 | 15 | — | |
| Worthy Down .. | 51° 7' | 1° 19' W | 83 | — | — | — | — | 1 | 1 | 7 | 9 | 13 | — | |
| S. Farnborough .. | 51° 17' | 0° 45' W | 70 | — | — | — | — | 1 | 1 | 7 | 8 | 14 | — | |
| Croydon | 51° 21' | 0° 7' W | 74 | — | — | — | 1 | 2 | 6 | 16 | 6 | — | — | |
| Shoeburyness .. | 51° 32' | 0° 47' E | 3 | — | — | — | — | 1 | 1 | 4 | 7 | 18 | — | |
| Felixstowe | 51° 57' | 1° 20' E | 5 | — | — | 1 | — | 1 | 6 | 5 | 5 | 11 | — | |
| Biggin Hill | 51° 19' | 0° 2' E | 183 | — | — | — | 1 | 1 | 3 | 10 | 14 | 2 | — | |
| Lympne | 51° 5' | 1° 1' E | 107 | — | 1 | — | 1 | 1 | 8 | 7 | 5 | 7 | — | |
| Mount Batten .. | 50° 22' | 4° 8' W | 25 | — | — | 1 | — | — | — | 5 | 7 | 12 | — | |
| Calshot | 50° 49' | 1° 18' W | 2 | — | — | — | — | 1 | 2 | 9 | 7 | 12 | — | |
| Upper Heyford .. | 51° 56' | 1° 15' W | 123 | — | — | — | — | 2 | 1 | 14 | 5 | 9 | — | |
| Lerwick | 60° 9' | 1° 8' W | 17 | — | — | — | — | — | — | 1 | 14 | 16 | — | |
| Stornoway | 58° 11' | 6° 22' W | 9 | — | — | — | — | — | 1 | 9 | 12 | 9 | — | |
| Scilly | 49° 56' | 6° 18' W | 39 | — | — | — | — | 1 | — | 4 | 16 | 9 | — | |
| Tynemouth | 55° 1' | 1° 25' W | 21 | — | — | — | — | — | 1 | 11 | 14 | 5 | — | |
| Pembroke | 51° 41' | 5° 10' W | 46 | 1 | — | — | — | 3 | — | 8 | 8 | 11 | — | |
| Leafield | 51° 50' | 1° 35' W | 187 | — | — | — | — | — | 2 | 7 | 9 | 9 | — | |
| Cardington | 52° 6' | 0° 25' W | 30 | — | — | — | — | — | 1 | 13 | 9 | 8 | — | |
| Manston | 51° 21' | 1° 21' E | 43 | — | — | 1 | — | — | 2 | 9 | 5 | 14 | — | |

TABLE 3.—Observations of Visibility at 1800 h. G.M.T.

| Station. | Latitude. | Longitude. | Height. Metres. | Number of Observations Between the Following Limits. | | | | | | | | | | More than 50000m. |
|-------------------|-----------|------------|--------------------|--|----------------|-----------------|------------------|-------------------|-------------------|--------------------|---------------------|---------------------|---|----------------------|
| | | | | Less than 50m. | 50 to 200m. | 200 to 500m. | 500 to 1000m. | 1000 to 2000m. | 2000 to 4000m. | 4000 to 10000m. | 10000 to 20000m. | 20000 to 50000m. | | |
| | N. | | | | | | | | | | | | | |
| Aberdeen | 57° 10' | 2° 6' W | 14 | — | 1 | — | — | — | 4 | 7 | 9 | 10 | — | — |
| Renfrew | 55° 52' | 4° 24' W | 11 | — | — | 1 | 3 | 2 | 6 | 6 | 7 | 5 | — | — |
| Leuchars | 56° 23' | 2° 53' W | 12 | — | 1 | — | — | 1 | 1 | 5 | 6 | 13 | — | — |
| Eskdalemuir .. | 55° 19' | 3° 12' W | 237 | — | — | — | — | 1 | 5 | 6 | 3 | 15 | — | — |
| Holyhead | 53° 18' | 4° 37' W | 8 | — | — | — | — | 1 | 3 | 11 | 7 | 9 | — | — |
| Aldergrove | 54° 39' | 6° 13' W | 73 | — | — | — | — | — | 3 | 8 | 5 | 12 | — | — |
| Sealand | 53° 13' | 3° 0' W | 5 | — | — | — | 1 | 4 | 4 | 8 | 11 | 3 | — | — |
| Cranwell | 53° 1' | 0° 30' W | 72 | — | — | 1 | 2 | 1 | — | 18 | 3 | 6 | — | — |
| Valentia | 51° 56' | 10° 15' W | 9 | — | — | — | 1 | — | 1 | 3 | 7 | 15 | — | — |
| Worthy Down .. | 51° 7' | 1° 19' W | 83 | — | — | — | — | 1 | 3 | 3 | 15 | 9 | — | — |
| S. Farnborough .. | 51° 17' | 0° 45' W | 70 | — | — | — | — | 1 | 3 | 13 | 7 | 7 | — | — |
| Croydon | 51° 21' | 0° 7' W | 74 | — | — | — | 1 | 3 | 15 | 11 | 1 | — | — | — |
| Shoeburyness .. | 51° 32' | 0° 47' E | 3 | — | — | — | — | 2 | 2 | 5 | 8 | 14 | — | — |
| Felixstowe | 51° 57' | 1° 20' E | 5 | — | — | — | — | 3 | 5 | 5 | 6 | 12 | — | — |
| Biggin Hill | 51° 19' | 0° 2' E | 183 | — | — | — | 1 | 1 | 1 | 16 | 9 | 3 | — | — |
| Lympne | 51° 5' | 1° 1' E | 107 | — | 1 | — | 1 | 1 | 9 | 11 | 5 | 3 | — | — |
| Mount Batten .. | 50° 22' | 4° 8' W | 25 | — | — | — | — | 1 | 1 | 6 | 9 | 9 | — | — |
| Calshot | 50° 49' | 1° 18' W | 2 | — | — | 1 | — | 1 | 2 | 11 | 6 | 10 | — | — |
| Upper Heyford .. | 51° 56' | 1° 15' W | 123 | — | — | — | — | — | 2 | 13 | 6 | 10 | — | — |
| Lerwick | 60° 9' | 1° 8' W | 17 | — | — | — | — | 1 | — | 4 | 11 | 15 | — | — |
| Stornoway | 58° 11' | 6° 22' W | 9 | — | 1 | — | — | 1 | 4 | 7 | 15 | 3 | — | — |
| Scilly | 49° 56' | 6° 18' W | 39 | — | — | — | — | — | — | 4 | 15 | 12 | — | — |
| Tynemouth | 55° 1' | 1° 25' W | 21 | — | — | — | — | — | — | 4 | 15 | 12 | — | — |
| Pembroke | 51° 41' | 5° 10' W | 46 | — | 1 | — | — | 1 | 1 | 11 | 13 | 5 | — | — |
| Leafeld | 51° 50' | 1° 35' W | 187 | — | — | — | — | — | 1 | 7 | 11 | 10 | — | — |
| Cardington | 52° 6' | 0° 25' W | 30 | — | — | — | — | — | 1 | 7 | 6 | 13 | — | — |
| Manston | 51° 21' | 1° 21' E | 43 | — | — | — | — | — | 1 | 17 | 9 | 4 | — | — |
| | | | | | | | | | 5 | 7 | 11 | 8 | | |

MONTHLY FREQUENCY TABLES: MARCH, 1930.

Tables 4 to 6: Frequency of Observations of Height of Base of Low Cloud above Ground Level at 0700 h., 1300 h. and 1800 h. G.M.T.

TABLE 4.—Observations of Height of Low Cloud at 0700 h. G.M.T.

| Station. | Latitude. | Longitude. | Height. Metres. | Number of Observations Between the Following Limits. | | | | | | | | | | No low cloud. |
|-------------------|-----------|------------|--------------------|--|----------------|-----------------|-----------------|-----------------|------------------|-------------------|-------------------|-------------------|----|------------------|
| | | | | Less than 50m. | 50 to 100m. | 100 to 200m. | 200 to 300m. | 300 to 600m. | 600 to 1000m. | 1000 to 1500m. | 1500 to 2000m. | 2000 to 2500m. | | |
| Aberdeen | N. | | | | | | | | | | | | | |
| Renfrew | 57° 10' | 2° 6' W | 14 | 1 | — | 1 | — | 10 | 12 | 3 | 1 | — | 3 | |
| Leuchars | 55° 52' | 4° 24' W | 11 | 1 | — | 4 | 2 | 9 | 6 | 2 | 1 | — | 6 | |
| Eskdalemuir .. | 56° 23' | 2° 53' W | 12 | 1 | — | — | 4 | 5 | 6 | 9 | — | — | 6 | |
| Holyhead | 55° 19' | 3° 12' W | 237 | 4 | 5 | — | 2 | 10 | 4 | 2 | — | — | 4 | |
| | 53° 18' | 4° 37' W | 8 | 2 | — | 2 | 4 | 6 | 9 | 3 | 2 | — | 3 | |
| Aldergrove .. | 54° 39' | 6° 13' W | 73 | 1 | — | 1 | 7 | 8 | 7 | 4 | — | — | 3 | |
| Sealand | 53° 13' | 3° 0' W | 5 | 1 | — | — | 5 | 7 | 9 | 4 | 4 | — | 1 | |
| Cranwell | 53° 1' | 0° 30' W | 72 | — | 5 | 3 | 3 | 2 | 2 | 6 | 3 | 1 | 6 | |
| Valentia | 51° 56' | 10° 15' W | 9 | — | 3 | 1 | 3 | 13 | 9 | 1 | — | — | 1 | |
| Worthy Down .. | 51° 7' | 1° 19' W | 83 | 2 | 1 | 2 | 3 | 3 | 5 | 4 | 4 | — | 7 | |
| S. Farnborough .. | 51° 17' | 0° 45' W | 70 | 1 | — | 2 | 4 | 6 | 1 | 4 | 5 | — | 8 | |
| Kew | 51° 28' | 0° 19' W | 5 | 1 | — | — | — | 7 | 9 | 5 | 1 | — | 8 | |
| Croydon | 51° 21' | 0° 7' W | 74 | — | — | 4 | 7 | 4 | 3 | — | 2 | — | 11 | |
| Shoeburyness .. | 51° 32' | 0° 47' E | 3 | — | — | 3 | 4 | 8 | 2 | 1 | 3 | — | 10 | |
| Felixstowe | 51° 21' | 1° 20' E | 5 | 2 | — | 4 | 3 | 3 | 3 | 5 | — | — | 11 | |
| Biggin Hill .. | 51° 19' | 0° 2' E | 183 | 10 | — | 2 | 1 | 3 | 2 | 1 | — | — | 12 | |
| Lympne | 51° 5' | 1° 1' E | 107 | 6 | — | 1 | 4 | 3 | 1 | 4 | 1 | 1 | 10 | |
| Mount Batten .. | 50° 22' | 4° 8' W | 25 | 3 | 1 | — | 3 | 11 | 4 | 6 | — | — | 3 | |
| Calshot | 50° 49' | 1° 18' W | 2 | 2 | — | — | 2 | 5 | 8 | 5 | 2 | — | 7 | |
| Upper Heyford .. | 51° 56' | 1° 15' W | 123 | 3 | 1 | 6 | 2 | — | 4 | 5 | — | 1 | 9 | |
| Cardington .. | 52° 6' | 0° 25' W | 30 | 1 | 1 | 1 | 7 | 5 | 2 | 3 | 2 | — | 9 | |
| Manston | 51° 21' | 1° 21' E | 43 | 3 | 1 | — | 5 | 4 | 2 | 3 | 2 | — | 11 | |

TABLE 5.—Observations of Height of Low Cloud at 1300 h. G.M.T.

| Station. | Latitude. | Longitude. | Height. Metres. | Number of Observations Between the Following Limits. | | | | | | | | | |
|-------------------|---------------|------------|--------------------|--|----------------|-----------------|-----------------|-----------------|------------------|-------------------|-------------------|-------------------|------------------|
| | | | | Less than 50m. | 50 to 100m. | 100 to 200m. | 200 to 300m. | 300 to 600m. | 600 to 1000m. | 1000 to 1500m. | 1500 to 2000m. | 2000 to 2500m. | No low cloud. |
| Aberdeen | N. 57° 10' | 2° 6' W | 14 | 1 | — | — | — | 7 | 12 | 7 | 1 | — | 3 |
| Renfrew | 55° 52' | 4° 24' W | 11 | — | — | — | 3 | 10 | 9 | 5 | — | 1 | 3 |
| Leuchars | 56° 23' | 2° 53' W | 12 | — | — | 1 | 2 | 3 | 9 | 9 | 1 | — | 6 |
| Eskdalemuir .. | 55° 19' | 3° 12' W | 237 | — | — | 2 | 6 | 8 | 9 | 5 | — | — | 1 |
| Holyhead | 53° 18' | 4° 37' W | 8 | — | — | 2 | 1 | 8 | 14 | 2 | — | — | 4 |
| Aldergrove | 54° 39' | 6° 13' W | 73 | — | — | 1 | 5 | 7 | 8 | 8 | 1 | — | 1 |
| Sealand | 53° 13' | 3° 0' W | 5 | — | — | 1 | 3 | 6 | 12 | 6 | — | — | 3 |
| Cranwell | 53° 1' | 0° 30' W | 72 | — | — | 1 | 3 | 4 | 10 | 11 | — | — | 2 |
| Valentia | 51° 56' | 10° 15' W | 9 | — | 2 | 1 | 5 | 11 | 8 | 2 | — | — | 2 |
| Worthy Down .. | 51° 7' | 1° 19' W | 83 | — | 1 | 1 | 1 | 6 | 8 | 9 | 2 | — | 3 |
| S. Farnborough .. | 51° 17' | 0° 45' W | 70 | — | — | — | 4 | 5 | 5 | 11 | 1 | 2 | 3 |
| Kew | 51° 28' | 0° 19' W | 5 | — | — | — | — | 4 | 7 | 10 | 2 | — | 8 |
| Croydon | 51° 21' | 0° 7' W | 74 | — | — | 2 | 2 | 6 | 9 | 6 | 1 | — | 5 |
| Shoeburyness .. | 51° 32' | 0° 47' E | 3 | — | — | 1 | 1 | 5 | 3 | 9 | 2 | — | 10 |
| Felixstowe | 51° 21' | 1° 20' E | 5 | 1 | — | 1 | 2 | 2 | 6 | 11 | — | — | 8 |
| Biggin Hill | 51° 19' | 0° 2' E | 183 | 1 | 1 | — | 1 | 8 | 7 | 4 | 1 | 1 | 7 |
| Lympne | 51° 5' | 1° 1' E | 107 | 2 | — | 3 | 2 | 5 | 5 | 4 | 4 | — | 6 |
| Mount Batten .. | 50° 22' | 4° 8' W | 25 | 1 | 1 | 1 | 1 | 8 | 10 | 5 | — | — | 4 |
| Calshot | 50° 49' | 1° 18' W | 2 | — | — | — | 4 | 5 | 9 | 8 | 2 | — | 3 |
| Upper Heyford .. | 51° 56' | 1° 15' W | 123 | — | — | 1 | 5 | 9 | 7 | 7 | — | — | 2 |
| Cardington | 52° 6' | 0° 25' W | 30 | — | — | — | 3 | 4 | 6 | 12 | 2 | — | 4 |
| Manston | 51° 21' | 1° 21' E | 43 | — | — | 3 | 2 | 4 | 5 | 5 | 4 | — | 8 |

MONTHLY FREQUENCY TABLES: MARCH, 1930.

TABLE 6.—Observations of Height of Low Cloud at 1800 h. G.M.T.

| Station. | Latitude. | Longitude. | Height. Metres. | Number of Observations Between the Following Limits. | | | | | | | | | | No. below 2500m. |
|-------------------|------------|------------|--------------------|--|----------------|-----------------|-----------------|-----------------|------------------|-------------------|-------------------|-------------------|----|---------------------|
| | | | | Less than 50m. | 50 to 100m. | 100 to 200m. | 200 to 300m. | 300 to 600m. | 600 to 1000m. | 1000 to 1500m. | 1500 to 2000m. | 2000 to 2500m. | | |
| Aberdeen | N. 57° 10' | 2° 6' W | 14 | 1 | — | 1 | 1 | 5 | 13 | 5 | 2 | — | 3 | |
| Renfrew | 55° 52' | 4° 24' W | 11 | — | — | 1 | 2 | 3 | 11 | 6 | 1 | — | 3 | |
| Leuchars | 56° 23' | 2° 53' W | 12 | 1 | — | 1 | 2 | 2 | 8 | 12 | 4 | — | 1 | |
| Eskdalemuir .. | 55° 19' | 3° 12' W | 237 | — | 4 | 2 | 1 | 3 | 10 | 3 | — | — | 4 | |
| Holyhead | 53° 18' | 4° 37' W | 8 | — | 1 | 1 | 1 | 5 | 6 | 12 | 1 | 1 | 3 | |
| Aldergrove .. . | 54° 39' | 6° 13' W | 73 | — | — | — | 1 | 9 | 8 | 7 | 2 | — | 4 | |
| Sealand | 53° 13' | 3° 0' W | 5 | — | — | — | 3 | 3 | 10 | 5 | 3 | 1 | 2 | |
| Cranwell | 53° 1' | 0° 30' W | 72 | — | — | 2 | 3 | 1 | 7 | 9 | 2 | 1 | 6 | |
| Valentia | 51° 56' | 10° 15' W | 9 | 1 | — | 1 | 2 | 8 | 10 | 2 | — | 1 | 1 | |
| Worthy Down .. | 51° 7' | 1° 19' W | 83 | — | 1 | — | 2 | 2 | 7 | 11 | 4 | — | 4 | |
| S. Farnborough .. | 51° 17' | 0° 45' W | 70 | — | — | 1 | 1 | 4 | 4 | 8 | 3 | 4 | 6 | |
| Kew | 51° 28' | 0° 19' W | 5 | — | — | — | 1 | 3 | 6 | 2 | 2 | — | 12 | |
| Croydon | 51° 21' | 0° 7' W | 74 | — | — | — | 1 | 6 | 9 | 5 | 2 | 1 | 7 | |
| Shoeburyness .. | 51° 32' | 0° 47' E | 3 | — | — | — | 4 | 8 | 5 | 8 | 1 | — | 5 | |
| Felixstowe .. . | 51° 21' | 1° 20' E | 5 | — | — | — | 2 | 3 | 4 | 12 | 2 | 1 | 7 | |
| Biggin Hill .. . | 51° 19' | 0° 2' E | 183 | 1 | 1 | — | 1 | 8 | 4 | 4 | — | — | 12 | |
| Lympe | 51° 5' | 1° 1' E | 107 | 2 | — | 1 | — | 4 | 2 | 6 | 6 | 1 | 9 | |
| Mount Batten .. | 50° 22' | 4° 8' W | 25 | 2 | — | 1 | 1 | 9 | 10 | 4 | — | — | 4 | |
| Calshot | 50° 49' | 1° 18' W | 2 | 1 | — | 1 | 1 | 6 | 7 | 9 | — | — | 4 | |
| Upper Heyford .. | 51° 56' | 1° 15' W | 123 | — | — | 1 | 3 | 13 | 3 | 6 | 1 | — | 4 | |
| Cardington .. . | 52° 6' | 0° 25' W | 30 | — | — | — | 2 | 6 | 3 | 7 | 4 | 3 | 6 | |
| Manston | 51° 21' | 1° 21' E | 43 | — | — | — | 3 | 4 | 4 | 2 | 5 | — | 13 | |

Tables 7 to 11: Frequency of Observations at or near 1200 h. G.M.T. of Winds at the Surface and at 500, 1000, 2000 and 3000 metres above Mean Sea Level.

TABLE 7.—Observations of Wind at the Surface.

| Station. | Latitude. | Longitude. | Height. Metres. | Speed limits K/hr. | Number of Observations. | | | | | | | | Skm. per hour or less. |
|---------------|------------|------------|--------------------|--------------------------------|-------------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------------------|
| | | | | | N. | N.E. | E. | S.E. | S. | S.W. | W. | N.W. | |
| Croydon .. | N. 51° 21' | 0° 7' W | 74 | 6-25 26-50 51-75 > 75 | 1 — — — | — 1 — — | 2 1 — — | 3 — — — | 3 1 — — | 2 3 — — | 7 1 — — | 2 — — — | 3 |
| Felixstowe .. | 51° 21' | 1° 20' E | 5 | 6-25 26-50 51-75 > 75 | 1 — — — | — 2 — — | 1 1 — — | — 1 — — | 5 — — — | — 1 — — | 6 1 — — | 5 — — — | 6 |
| Calshot .. | 50° 49' | 1° 18' W | 2 | 6-25 26-50 51-75 > 75 | 2 1 — — | — — — — | — 1 — — | 1 2 — — | — 2 — — | 5 3 — — | 1 1 — — | 2 1 — — | 2 |
| Cranwell .. | 53° 1' | 0° 30' W | 72 | 6-25 26-50 51-75 > 75 | — — — — | 2 1 — — | 1 — — — | — 2 — — | 1 1 — — | 3 3 — — | 3 4 — — | 1 — — — | 1 |
| Sealand .. | 53° 13' | 3° 0' W | 5 | 6-25 26-50 51-75 > 75 | 1 — — — | 1 — — — | 3 — — — | 2 2 — — | 1 1 — — | 4 2 — — | 3 1 — — | 4 2 — — | 1 |
| Aldergrove .. | 54° 39' | 6° 13' W | 73 | 6-25 26-50 51-75 > 75 | 2 — — — | 2 — — — | 1 1 — — | 2 — — — | 2 1 — — | 3 — — — | 4 1 — — | 3 — — — | 5 |
| Leuchars .. | 56° 23' | 2° 53' W | 12 | 6-25 26-50 51-75 > 75 | 1 — — — | 2 — — — | 4 — — — | 4 — — — | — — — — | 5 2 — — | 3 3 — — | 4 — — — | — |

MONTHLY FREQUENCY TABLES: MARCH, 1930.

TABLE 8.—Observations of Wind at 500 metres above Mean Sea Level.

| Station. | Latitude. | Longitude. | Height. Metres. | Speed limit K/hr. | Number of Observations. | | | | | | | | 5km. per hour or less. |
|------------------|---------------|------------|--------------------|---|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|
| | | | | | N. | N.E. | E. | S.E. | S. | S.W. | W. | N.W. | |
| Croydon | N. 51° 21' | 0° 7' W | 74 | <div>6-25 26-50 51-75 > 75</div> | <div>1 2 — —</div> | <div>— — — —</div> | <div>— 2 — —</div> | <div>1 1 — —</div> | <div>— 3 1 —</div> | <div>4 3 — —</div> | <div>3 2 1 —</div> | <div>2 1 — —</div> | <div>— — — —</div> |
| Felixstowe | 51° 21' | 1° 20' E | 5 | <div>6-25 26-50 51-75 > 75</div> | <div>1 — — —</div> | <div>— 2 — —</div> | <div>2 1 — —</div> | <div>— 1 — —</div> | <div>— 1 — —</div> | <div>3 2 — —</div> | <div>4 3 — —</div> | <div>3 4 — —</div> | <div>— — — —</div> |
| Calshot | 50° 49' | 1° 18' W | 2 | <div>6-25 26-50 51-75 > 75</div> | <div>— 2 — —</div> | <div>— 1 — —</div> | <div>— 1 — —</div> | <div>1 — — —</div> | <div>— 2 1 —</div> | <div>2 3 1 —</div> | <div>3 — — —</div> | <div>3 3 — —</div> | <div>— — — —</div> |
| Cranwell | 53° 1' | 0° 30' W | 72 | <div>6-25 26-50 51-75 > 75</div> | <div>— — — —</div> | <div>— 1 — —</div> | <div>1 1 — —</div> | <div>— — — —</div> | <div>— 4 — —</div> | <div>2 2 1 —</div> | <div>2 6 1 —</div> | <div>— 1 — —</div> | <div>— — — —</div> |
| Sealand | 53° 13' | 3° 0' W | 5 | <div>6-25 26-50 51-75 > 75</div> | <div>— 1 — —</div> | <div>1 — — —</div> | <div>1 2 — —</div> | <div>— 2 — —</div> | <div>1 2 1 —</div> | <div>2 1 2 —</div> | <div>3 1 1 —</div> | <div>2 5 — —</div> | <div>— — — —</div> |
| Aldergrove | 54° 39' | 6° 13' W | 73 | <div>6-25 26-50 51-75 > 75</div> | <div>1 2 — —</div> | <div>— 1 — —</div> | <div>1 2 — —</div> | <div>1 1 — —</div> | <div>— 2 — —</div> | <div>1 1 — —</div> | <div>1 2 1 —</div> | <div>5 3 — —</div> | <div>1 — — —</div> |
| Leuchars | 56° 23' | 2° 53' W | 12 | <div>6-25 26-50 51-75 > 75</div> | <div>— 1 — —</div> | <div>1 2 — —</div> | <div>1 — — —</div> | <div>1 2 — —</div> | <div>1 1 — —</div> | <div>1 1 2 —</div> | <div>1 5 1 —</div> | <div>3 2 — —</div> | <div>1 — — —</div> |

TABLE 9.—Observations of Wind at 1000 metres above Mean Sea Level.

| Station. | Latitude. | Longitude. | Height. Metres. | Speed limit K/hr. | Number of Observations. | | | | | | | | | 5km. per hour or less. |
|------------------|---------------|------------|--------------------|----------------------|-------------------------|------|----|------|----|------|----|------|---|------------------------------|
| | | | | | N. | N.E. | E. | S.E. | S. | S.W. | W. | N.W. | | |
| Croydon | N. 51° 21' | 0° 7' W | 74 | 6-25 | 1 | — | — | — | 3 | — | 5 | — | 1 | |
| | | | | 26-50 | 1 | — | — | 1 | 2 | 3 | 1 | — | | |
| | | | | 51-75 | — | 1 | 1 | — | — | 1 | — | — | | |
| | | | | > 75 | — | — | — | — | — | — | — | — | | |
| Felixstowe | 51° 21' | 1° 20' E | 5 | 6-25 | — | 1 | — | 1 | 1 | 4 | 2 | — | | |
| | | | | 26-50 | 1 | 1 | — | — | 1 | 4 | 4 | — | | |
| | | | | 51-75 | 1 | — | 2 | — | 1 | — | — | — | | |
| | | | | > 75 | — | — | — | — | — | — | — | — | | |
| Calshot | 50° 49' | 1° 18' W | 2 | 6-25 | 2 | — | — | — | 2 | 1 | 4 | 1 | — | |
| | | | | 26-50 | — | 1 | — | — | 1 | 2 | 4 | 3 | — | |
| | | | | 51-75 | — | — | — | — | 1 | — | — | — | — | |
| | | | | > 75 | — | — | — | — | — | — | — | — | — | |
| Cranwell | 53° 1' | 0° 30' W | 72 | 6-25 | — | — | 1 | — | — | 1 | 1 | 1 | — | |
| | | | | 26-50 | — | 1 | 1 | — | 1 | — | 6 | 2 | — | |
| | | | | 51-75 | — | — | — | 1 | 1 | 1 | — | — | — | |
| | | | | > 75 | — | — | — | — | — | 1 | — | — | — | |
| Sealand | 53° 13' | 3° 0' W | 5 | 6-25 | — | 1 | — | — | — | 1 | 3 | — | — | |
| | | | | 26-50 | 1 | — | — | 1 | — | 2 | 2 | 6 | — | |
| | | | | 51-75 | — | — | — | 1 | 3 | — | 1 | — | — | |
| | | | | > 75 | — | — | — | — | 1 | — | 2 | — | — | |
| Aldergrove | 54° 39' | 6° 13' W | 73 | 6-25 | — | — | 1 | — | — | — | 1 | 5 | — | |
| | | | | 26-50 | 2 | 1 | — | 2 | — | 3 | 3 | 1 | — | |
| | | | | 51-75 | — | — | — | — | — | 1 | — | — | — | |
| | | | | > 75 | — | — | — | — | — | — | 1 | — | — | |
| Leuchars | 56° 23' | 2° 53' W | 12 | 6-25 | 1 | — | 2 | 2 | — | 1 | 1 | 3 | — | |
| | | | | 26-50 | 1 | 1 | — | 1 | 1 | 1 | 1 | 3 | — | |
| | | | | 51-75 | — | — | — | — | — | 1 | 1 | 1 | — | |
| | | | | > 75 | — | — | — | — | — | 1 | — | — | — | |

MONTHLY FREQUENCY TABLES: MARCH, 1930.

TABLE 10.—Observations of Wind at 2000 metres above Mean Sea Level.

| Station. | Latitude. | Longitude. | Height. Metres. | Speed limits K/hr. | Number of Observations. | | | | | | | | Skns. per hour. |
|------------------|---------------|------------|--------------------|-----------------------|-------------------------|------|----|------|----|------|----|------|--------------------|
| | | | | | N. | N.E. | E. | S.E. | S. | S.W. | W. | N.W. | |
| Croydon | N. 51° 21' | 0° 7' W | 74 | 6-25 | — | — | — | — | — | 1 | 3 | 1 | |
| | | | | 26-50 | — | — | — | — | 2 | 1 | 1 | 1 | |
| | | | | 51-75 | — | — | — | — | — | 1 | — | — | |
| | | | | > 75 | — | — | — | — | — | — | — | — | |
| Felixstowe | 51° 21' | 1° 20' E | 5 | 6-25 | — | — | — | — | — | — | 1 | 2 | |
| | | | | 26-50 | 1 | — | — | — | — | 1 | 3 | 4 | |
| | | | | 51-75 | — | — | — | — | — | — | — | 1 | |
| | | | | > 75 | — | — | — | — | — | — | — | — | |
| Calshot | 50° 49' | 1° 18' W | 2 | 6-25 | — | — | — | — | — | 1 | 2 | 1 | |
| | | | | 26-50 | — | — | — | — | 1 | 1 | — | 4 | |
| | | | | 51-75 | — | — | — | — | — | — | — | — | |
| | | | | > 75 | — | — | — | — | — | — | — | — | |
| Cranwell | 53° 1' | 0° 30' W | 72 | 6-25 | — | — | — | — | — | — | — | — | |
| | | | | 26-50 | 1 | — | 1 | — | 1 | 1 | 3 | 2 | |
| | | | | 51-75 | — | — | — | — | — | — | — | — | |
| | | | | > 75 | — | — | — | — | — | — | — | — | |
| Sealand | 53° 13' | 3° 0' W | 5 | 6-25 | — | — | — | — | — | — | 1 | 1 | |
| | | | | 26-50 | — | — | — | — | — | 1 | 3 | 4 | |
| | | | | 51-75 | — | — | — | — | — | — | 1 | 2 | |
| | | | | > 75 | — | — | — | — | — | — | — | — | |
| Aldergrove | 54° 39' | 6° 13' W | 73 | 6-25 | 1 | — | — | — | — | — | — | 2 | |
| | | | | 26-50 | — | 1 | — | — | — | — | 2 | 2 | |
| | | | | 51-75 | 1 | — | — | — | — | 1 | — | 1 | |
| | | | | > 75 | — | — | — | — | — | 1 | — | — | |
| Leuchars | 56° 23' | 2° 53' W | 12 | 6-25 | 1 | — | 1 | — | — | — | — | 3 | |
| | | | | 26-50 | — | — | — | — | — | — | — | 2 | |
| | | | | 51-75 | — | — | — | — | — | — | — | 1 | |
| | | | | > 75 | — | — | — | — | — | — | — | — | |

TABLE 11.—Observations of Wind at 3000 metres above Mean Sea Level.

| Station. | Latitude. | Longitude. | Height. Metres. | Speed limit K/hr. | Number of Observations. | | | | | | | | Skns. per hour. |
|------------------|---------------|------------|--------------------|----------------------|-------------------------|------|----|------|----|------|----|------|--------------------|
| | | | | | N. | N.E. | E. | S.E. | S. | S.W. | W. | N.W. | |
| Croydon | N. 51° 21' | 0° 7' W | 74 | 6-25 | — | — | — | — | — | 1 | — | — | |
| | | | | 26-50 | — | — | — | — | — | — | — | — | |
| | | | | 51-75 | — | — | — | — | — | — | — | — | |
| | | | | > 75 | — | — | — | — | — | — | — | — | |
| Felixstowe | 51° 21' | 1° 20' E | 5 | 6-25 | 1 | — | — | — | — | — | — | — | |
| | | | | 26-50 | — | — | — | — | — | — | — | — | |
| | | | | 51-75 | — | — | — | — | — | — | — | — | |
| | | | | > 75 | — | — | — | — | — | — | — | — | |
| Calshot | 50° 49' | 1° 18' W | 2 | 6-25 | — | — | — | — | — | 2 | — | — | |
| | | | | 26-50 | — | — | — | — | — | — | — | 1 | |
| | | | | 51-75 | — | — | — | — | — | — | — | — | |
| | | | | > 75 | — | — | — | — | — | — | — | — | |
| Cranwell | 53° 1' | 0° 30' W | 72 | 6-25 | — | — | — | — | — | — | — | — | |
| | | | | 26-50 | 1 | — | — | — | — | — | — | 1 | |
| | | | | 51-75 | — | — | — | — | — | — | — | — | |
| | | | | > 75 | — | — | — | — | — | — | — | — | |
| Sealand | 53° 13' | 3° 0' W | 5 | 6-25 | — | — | — | — | — | — | 1 | — | |
| | | | | 26-50 | — | — | — | — | — | — | 2 | 1 | |
| | | | | 51-75 | — | — | — | — | — | — | — | 2 | |
| | | | | > 75 | — | — | — | — | — | — | 1 | 1 | |
| Aldergrove | 54° 39' | 6° 13' W | 73 | 6-25 | — | — | — | — | — | — | — | — | |
| | | | | 26-50 | 1 | — | 1 | — | — | — | — | 2 | |
| | | | | 51-75 | — | — | — | — | — | — | — | 1 | |
| | | | | > 75 | — | — | — | — | — | — | — | — | |
| Leuchars | 56° 23' | 2° 53' W | 12 | 6-25 | — | — | — | — | — | — | — | — | |
| | | | | 26-50 | — | — | — | — | — | — | — | — | |
| | | | | 51-75 | — | — | — | — | — | — | — | 1 | |
| | | | | > 75 | — | — | — | — | — | — | — | — | |

London, 1929.

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C.E.M. 9/1929.

APPENDIX II.—MEMORANDUM ON METEOROLOGY AND AIRSHIPS IN THE BRITISH EMPIRE.

By M. A. GIBLETT,
Superintendent, Airship Services Division, Meteorological Office.

CONTENTS.

- I. Introductory.
- II. Meteorological Investigations in Connection with Airships.
- III. Meteorological Reporting and Forecasting Organization for Airships.
- IV. Standardisation of Methods.
- V. Collection of Information and Statistics as to Routes and Bases.
- VI. General.

I. Introductory.—I. Special meteorological work in connection with the present Airship Development Scheme commenced early in 1925, i.e., shortly after the commencement of the Airship Scheme, with the creation of a new division of the Meteorological Office, Air Ministry, now known as the Airship Services Division, to deal with the investigational work arising out of the Scheme and, initially, with the planning of the necessary reporting and forecasting organization required for a route from England to India via Egypt. The Division works in close liaison with the Directorate of Airship Development, Air Ministry, which is located at the Royal Airship Works, Cardington.

2. The discussion of Empire airship routes at the Imperial Conference in the autumn of 1926 led to the extension of the scope of the work of the Division, and, in preparation for the Conference, memoranda were prepared on a preliminary survey of main Imperial airship routes and on the meteorological investigational work and the reporting and forecasting services necessary in connection with airship operations in general. These were published in "The Approach towards a system of Imperial Air Communications. Memorandum by the Secretary of State for Air," (H.M. Stationery Office, 1926), which also contained examples of the work done on the England-Egypt-India route. An accompanying chart (Fig. 1) shows the areas in which, according to the preliminary survey mentioned above, main Imperial airship routes will probably develop. (It has been very slightly amended since the first survey). The chief considerations on which it is based are given in Appendix E.11 of "The Approach towards a System of Imperial Air Communications." At the same time, reports were drawn up on meteorological conditions at a selection of places throughout the British Empire which might conceivably become airship bases in the future so far as these routes are concerned. These reports were based on such information as was available at the time in the Meteorological Office, London.

3. In 1927, following on the Conference, Airship Missions from the British Government visited the Dominions and certain other parts of the British Empire and selected sites suitable for airship bases. The reports on meteorological conditions, drawn up before the departure of the Missions, were supplemented as necessary during the visits from local resources and formed an important factor in this choice of prospective bases. The opportunity was also taken of acquainting the Governments concerned, in rather more detail than had been possible at the Imperial Conference, of the meteorological requirements if a system of Imperial airship routes were to be developed.

4. It is not proposed, in the present memorandum, to repeat all the details contained in the reports of the Airship Missions to the respective Governments, but rather to supplement them where necessary, while dealing as far as possible with general questions.

5. The present position as regards airship development is that the two new airships (5,000,000 cu. ft. capacity), are now being inflated, R. 101 at Cardington, Beds., and R. 100 at Howden, Yorks., and home trials are due to begin at the end of September. Airship operational bases exist as follows:—

| | | | |
|---------------|--|----|---|
| England | Cardington (Operational and Constructional). | .. | Two sheds. One mooring tower. |
| Egypt | Ismailia | .. | One mooring tower. |
| India | Karachi | .. | One shed. One mooring tower. (Mooring tower provided by Government of India.) |
| Canada | Montreal | .. | One mooring tower. (Base and tower provided by Canadian Government.) |

The present authorised programme of airship development provides for the home trials of the two airships and a flight to India. Home trials are expected to be completed by the end of the year, and arrangements are being made for a flight to India by R. 101 early in 1930, and a flight to Canada by R. 100 in the spring of 1930. Proposals have been drawn up for further systematic flying, particularly on the Indian route, which has been organized and subjected to intensive meteorological investigation: but until the home trials have been carried out no definite programme can be finally decided upon.

6. As regards other parts of the Empire, sites for bases were surveyed by the Airship Missions, as follows:—

| | |
|-----------------------------------|-------------------------------|
| The Gambia | Near Bathurst. |
| Sierra Leone | „ Freetown. |
| St. Helena | „ Cape Town. |
| Union of South Africa | „ Durban. |
| Kenya Colony | „ Mombasa. |
| Commonwealth of Australia | „ Perth (Western Australia). |
| | „ Adelaide (South Australia). |
| | „ Melbourne (Victoria). |
| | „ Hobart (Tasmania). |
| | „ Sydney (New South Wales). |
| | „ Palmerston (North Island). |

Five sites from which choice can only be made after a period of meteorological investigation.

These places are shown on the chart in Fig. 1.

7. The Union of South Africa has under consideration the establishment of a mooring-tower base on the site at Groutville, near Durban. The Governments of the Commonwealth of Australia and of the Dominion of New Zealand undertook to proceed at once with certain preliminary meteorological work as recommended in the reports of the Airship Mission of 1927. The Government of Ceylon is establishing, on the five sites selected by the Mission, meteorological stations equipped with Dines pressure-tube anemometers and other self-recording instruments in order to collect the data on which would largely depend the final choice of a site for a base. The East African Meteorological Service has established a first-order station at Mombasa on a site near that chosen as suitable for an airship base, in order to collect data of the kind required for a better knowledge of the meteorological characteristics of this locality.

II. Meteorological Investigations in connection with Airships.—I. Meteorological work in connection with airships falls into two sections:—

- investigational work,
- provision of a reporting and forecasting service operating in conjunction with the communications organization.

2. The purpose of the investigational work is to provide essential preliminary information in connection with:—

- the development of airship design,
- the development of airship mooring,
- the choice of airship routes,
- the choice of airship bases,
- the operation of airships along the chosen routes,
- the operation of airships at the chosen bases,
- the development of the meteorological reporting and forecasting services.

3. The purpose of the reporting and forecasting service is to provide, on the occasion of actual operation of airships, immediate information as to the existing meteorological conditions over the area between the bases, and at the bases, together with forecasts of changes. The information so provided serves two purposes by assisting in securing—

- economical operation,
- safe operation.

4. An exhaustive account of the investigational work necessary in the connections mentioned in § II, 2, is not possible within the scope of the present memorandum, but some of the leading features will now be indicated. With regard to airship design (§ II, 2 (a)):—

(a) Information is being collected as to the more violent, relatively small-scale atmospheric motions in the free air. This is difficult to acquire, but the magnitude of vertical currents in thunderstorms has been deduced from the size of hailstones, while there is some direct information from the behaviour of free manned balloons, aeroplanes and registering balloons caught in such phenomena. In clear air information is available from pilot balloons followed by the two-theodolite or tail method. Some quantitative measurements on waterspouts and tornadoes have also been made from time to time.

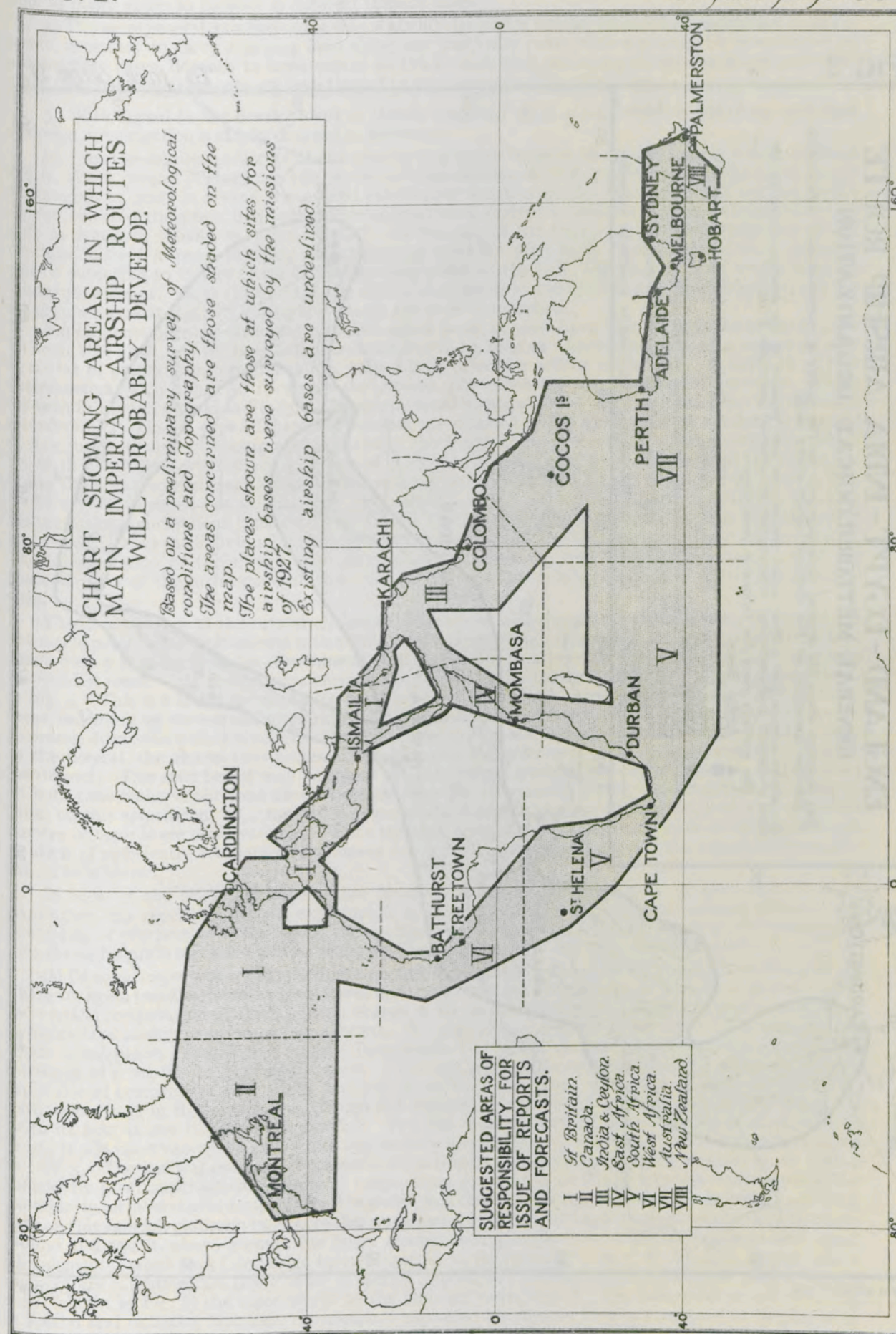
Any further information which the various services of the British Empire can supply or acquire on the following would be of value:—

- the magnitude of strong vertical currents in the free air, including the vertical and horizontal extent of the currents and the sharpness of the boundaries.
 - authentic information as to the size of large hailstones,
 - quantitative measurements on waterspouts and tornadoes, e.g., their dimensions, the associated wind speeds and the reduction of pressure in the centre.
- The bearing of information as to vertical currents on airship design is not limited to questions of strength of structure but also affects the provision of suitable valves for the automatic release of gas if the airship is constrained to rise above a level at which the gas bags, which are not extensible, become full.*

* See Richmond, V.C., "R. 101," *Journal of Royal Aeronautical Society*, No. 224, 33, pp. 686-723, August, 1929.

FIG. 1.

To face page 96

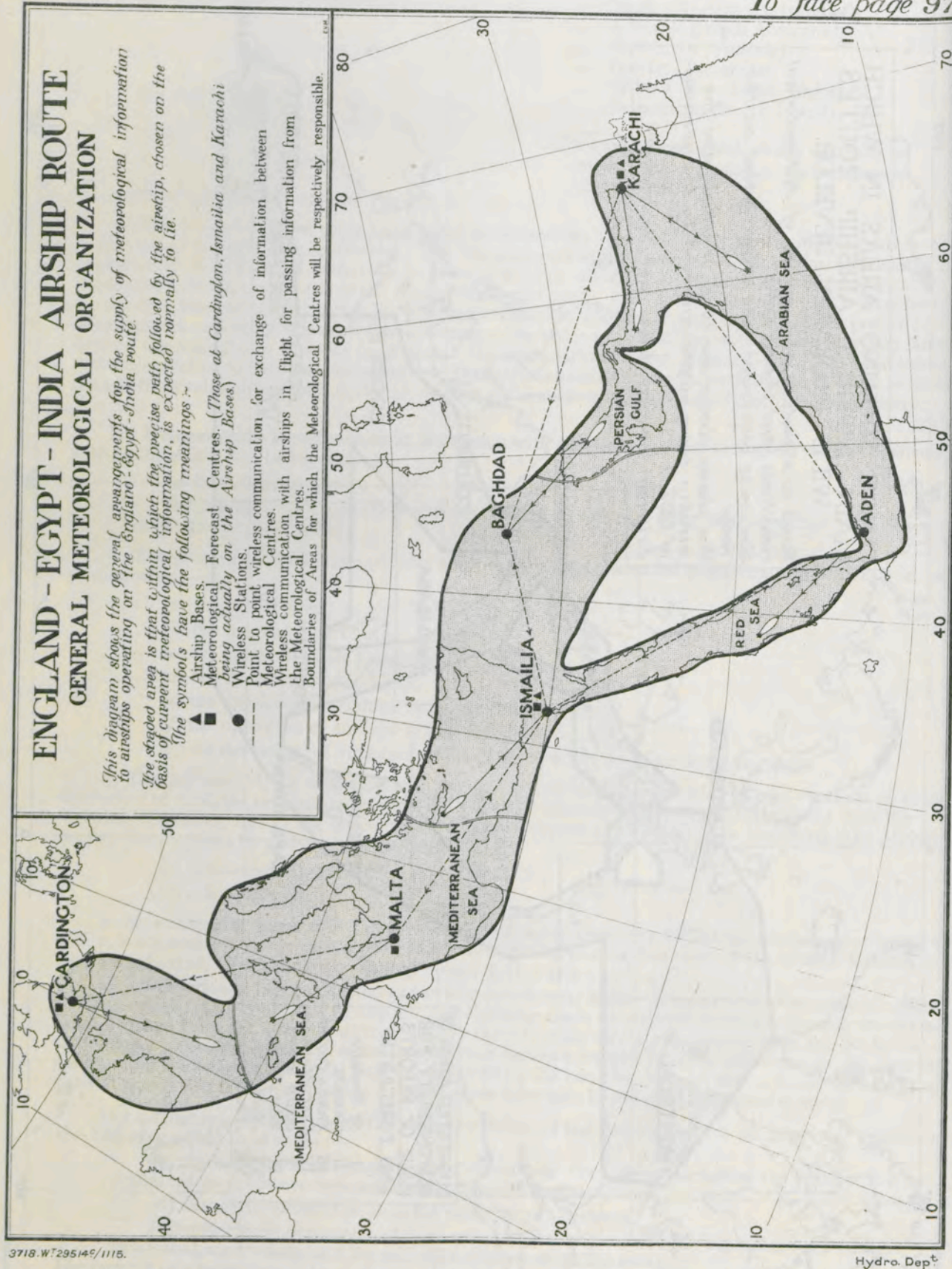


3718. WT 295149/1115.375.6.30

Hydro. Dep.

FIG. 2.

To face page 97



(b) The development of a system for recovering water from the exhaust gases of the engines, to replace water ballast released during flight, may depend for its efficiency on the temperature and humidity of the air taken in by the engines, and therefore information as to temperature and humidity in the free air is of interest in this connection, and data up to a height of 10,000 feet above M.S.L. are being collected from as many places as possible in different climatic zones.

(c) The more general question of the size of airship, its engine equipment and fuel and ballast arrangements, necessary to carry a paying load along any particular route with a practicable distribution of intermediate bases, depends to some extent on the normal wind and temperature conditions and their variations, but these elements are investigated in any case under later headings.

5. With regard to the development of airship mooring,* (§ II 2 (b)), which is linked up with that of design, investigation is chiefly directed as follows:—

(a) Into the detailed structure of the wind in the layers between the ground and a height of about 250 ft. above ground. There are two aspects of the question, firstly, that relating to the short-period fluctuations or gusts in a wind the general direction of which is steady; secondly, that relating to the sudden or rapid transition from one rather general wind current to another from a different direction such as occurs in squalls, or "line-squalls." In the case of the former, the airship while moored will continue to lie in a mean direction down the mean wind but with rapid fluctuations of wind direction will be subjected to lateral forces at the mooring point at the bow, the magnitude of which must be taken into account. In the latter case, the airship must swing round into the new wind direction, and the maximum forces at the bow during the change are to be determined.

Experiments on wind structure from the above point of view have been in progress at Cardington for some time past. As the installation and results will be seen at Cardington, and as a report is now in course of preparation for publication, only a brief reference will be made here. A network of four anemometers, with vanes 50 ft. above the ground, serves for the investigation of gustiness. These are seen in the foreground in Fig. 3. The speed recorders are of Dines pressure-tube type, the direction recorders of Baxendell type. Three instruments are situated at the corners of an equilateral triangle of side 700 ft. (length of airship approximately), the fourth being at the middle point of the side which lies in the prevailing wind direction. Special clocks are adapted to the recorders so that the time scale is 144 times the normal, each chart accommodating only 10-minutes record instead of 24 hours. The traces are thus opened out so that each fluctuation is seen. An electrically controlled time-marking system makes synchronous time marks on all the four speed and four direction records at intervals of 30 seconds, so that the individual fluctuations at the various huts can be accurately timed and correlated. The interpretation of these very open-scale records necessitated first a detailed examination of the characteristics of the instrument, so that real effects could be distinguished from purely instrumental ones.

The investigation of the rate of change of wind speed and direction in squalls, etc., is carried out at a single point, using instruments with a time scale less open than those used for gustiness. There is at Cardington a fifth anemometer, the vane of which is at 150 ft. above the ground, and which records in the forecast room. The mast of this anemometer is seen in the background in Fig. 3, and in more detail in Fig. 4. This is a Dines pressure-tube speed recorder with Dines twin-pen direction-recording attachment, recording on the normal time scale. To this instrument there has been attached a second speed-recording drum and a Baxendell direction-recording drum, each with a time scale twelve times as open as the normal, the charts thus accommodating a two hours' record. Fig. 5 illustrates the complete instrument. This attachment may be run as desired, *without breaking the normal record*, so that a record on both time scales is obtained simultaneously from the same anemometer. An endeavour is made to catch on this attachment all "fronts" and pronounced squalls passing Cardington, and a considerable number of records are now available. While the time scale of the normal instrument is not open enough to allow of sufficiently accurate measurement for the purpose in hand, that of the attachment enables this to be achieved.

In view of the work and expenditure involved in the use of a network of anemometers as at Cardington, the repetition of such experiments in other localities is not recommended at present, but, at existing or prospective airship bases, an attachment to the normal Dines anemometer to obtain quick runs through squalls on twelve times the normal time scale would be of very great value indeed.

(b) Of equal importance is the thermal structure of the air in the first 200 to 300 ft. above the ground. There are again two aspects to be considered, first, rapid changes of temperature with time, and secondly, the vertical temperature gradient. Each change of air temperature gives rise to a change of buoyancy of the moored airship which must be corrected. In particular, a measure of the rapid fall of temperature which accompanies thunderstorms and "line-squalls," or which, in some localities, accompanies the setting-in of a sea breeze, is of importance. There are regions, though less common, where an equally rapid rise of temperature may occur, and this is no less important. Ordinary thermographs give information of use in this connection, though not exposed at the height at which the airship is moored (with its bow at 200 ft. above the ground). But the time scale of the thermographs most commonly in use is not open enough to give really satisfactory measurements, and this point is referred to again in § IV 3. The vertical gradient of temperature is important because an airship moored in air with a sufficiently great super-adiabatic vertical temperature gradient is unstable, whereas when moored, for example, in an inversion of temperature it is stable, and these effects have to be met. In order to provide data on this subject, platinum resistance thermometers are exposed at Cardington at two levels, 4 ft. above ground and 150 ft. above ground, the latter element being supported on the high anemometer mast. The elements record on a Cambridge thread-recorder in the forecast room. At Ismailia, Egypt, where temperature conditions are likely to be of special importance, a separate meteorological mast of lattice steel, (shown in Fig. 6) the same height as the mooring tower, 200 ft., has been erected and elements in special anti-radiation housings, continuously aspirated by electric fans, are exposed at heights of 4,

* An account, with reference to meteorological factors, will be found in the following papers:—Scott, G. H., "The Development of Airship Mooring," *Journal of Royal Aeronautical Society*, No. 188, 30, pp. 459-481, August, 1926 and "The Mooring and Handling of Large Airships," delivered before the Royal Aeronautical Society, April, 1929, shortly to be published in the *Journal*.

50, 150 and 200 ft. above the desert surface. The records are made on a single chart on a Cambridge twin-galvanometer triple-thread recorder in the forecast room about half a mile away and give directly:—

- (i) the temperature at 4 ft.
- (ii) the difference of temperature between 4 and 50 ft.,
- (iii) the difference of temperature between 50 and 150 ft.,
- (iv) the difference of temperature between 150 and 200 ft.

The general lay-out is shown in Fig. 7.

An installation of similar type is being provided at the Karachi airship base by the Indian Meteorological Department.

The information provided by such apparatus is of such great importance that its installation at all existing or prospective airship bases would be a valuable contribution to airship meteorology, though it has not been laid down as an essential provision for a demonstration flight.

(c) The dynamical effect of falling rain on a moored airship has to be considered. A special instrument would be required to measure this directly, but an approximation can be made by combining measured "rate of rainfall" with an assumed average terminal velocity of the drops. The records of self-recording rain-gauges are therefore of value, the information chiefly required being extreme rates of fall taken over very short intervals of time.

(d) At bases in cold climates snow and frost data are required, but special observations are not necessary except such as may be needed to give extreme values of the weight of snow falling per unit area per unit time and the total weight per unit area in a continuous fall.

6. With regard to the choice of airship routes (§ II 2 (c)), numerous factors may enter, but two of the most important from the present point of view are the normal distribution of (a) upper winds up to 10,000 ft. above mean sea level, (b) thunderstorms.

As will be seen from Fig. 1, such routes as have already been visualised are indicated only as broad strips, since the precise path followed on the occasion of any particular flight would be chosen on the basis of the current weather information and forecasts, but would normally lie within the corresponding strip. The routes shown in Fig. 1, were laid down tentatively, merely as the most probable along which main routes linking the Dominions and India would develop. Development would hardly cease with these routes only, and all parts of the empire can assist now by initiating upper wind measurements where they are not already carried out, and by collecting information as to thunderstorms on a uniform plan.

There is a tendency when possible for airship routes to lie over the sea, in view of the generally more favourable temperature conditions prevailing there, and, consequently, special importance attaches to measurements of upper wind over the sea and on ocean islands. The investigation of the upper wind in the trade-wind belts is of particular importance, especially along the two routes in Fig. 1 lying between the equator and South Africa in the South Atlantic Ocean and between the equator and Western Australia in the South Indian Ocean. There is undoubtedly a good case for giving serious consideration to the investigation of these areas by means of an expedition or expeditions, using vessels specially allocated for the purpose. Although conditions in the trade winds are not the same from year to year, yet a single year's observations would give a reasonable picture of the upper-wind structure, since departures from the average in any year are not likely to be so great in these areas as in the temperate zones. The possibility of flying above the SE. trade wind when southward bound along these generalised routes, without ascending to an uneconomical height, by a proper choice of actual path, is a point likely to be of very great commercial importance.

7. The choice of airship bases (§ II 2 (d)), is not a subject which need be entered into in this memorandum beyond pointing out that in areas where it is at all likely that bases will need to be chosen in the future, apart from those already provisionally sited, any information as to the conditions relating to bases mentioned in other paragraphs would be of assistance. It may be mentioned incidentally that an airship base should be as near sea level as possible, as the lower the level the greater the load which can be carried on leaving the base.

8. It is necessary that the captain of an airship should be in possession of information as to the general meteorological characteristics of any route along which he is going to fly. (§ II 2 (e)). The characteristics should be presented not only on a statistical basis, but by reference to *types of conditions which may occur on individual occasions* and the manner in which they change. The study of conditions along airship routes aims, for example, at the provision of:—

- (a) charts showing the monthly distribution of the usual meteorological elements observed generally at present,
- (b) information, as detailed as possible, of
 - (i) the average distribution of thunderstorms in each month, based on as close a network of stations as possible, and
 - (ii) the diurnal variation of thunderstorms based on key stations in each climatic unit of area.
- (c) information as to the occurrence of hail, snow, heavy rain, sand storms, waterspouts or tornadoes, line-squalls, tropical revolving storms, strong persistent winds such as the mistral, etc.,
- (d) information as to the normal monthly distribution of wind up to 10,000 ft. above mean sea level,
- (e) information as to the distribution of temperature and humidity up to 10,000 ft. above mean sea level, and, in particular, the occurrence of and magnitude of inversions of temperature in the upper air,
- (f) particulars of the types of meteorological conditions which occur on individual occasions, and their day-to-day changes.

This matter is referred to again in §§ IV and V.



FIG. 3.—General view of the wind structure research installation of the Meteorological Office, Royal Airship Works, Cardington.



FIG. 4.—View of Meteorological Office, Royal Airship Works, Cardington, showing the elevated forecast room and the high anemometer mast.

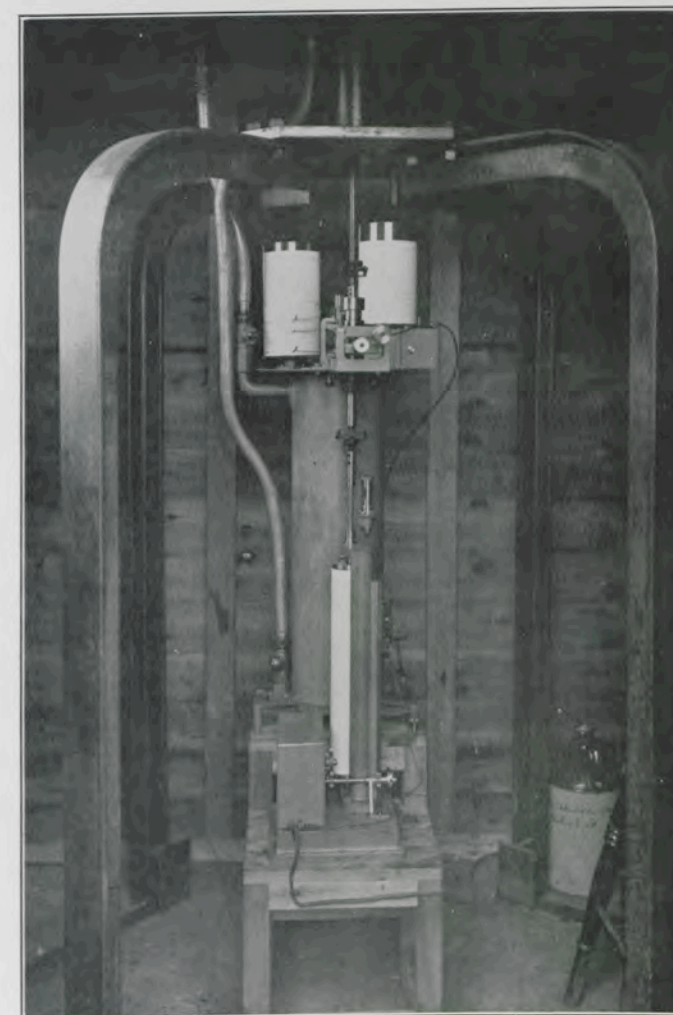


FIG. 5.—Illustrating the combined normal and quick-run anemograph as used at Cardington. The normal speed and direction records are made on the upper left hand drum and the quick-runs on the other two drums, the upper one being that for wind speed.

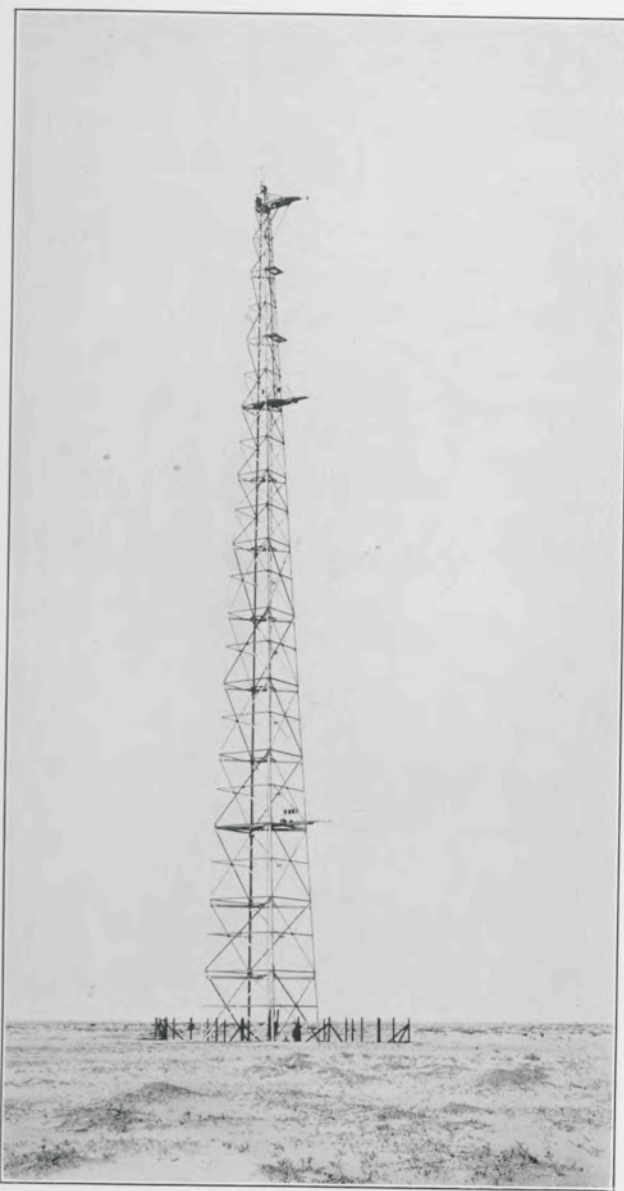


FIG. 6.—The 200-ft meteorological mast at the Airship Base, Ismailia, Egypt, showing the platforms supporting the aspirated platinum resistance thermometers.

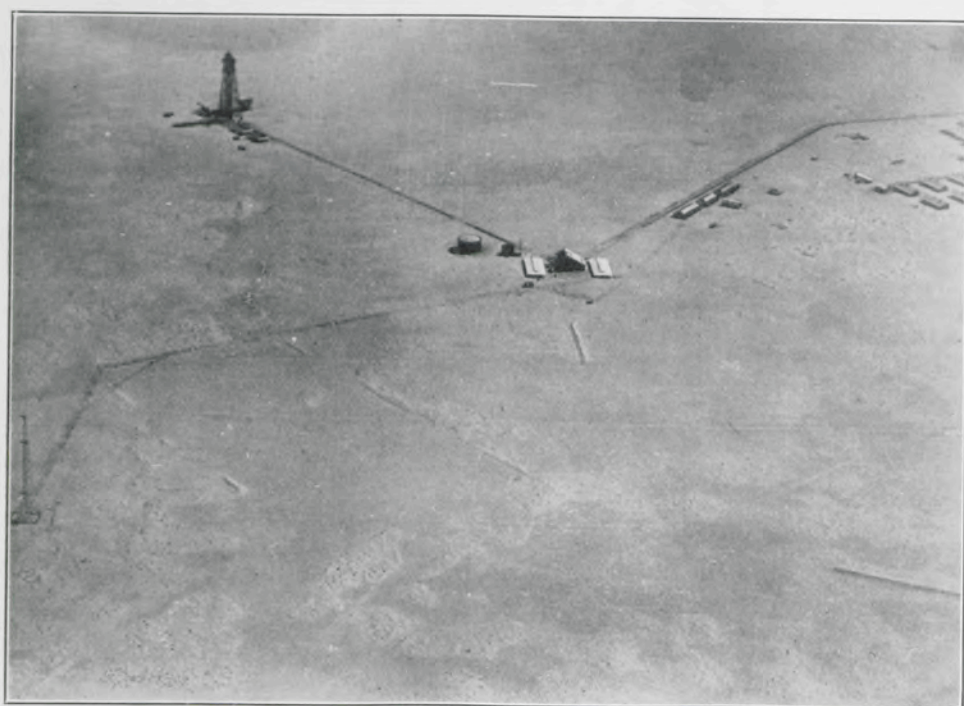


FIG. 7.—Aerial view of the Airship Base, Ismailia, Egypt, showing the airship mooring tower in the left distance and the meteorological mast in the left foreground. The electrical thermometers on the meteorological mast record in the Meteorological Office, viz., the furthest of the three huts in line against the road on the right of the picture.

9. As for routes, so it is necessary for the captain of an airship to be acquainted with the meteorological characteristics of the bases at which he is to operate (§ II 2 (f)). The study of conditions at bases aims, for example, at providing:—

- (a) climatological summaries giving the seasonal and diurnal variation of the usual elements and phenomena, and the extent to which departures from the means occur,
- (b) information as to the wind, temperature and humidity régime in the upper air, including diurnal variation,
- (c) more detailed information as to the wind and temperature régime in the first 250 feet above the surface. This will also be referred to again in §§ IV and V.

10. The development of the meteorological reporting and forecasting services is included as dependent on investigational work (§ II 2 (g)), not only because this is so in general, but also because airship development may be expected to lead to such services in regions where they do not exist at present or have only lately been established, and where a special technique of forecasting may have to be devised.

III.—**Meteorological reporting and forecasting organization for Airships.**—1. A general description of the arrangements for the provision of reports of current conditions and forecasts for airships operating along the England-Egypt-India route will now be given, as illustrating the principles on which such a service along other routes would be based. Details are not given, as they would be the subject of direct negotiation between the Meteorological Office, Air Ministry, and the other services concerned.

2. Fig. 2 illustrates the general arrangements, the communications organization being an essential feature on the efficiency of which the effectiveness of the meteorological service largely depends. The figure carries an explanatory note. It is an important principle that there shall be a forecasting centre actually on each airship base so that, prior to an operation, the captain of an airship may inspect the weather charts and discuss the situation with the forecaster. It is impossible to meet all contingencies by a set form of report or forecast telegraphed from a distant centre, and experience has shown how essential for an efficient organization is the principle just laid down. There may be, however, intermediate forecasting centres at points along the route where there is no airship base, as in the case of Malta, where conditions suggest the need for such a service.

3. Taking the case of a flight from Cardington to Ismailia as an example, the procedure would be as follows: As soon as the flight is impending, the centres at Cardington, Malta and Ismailia would commence preparing forecasts and further outlooks for their respective areas shown in Fig. 2. These would be exchanged using the point-to-point wireless communication. The captain of the airship would then inspect the weather charts at Cardington, which would be such as to show conditions *over the whole stretch to the next airship base*, viz., Ismailia. He would discuss the situation and would receive from the forecaster a forecast for the whole route, detailed for the first stages and more general for the later stages, based on the forecasts prepared at Cardington taken in conjunction with those received at Cardington from Malta and Ismailia. Copies of the recent weather charts would also be supplied for use in flight.

The flight having commenced, the airship would at first be in wireless communication with Cardington and after the next weather chart became available six hours later, would receive by wireless from the Cardington Office a revised set of forecasts covering the remainder of the route, based again on forecasts made at Cardington taken in conjunction with revised forecasts received there from Malta and Ismailia. (The meteorological centres would be kept informed periodically of the airship's position). A skeleton weather chart would be prepared in the airship from data received by wireless, and this, used with the charts taken on board at Cardington, would provide a sequence enabling the forecasts received by wireless to be interpreted much more effectively than in the absence of a chart.

Approximately half way to Malta the airship would cease communication with Cardington and would be in touch direct with Malta. The meteorological centre at Malta would then become the office for issuing forecasts for the rest of the route, those received at Malta from Ismailia being taken into account. Later still the airship would be in direct touch with Ismailia, from which forecast centre the detailed forecasts for the last stages of the route and the information required in connection with landing, would be received.

4. During a flight, the meteorological and communications organization must be continuously available throughout the day and night, and when an airship is moored at a base, a continuous day-and-night meteorological watch must be maintained there. The point-to-point communication need not of necessity be by wireless provided a rapid, continuously available link can be supplied by land-line or cable, but it will probably be found that wireless is in general the more practicable.

5. The type of information required by the airship in flight may be gathered from preceding paragraphs; it is concerned mainly with the structure of the atmosphere up to 10,000 feet as regards motion and temperature, together with information as to precipitation, thunderstorms, squalls, etc., and indeed as to any areas where vertical atmospheric currents are likely to be pronounced. The location of discontinuities or "fronts" is of special importance, all the airship officers having received courses of instruction in meteorology and being familiar with the properties of such phenomena. The routine forecasts may be supplemented by special warnings transmitted at any time as necessary.

6. The arrangements at a base may be briefly indicated by reference to Cardington. Here a meteorological building (see Fig. 4) has been erected for operational purposes and has the following special features:—

- (a) The forecast room is elevated and has windows all round so that the forecaster has the sky continuously under observation to assist in the making of local forecasts and to enable the approach of phenomena of the squall type to be observed.

(b) The data incoming by wireless for the preparation of weather charts are received in the same building, below the forecast room, and a communicating lift enables the messages to reach the forecaster without relaying by telephone which may increase the chances of errors and involve delay.

(c) The following recording instruments are under the forecaster's eye in the forecast room :—
Dines pressure-tube anemometer (speed and direction).
Electrically recording thermograph (Cambridge thread-recorder) giving wet and dry bulb at 4 feet above aerodrome and dry bulb at 150 feet above ground.

Barograph. Dines float barograph and Short & Mason open-scale barograph.

(d) The forecast room is close to and is also connected by direct telephone with the airship operations control room which is a "clearing house" for all messages passing to and from an airship in flight.

(e) The forecast room is connected by a remote control line (through the operations control room) with the radio-telephony transmitting station on the base, so that, when switched through by the control room, speech may be held between the forecaster and the captain of the airship when the latter is in flight within about a hundred miles of the base. This permits of the discussion of local conditions as necessary, especially of conditions for landing.

(f) Provision is made for telephonic communication between the forecast room and the control car of the airship when moored, for the discussion of conditions with the duty officer in the airship.

(g) The telephones and radio-telephony microphone in the forecast room are so arranged that the weather charts and all the recording instruments may be readily consulted during speech.

7. Specimens of the blank maps (Forms 2213 and 2205) used at Cardington for the preparation of weather charts are attached*, and the method of charting is shown in Form 2458*. "Fronts" are drawn on the working charts according to the Norwegian system. Form 2213 is on conical orthomorphic projection with standard parallels 60° N. and 45° N., where the scale is 1 : 5,000,000. The area covered extends from Greenland, Iceland and Finland in the north to the Azores and Sicily in the south, the size of the chart being about 32 inches by 25 inches. It is used primarily for the preparation of weather reports and detailed forecasts for a relatively short period ahead. It is prepared four times a day at intervals of about six hours. Subsidiary charts showing observations at selected stations in the British Isles and along the Continental seaboard are prepared on the smaller map on the reverse side at three other intermediate hours. The result is a new chart every three hours, except at night when there is one interval of six hours. Form 2205 is on conical orthomorphic projection with standard parallels 50° N. and 20° N. where the scale is 1 : 20,000,000. The area covered comprises most of the Northern Hemisphere south of latitude 80° N., with the exception of the Pacific. The size of the chart is the same as that on Form 2213. It is used in conjunction with Form 2213 for the study of day-to-day changes over a wide area and thus for the preparation of "further outlooks," i.e., forecasts of the general tendency for some days ahead. It is also used as the basis of information for long-distance flights beyond the area covered by Form 2213. It is normally prepared as a complete chart morning and evening.

A specimen is also attached* of another chart (Form 2206) which is used at Cardington for investigational work on the England-India route and of which sections are used for forecasting purposes at certain other points on the route to India, e.g., Malta. Form 2206 is on conical orthomorphic projection with standard parallels 50° N. and 20° N., where the scale is 9/10 of 1 : 10,000,000. The area covered comprises Iceland, Europe, most of Asia and North Africa to about latitude 5° N. The size of the chart is 39 inches by 29 inches.

8. The forecasting staff at Cardington consists of five professional officers with university training viz.:

One assistant superintendent,
Four professional assistants;
the observing staff, of five clerical officers, viz. :
One Grade II clerical assistant,
Four Grade III clerical assistants.

(The Division, which is in the charge of a superintendent, also has, for investigational work,
One professional assistant,
Two Grade III clerical assistants,
in addition to a draughtsman and a typist).

9. The type of information required for airship operations at a base may be largely inferred from preceding paragraphs. Three phases have to be catered for :—

- Airship leaving or entering shed (where such exists).
- Airship landing (to ground or more commonly to mooring tower).
- Airship riding at mooring tower (the normal place when not in flight).

Under (a), wind is the main consideration, a calm being necessary for this operation, sufficient notice being given for the summoning of a handling party.

Under (b), the airship is supplied, prior to landing, with data mainly as to barometric pressure (for checking altimeter), temperature (for ballasting up) and wind. The thermal and wind structure in the lowest few hundred feet are of special importance for the operation of landing.

* Not reproduced with printed memorandum.

Under (c), warning of sudden changes of wind and temperature and warnings of heavy precipitation, together with information as to vertical temperature gradient and cloudiness (insolation) form the chief items of importance. The provision of warnings of the approach of line-squalls, etc., is facilitated in this country by an arrangement by which selected stations, particularly to the west and north-west (from which direction such phenomena normally arrive), report immediately direct to Cardington in a special code, the time of occurrence and particulars of such phenomena passing them. A very short-period warning may also be given on the basis of visual observations from the windows of the elevated forecast room.

IV. **Standardisation of Methods.**—I. There are certain features in connection with meteorology for airships which it is desirable to standardise as soon as feasible, and it is proposed next to deal with these, though at this early stage in airship development it is not possible to approach anything like finality.

2. The matter may be conveniently dealt with under three headings.

- Instruments at airship bases,
- Statistical summaries, (i) general, (ii) for airship bases.
- Reporting and forecasting organization.

3. With regard to instruments at airship bases the following items are necessary :—

- Mercury barometer.
- Barograph.
- Thermograph, with ordinary and maximum and minimum thermometers.
- Hygograph, with ordinary wet and dry-bulb thermometers.
- Dines pressure-tube anemometer (speed and direction), with latest improvements.
- Self-recording rain-gauge with check eye-reading gauge.
- Pilot-balloon apparatus (tail-method or equivalent).
- Nephoscope (or equivalent equipment for observations of cloud motion).
- Sunshine recorder.

It is important that the self-recording instruments should have as open time scales as possible. Specimens of the charts used at Cardington are attached*, and it is considered that these have time scales which are the minimum to meet requirements. In order to facilitate the detailed study of phenomena on the basis of the autographic records at Cardington an electrically controlled time-marking system is provided, making synchronous time marks on all the records every hour.

The question of standardising the type and exposure of anemometers at airship bases has already been raised with the Dominions and India, and a copy of a circular letter sent from the Meteorological Office on February 15th, 1928, appears in Annex A. The installation, as at Cardington, of an additional higher anemometer, giving a record of wind at approximately the height of the mooring tower (200 feet) where conditions allow, would also be useful though not suggested as standard at this stage.

The provision of a vertical-temperature-gradient recorder, such as that at Ismailia, may conceivably become to be regarded, after actual experimental operation with the new airships, as just as essential a part of the standard equipment of an airship base as an anemometer. This stage has not been reached yet, but the value of such a recorder is known to be great, so that its installation wherever possible would be welcomed, and the only reason for not pressing it now is purely one of cost.

Possibly a "rate-of-rainfall" recorder may at some stage also become a part of the standard equipment of an airship base.

4. With regard to general statistical summaries, the most important are those relating to (a) upper wind and (b) thunderstorms.

(a) The form of summary for upper winds already extensively used in the Meteorological Office, Air Ministry, and certain other parts of the Empire is that recommended by the International Commission for Air Navigation. A note on it is given in Annex B, and it is recommended that this form be adopted throughout the Empire for such summaries.

(b) The basis suggested for summaries of thunderstorms for general purposes is the monthly frequency of days of "thunder heard," together with the diurnal variation of "thunder heard" at selected key stations.

As regards upper-air temperature and humidity, it is difficult at present to suggest a suitable form of summary and records of individual ascents are probably the most useful at this stage.

No explicit mention has been made so far of low cloud and visibility, as these are of secondary importance from the airship point of view, any summaries prepared in the form recommended in the memorandum on Meteorology and Aviation (Appendix I), meeting airship requirements at the same time.

5. Statistical summaries for airship bases are very important, and, as airship bases will always be relatively few in number, there is little objection to recommending that extensive tabulations and summaries be made for them.

In addition to general climatological summaries in the form recommended in the memorandum on "The Collection, Tabulation and Publication of Climatological Data" (Appendix XII), the following are suggested at this stage :—

- Barometric pressure (mean sea level). Tabulation of values at exact hours (on the standard of time in force in the locality); hourly means and extremes for each month.
- Temperature. Tabulation of values at exact hours; hourly means and extremes for each month.

* Not reproduced.

- (c) Humidity. Ditto for (i) relative humidity. (ii) vapour pressure.
- (d) Air Density, (station level). Tabulation of values at exact hours; hourly means and extremes for each month.
- (e) "Surface" wind. Tabulation of hourly values of speed and direction, meaned over the ten minutes preceding each exact hour; frequency summaries for each month for the hours midnight, 0300, 0600, 0900, noon, etc., in the same form as those of upper winds (Annex B) but sub-dividing the ranges of speed into the following:—0-3, 4-8, 9-15, 16-32, 24-31, 32-39, 40-47, 48 and over; hourly means and extremes of speed for each month from the above tabulations; tabulations of highest gust in each interval of one hour centred at exact hours; hourly extremes of those for each month.
- (f) Rainfall. Tabulation of falls during each interval of one hour; totals by hours and by days for each month; tabulation of high rates of fall in intervals of, say, 5, 10 and 15 minutes.
- (g) Sunshine. Tabulation of duration in each interval of one hour; totals by hours and by days for each month.
- (h) Visibility. As for aviation requirements (Appendix I).
- (i) Low cloud. Ditto.
- (j) Thunderstorms.
- (i) Monthly frequency of days of thunder heard.
- (ii) Monthly frequency of days with thunderstorms actually at station determined by occurrence of thunder, lightning and precipitation combined.
- (iii) Monthly frequency of occurrence of (i) and (ii) in each hourly interval.
- (k) Hail, snow, sandstorms, dust devils, etc. Monthly frequency of days of occurrence.
- (l) Vertical temperature gradient. Form of summary to be determined later.
- (m) Upper winds. As in § IV. 4 (a).
- (n) Upper air temperature and humidity. Individual values at present.

6. As regards the reporting and forecasting organization, assuming that the general principles of the England-Egypt-India route will be applied to other routes, the points which might profitably be discussed at present are:—

- (a) The use at all airship bases of working charts of similar type, *i.e.*, printed in a similar colour, showing the same contours, and on similar projections and scales. This would be advantageous from the point of view of airship officers who will consult the weather charts at the various bases.
- (b) The use of a similar method of charting for the *main* charts showing the main elements and consulted by the airship officers, as distinct from any subsidiary chart used purely as aids to forecasting. The method at present in use in the Meteorological Office, Air Ministry, (embracing Cardington), is shown in Form 2458.
- (c) The more extensive collection of reports from ships at sea for use at the forecasting centres. This is mentioned in view of its importance, airship routes lying largely over the oceans, but it will presumably be discussed in connection with marine meteorology.
- (d) The allocation of areas of responsibility for the issue of reports and forecasts for the other routes of Fig. 1 on a principle similar to that shown in Fig. 2 for the England-Egypt-India route. A tentative suggestion is made in Fig. 1 to serve as a basis of discussion. The procedure would be such that the responsibility for arranging for the contribution of observations from any foreign territory or part of the Empire lying within any of the areas indicated would rest on the meteorological service controlling the meteorological centre lying within that area and participating in the airship meteorological organization. (This does not necessarily mean assuming financial responsibility for foreign reports any more than Great Britain assumes financial responsibility for reports from France which are collected at Cardington). For example, the arrangements for the collecting at the forecast centre of the airship base at Durban, of reports from Portuguese East Africa or from Mauritius would rest with the meteorological service of the Union of South Africa, and the sole responsibility for the reports of current conditions and the forecasts issued to the airship from Durban, for the area indicated, would rest with Durban.

The question of codes is not put forward at this stage for special discussion from the airship point of view, as present needs would be met by the adoption of international codes for the issue of data. In the early stages of the airship programme at least, forecasts and general reports are likely to be given in plain language.

Similarly, hours of observation for synoptic reports have been recommended internationally, and, if these recommendations are followed, general airship requirements will be met.

The frequency of synoptic observations and the density of the network of stations actually adopted is very much ruled by what is practically possible in any area, but a single chart a day is certainly inadequate to give the detailed information required by airships. Charts at intervals of about six hours should certainly be aimed at where at all possible, in order that the smaller and more rapidly changing features of the situation may be followed in sufficient detail, and also in order that account may be taken of effects of diurnal variation which then become revealed.

V. Collection of Information and Statistics as to Routes and Bases.—1. It is very probable that there will arise, at some later stage of the airship programme, a demand for an "airship pilot" which would be largely meteorological and would contain full details of the meteorological characteristics of each airship base, together with the charts and descriptive matter relating to the routes joining them. Its place is at present being taken by a series of duplicated reports prepared in the Airship Services Division of the Meteorological Office and issued to the Directorate of Airship Development.

The commencement now of the preparation of the summaries indicated in §§ IV 4 and IV 5, would be working towards such a "pilot," and, as the airship staff is in need of as much information as possible about areas which may be visited on early flights before airship traffic becomes regular, it would be of assistance if other services of the Empire would commence making monthly summaries and where they are not published, would supply copies to the Meteorological Office, Air Ministry.

2. The following would be welcomed from any part of the Empire irrespective of position:—

(a) Summaries and observations as mentioned in § IV 4, the frequency of days of thunder relating to as many stations as possible.

(b) Accounts of the characteristics of squalls, sudden changes of wind, sudden changes of temperature, exceptionally large hailstones, waterspouts, tornadoes, sandstorms, etc., with quantitative measurements when possible.

3. Services in parts of the Empire with existing airship bases, or where sites for airship bases have been definitely chosen and a meteorological station established thereon (or where a representative station exists near by), could assist materially by providing for those bases—

(a) summaries and observations as mentioned in § IV 5,

(b) accounts as in (b) of the preceding paragraph,

(c) the loan to the Meteorological Office, Air Ministry, of autographic records, especially of wind and temperature, as required for the study of individual characteristics in collaboration with the airship staff. A similar procedure is requested to meet the requirements of the Army Services Division (*see* Appendix VI) and the two requirements could be combined to avoid unnecessary duplication of loans.

VI. General.—There are three recent developments which may assist in the meteorological organisation and of which mention may appropriately be made here.

(a) The Meteorological Office, Air Ministry, has devoted considerable attention to the question of small hydrogen generators for use at pilot balloon stations, especially those in remote places where the transport of hydrogen in heavy cylinders is difficult and very costly. Two small generators depending on the action of caustic soda on silicol have actually been tested, and any service interested can obtain information from the Meteorological Office.

(b) The application of radio-goniometric methods to the location of the sources of atmospheric is being investigated in conjunction with the Radio Research Station of the Department of Scientific and Industrial Research, to ascertain whether such a system would provide a practicable means of detecting areas of thunderstorm activity in regions where observing stations are lacking or widely separated. Observations of the direction of arrival of atmospheric at the Radio Station at Slough, Bucks., and at Leuchars, Fifeshire, are made simultaneously during an interval of about ten minutes at 1 p.m. each day, the two stations being connected by a direct telephone line to enable synchronisation to be effected. The positions of the sources determined by the observations at the end of this baseline are then immediately transmitted in an experimental code to Cardington where they are plotted on, and studied, in the first instance, in relation to, the working charts. This is to continue for an experimental period when a report on the results will be prepared. If successful, the application of such methods to airship routes would be of great value, for such routes pass over some areas, particularly ocean areas, where the location of thunderstorms by visual observation will always present difficulty owing to lack of possible observing stations.

(c) The application of methods of facsimile transmission by wireless to the transmission of weather charts and weather information in words or figures, has been under consideration for some time past. Numerous methods have been looked into and one method, the Fultograph*, has been tried in practice. The Fultograph transmitting apparatus is compact and can be attached to an ordinary radio-telephony transmitter, taking the place of the microphone used for ordinary speech. The receiver is very light and can be attached to an ordinary wireless receiver. The picture to be sent is normally photographed and the negative placed on the transmitter, but a weather chart or message, drawn or written on a semi-transparent medium, can be placed directly on the instrument. In this case the received picture would come out as a "negative" in the ordinary way, but a rectifying attachment is understood to be available, so that the positive can be received from a positive.

In March, 1929, a Fultograph transmitter was attached to the radio-telephony transmitter at Cardington and weather charts and forecasts in writing were issued experimentally on several occasions, the transmitter being operated by Wireless Pictures Ltd. personnel. They were received at a number of points in southern England, in particular in the rooms of the Royal Meteorological Society on the evening of March 20th, 1929, during the course of a lecture on "Wireless and Weather" by Mr. R. A. Watson Watt. Reproductions of the latter, the first current chart and forecast to be transmitted and received by wireless in the British Isles, will be found in the *Meteorological Magazine* for April, 1929.

More recently, a weather chart has been included on Tuesdays and Thursdays in the picture programme broadcast from Daventry 5XX by the British Broadcasting Corporation, using the same method. On two occasions a "general inference" and a forecast in words have been included. This is continuing for an experimental period.

The size of the picture received at present is about 5 inches by 3½ inches, the time taken for transmission being 4 minutes. It should not involve much modification to double this area to 5 inches by 7 inches, the time of transmission being doubled at the same time.

The application of such a method to the supply of weather charts, data and forecasts to airships in flight would have great advantages, and it is hoped to experiment during the home trials of the new airships. Among the advantages are:—

(i) That the chart received in the airship would be one based on the full resources of the ground meteorological organization, and not merely on the amount of data which could be received in the airship for the construction of a chart in flight. The latter would of necessity be less than is

* Wireless Pictures (1928) Ltd., Dorland House, 14-16, Regent Street, London, S.W.1.

available on the ground as the receiving capacity of the airship's wireless installation is necessarily limited. A better representation of the isobars and "fronts" is therefore to be expected if the chart itself can be received by wireless.

(ii) In commercial practice, it may well be that for reasons of economy a special meteorological staff could not be carried, meteorological duties devolving upon the airship's officers. The latter, though well trained in meteorology could hardly be expected to produce so good a representation on the situation, particularly as to "fronts" as the specialist meteorologist at the ground forecasting centre.

(iii) The transmission of data and forecasts in writing is likely to be more accurate in the long run than by speech or morse, as the picture is received automatically exactly as sent.

(iv) The messages in writing may still be legible in spite of atmospheric conditions which produce dots, or, up to a point, in spite of interference from other stations, even though morse or speech might be impossible.

Specimens of weather maps, etc., received by wireless are available for inspection.

ANNEX A.

Meteorological Office,
Air Ministry,
Kingsway,
London, W.C.2.

15th February, 1928.

Dear Sir,

On the 13th of last month I despatched a cable to you in the following terms:—

... "Re Giblett's visit forty feet above level ground in open exposure is Meteorological Office standard height for Dines Anemometer vane. Highly desirable this be adopted at stations established for airships. Letter follows."

In making this proposal as to the standard height for the Dines Anemometer vane, I was guided by the following resolutions passed at the meeting of the Commission for Synoptic Weather information at Zurich in September, 1926, and subsequently adopted at Vienna by the International Meteorological Committee, namely:—

XX.—"That it is important that the force (and direction) of wind in reports for synoptic purposes should give a good representation of the general current of air over the surface of the earth in the region where the reporting station is situated."

XXI.—"That it is important that the basis taken for reports should be such as to give values from different stations which are inter-comparable."

XXII.—"That the Beaufort Scale is in accordance with the conditions of Resolutions XX and XXI and the Commission recommends that this scale should be the scale of wind for International Weather Telegraphy."

XXIII.—"That the velocity equivalents of the Beaufort Scale should be the values in the Table VI of Dr. Simpson's report (*see below*) with the addition of a note that these values for the Beaufort Scale correspond on land with the speeds at a height of approximately 6 metres above a level surface free from all obstructions. Such an exposure of an anemometer would be called the standard exposure for synoptic purposes."

Velocity Equivalents of Beaufort Scale.

(The speeds refer to a height of approximately 6 metres above level ground free from obstruction.)

| Beaufort Number. | Limits of Velocity. | | |
|------------------|---------------------|-----------------|----------------------|
| | Metres per second. | Miles per hour. | Kilometres per hour. |
| 0 | 0-0.5 | 0-1 | 0-1 |
| 1 | 0.6-1.7 | 2-3 | 2-6 |
| 2 | 1.8-3.3 | 4-7 | 7-12 |
| 3 | 3.4-5.2 | 8-11 | 13-18 |
| 4 | 5.3-7.4 | 12-16 | 19-26 |
| 5 | 7.5-9.8 | 17-21 | 27-35 |
| 6 | 9.9-12.4 | 22-27 | 36-44 |
| 7 | 12.5-15.2 | 28-33 | 45-54 |
| 8 | 15.3-18.2 | 34-40 | 55-65 |
| 9 | 18.3-21.5 | 41-48 | 66-77 |
| 10 | 21.6-25.1 | 49-56 | 78-90 |
| 11 | 25.2-29.0 | 57-65 | 91-104 |
| 12 | > 29.0 | > 65 | > 104 |

XXIV.—"That in cases where the exposure of the anemometer differs from the standard in a manner such that the effect is known either by direct experiment or by straightforward deduction from well-established results, the records of the instrument should be converted to the Beaufort Scale by an appropriate table. For example, if an anemometer were exposed at a height of 20m. above level ground free from obstructions, the conversion would be made by a table in which the speeds of Resolution XXIII were increased by 23 per cent."

If the correction required is less than 5 per cent. the standard table should be used."

It was found on examination that the velocity equivalents of the Beaufort Scale as used in this country, namely:—

| Beaufort number | Limits of speed | |
|-----------------|-----------------|-------------------|
| | Miles per hour | Metres per second |
| 0 | Less than 1 | Less than 0.3 |
| 1 | 1-3 | 0.3-1.5 |
| 2 | 4-7 | 1.6-3.3 |
| 3 | 8-12 | 3.4-5.4 |
| 4 | 13-18 | 5.5-7.9 |
| 5 | 19-24 | 8.0-10.7 |
| 6 | 25-31 | 10.8-13.8 |
| 7 | 32-38 | 13.9-17.1 |
| 8 | 39-46 | 17.2-20.7 |
| 9 | 47-54 | 20.8-24.4 |
| 10 | 55-63 | 24.5-28.4 |
| 11 | 64-75 | 28.5-33.5 |
| 12 | Above 75 | Above 33.5 |

when applied to an anemometer exposed 12 metres or 40 feet above level ground in an open exposure, were in harmony with those given in Resolution 23 when allowance was made for the difference of wind velocity at different heights as given on page 41 of the Meteorological Observer's Handbook M.O. 191 (1926), the following being the relevant extract from this publication:—

"No precise relation can be given for the variation of velocity with height, but the following table based on various experiments may be of service as giving an indication of the order of magnitude of the effect in open situations:—

| Height in metres | $\frac{1}{2}$ | 1 | 2 | 3 | 4 | 5 | 10 | 15 | 20 | 25 | 30 |
|---|---------------|-----|-----|-----|-----|-----|------|------|------|------|------|
| Ratio of velocity to that at 10 metres. | .50 | .59 | .73 | .80 | .85 | .89 | 1.00 | 1.07 | 1.13 | 1.17 | 1.20 |

In view of this and of the fact that 40 feet is the standard height of the anemometers in existence in this country, it appears to me that it is desirable to adopt this height for any new stations to be established for airship purposes so as to secure inter-comparability of results without computation. On an airship base an open exposure would normally be obtainable, but naturally allowance would be made for any appreciable obstructions by some increase in the height of the vane.

Yours faithfully,

(Sgd.) G. C. SIMPSON,

Director.

ANNEX B.

Notes on the preparation of frequency summaries of Upper Winds.

1. The purpose of these summaries is to provide uniform material for the preparation of wind charts along airship routes at definite specified levels, the wind data to be represented by wind roses showing frequencies of direction and velocity of the wind.
2. The form adopted by the International Commission for Air Navigation* has been used, but in some details it has been varied to meet special requirements.
3. The fundamental heights selected by the I.C.A.N. are given in metres namely, surface, 500 metres, 1,000 metres, 2,000 metres, 3,000 metres, above the surface of the ground. When summarising data for stations under the control of the Meteorological Office, Air Ministry, the standard heights are taken as surface (anemometer height), 1,500 feet, 3,000 feet, 6,000 feet and 10,000 feet (see also paragraph 5).
4. In the case of data from stations under the control of the Meteorological Office, Air Ministry, the wind at any height is normally the average wind in a layer 1,000 feet thick centred at that height.
e.g., the average wind in the layer between 1,000 and 2,000 feet is taken as the wind at the level 1,500 feet.

5. In the preparation of summaries for airship purposes, there have been one or two cases of high-level stations overseas under the control of the Meteorological Office. In the case of such stations (if over 1,000 feet altitude), the levels 3,000 feet, 6,000 feet and 10,000 feet in the upper-wind summary have been taken as above mean sea level instead of above station level, since it is desired to have wind charts for given levels in the free atmosphere independent of the contours of the ground below. Further when charts of upper winds are prepared it is intended to include, in addition to the wind-roses, the computed mean isobars at the corresponding levels. On the other hand the level of 1,500 feet above the surface of the ground is approximately that at which the free-air wind is first encountered and as a supplementary chart showing such data may also be useful, summaries for this height above ground have been made for high as well as low-level stations.

6. The I.C.A.N. resolution is framed in terms of km. per hour as unit of velocity. Below is given a table shewing the corresponding limits of velocities with the units of the metre per second and the mile per hour.

| I.C.A.N. limits of velocity km/hr. | Corresponding limits in m/sec. | Corresponding limits in mi/hr. |
|---------------------------------------|-----------------------------------|-----------------------------------|
| 5 or less | 1 or less | 3 or less |
| 6 to 25 | 2 to 7 | 4 to 15 |
| 26 to 50 | 8 to 14 | 16 to 31 |
| 51 to 75 | 15 to 20 | 32 to 47 |
| over 75 | over 20 | over 47 |

7. The I.C.A.N. proposes the use of 1300 G.M.T. as the standard hour for which data should be collected. In the regions of the Mediterranean Sea, Egypt and Iraq, it has been found that there were far more data available at 0800 local time. This hour has therefore so far been used in those localities with a tolerance of an hour or so in either side. An incidental advantage in using this hour is that, with single-theodolite observations, it is important to avoid errors due to convection currents which are far more frequent at mid-day than early in the morning. Whatever hour is selected, all observations used in the summary are for that hour only, (with the tolerance stated above).

8. A copy of Form 2325 (Form used for upper wind summaries) is attached, the classification of direction by eight points (N. meaning the range from $337\frac{1}{2}^{\circ}$ to $22\frac{1}{2}^{\circ}$ and so on) being in accordance with the I.C.A.N. resolutions.

Form 2325.

AIR MINISTRY; METEOROLOGICAL OFFICE.

FREQUENCY SUMMARY OF WINDS (SURFACE AND UPPER).

| STATION: | HOUR: | MONTH: | 192 . | | | | | | | |
|-------------------------------|-------|--------|-------|----|---|----|---|----|----------------------------|--|
| Surface (Feet above Ground). | | | | | | | | | | |
| Speed : m.p.h. | N | NE | E | SE | S | SW | W | NW | No. of cases of 0-3 m.p.h. | |
| 4-15 | | | | | | | | | | |
| 16-31 | | | | | | | | | | |
| 32-47 | | | | | | | | | | |
| 48 and over .. | | | | | | | | | | |
| Total .. | | | | | | | | | Total (all cases) | |

Note.—Similar tables are given for heights of 1,500 ft., 3,000 ft., 6,000 ft., and 10,000 ft.

* Annex G to the Convention relating to the regulation of Aerial Navigation dated 13th October, 1919, and later revisions.

C.E.M. 14/1929.

APPENDIX III.—METEOROLOGY AND THE INTERNATIONAL COMMISSION FOR AIR NAVIGATION.

BY LIEUT.-COL. E. GOLD,
Assistant Director, Meteorological Office.

At the end of the war it was realised that the great development of aircraft which had taken place during the war would be followed by a corresponding development of civil flying and that much of this flying would be international in character. It was recognized that the establishment of regulations of universal application would be in the interests of all concerned in such flying, while it was at the same time clear that no complete system of such regulations could be established without experience of the problems and difficulties arising in the actual operation of international air routes. Nevertheless, some principles and rules were sufficiently clearly indicated to warrant their adoption at that time. Accordingly 27 countries, represented at the Peace Conference, appointed plenipotentiaries to prepare an International Air Convention during the Peace Conference at Paris in the spring of 1919. The British Empire was represented by six plenipotentiaries for the United Kingdom and for the Dominions of Canada and New Zealand, the Commonwealth of Australia, the Union of South Africa, and for India.

During the preparation of this Convention it was realised that meteorology was one of the factors in civil aviation for which international co-operation and co-ordination were essential. A Sub-Commission was therefore appointed to consider the provisions in regard to meteorology which should be incorporated in the air Convention. This Commission met in Paris in April/May, 1919. There was neither time nor opportunity for consultation with the Meteorological Offices throughout the world; and the International Meteorological Organization had been practically suspended during the war. Accordingly the Sub-Commission based the recommendations which it made very largely on the recommendations which had been adopted at a meeting in the Meteorological Office, London, in December, 1918, when representatives of the military meteorological services of France, the United States of America and Britain had met under the Chairmanship of the then Director of the Meteorological Office, Colonel Sir Henry Lyons. At that meeting provisional agreement had been reached on the details of the more important changes in specifications and codes which the experience of the war had shown to be desirable.

The result of the Sub-Commission's work is shown in Article 35 of the International Air Convention of 1919 and in Annex G of that Convention. The relative portion of Article 35 reads

"The High Contracting Parties undertake as far as they are respectively concerned to co-operate as far as possible in international measures concerning

(a) The collection and dissemination of statistical, current, and special meteorological information, in accordance with the provisions of Annex G;"

The Air Convention of October, 1919, was duly ratified by nine of the signatory States, in addition to the British Empire,* of which all the members, viz., Great Britain, Canada, Australia, South Africa, New Zealand, Irish Free State and India, have ratified the Convention and are "contracting States," and the International Commission for Air Navigation, provided for in Article 34 of the Convention, came into being in 1922. The first session of the Commission was held in Paris on July 11-28, 1922. At that meeting, which was opened by M. Poincaré, President of the French Republic, the Commission adopted regulations for its own organization and procedure. The regulations of special interest to meteorology were article 10—"decisions entailing alterations to Annex G of the Convention shall be passed by a majority of three-quarters of the total possible number of votes, that is, the total number of votes that could be given if every State were present"—and Article 15, which refers to the appointment of sub-commissions for the examination of certain questions referred to them by the Commission, as well as of other questions relating to international aerial navigation which may be within their sphere. It was decided to appoint a sub-commission on meteorology with not more than one member from each contracting State. The first Sub-Commission consisted of representatives from Belgium, the British Empire, France and Japan, and the Commission referred to it the revision of Annex G of the Convention.

The Sub-Commission decided practically from the outset to make its proposals for a revised Annex G in agreement with the decisions of the International Meteorological Organization in regard to those questions on which the International Meteorological Organization had taken decisions. There were, however, questions dealing more particularly with the requirements of aviation which had not come before the International Meteorological Organization, and in regard to these questions the Sub-Commission had to be guided by the advice and experience of those engaged in international air navigation and in supplying meteorological information for such navigation.

The revision of the Annex proved by no means an easy problem, and it was not until October, 1925, at the 9th Session of the International Commission for Air Navigation that the revision of the Annex was adopted. It was printed in three languages, English, French and Italian, in Official Bulletin No. 9 of the International Commission for Air Navigation, and covers 22 pages. The introductory letterpress consists of four sections dealing with

- the Classification of Information,
- the Exchange of Information,
- the Exhibition of Information at Aerodromes, and
- the Meteorological Organization of International Airways.

The remaining part of the Annex is taken up with forms for statistical summaries, specifications of codes, detailed instructions for the exhibition of information at aerodromes,† arrangements for special warnings of storms and thunderstorms, and the scheme of ground signals to indicate to aircraft passing over an aerodrome the existing weather at neighbouring stations.

* At present the British Empire has only one vote on the Commission.

† This was an entirely new section and the form eventually adopted was based upon the form developed by the French Meteorological Service.

In addition to the revision of Annex G the Sub-Commission also considered the provision which should be made for meteorology in the examinations for air navigators' certificates. The results are shown in Section V of Annex E of the Convention. For a second-class certificate the schedule is

"Meteorology. Principles of the various meteorological observations. Arrangements for the issue of meteorological reports for aviation. Principles of forecasting; construction and interpretation of synoptic charts."

and for the first-class certificate

"Meteorology. More advanced knowledge of the subjects detailed in the schedule for second-class certificate."

This schedule is expressed in terms broad enough to make it applicable generally and there is nevertheless a sufficient indication of the kind of meteorological knowledge which a navigator should have if he is to benefit by it in his work.

The Sub-Commission shared also in the preparation of the specification of the international standard atmosphere for securing a uniform basis for the graduation of altimeters. This is given in the Official Bulletin of the Commission, No. 7, page 34, and it is reproduced approximately in Air Publication 1173, a copy of which is attached to this memorandum.

Since 1925 the Sub-Commission has continued the study of further questions on which agreement could not be reached until further experience had been gained, and it has recommended amendments of the provisions of the Annex where experience indicated that amendment was desirable.

The principal changes since the edition of October, 1925, have been the extension of the arrangements for warnings of dangerous phenomena to include warnings of fog or bad visibility, of low cloud, of snow and of gale. Arrangements have also been included for corresponding reports of improvement of the weather. These reports are essential for the safe and economic operation of an international airway. Provision has also been made for the issue of corrections to the readings of altimeters arising from the variation of pressure during a flight. This variation arises partly from the change of pressure with time and partly from the change of pressure with distance. This section was added on the initiative of Capt. Entwistle.

The last addition to the Annex has been the inclusion of a code for short-period forecasts for aviation. This code was subjected to a lengthy period of trial in England and France and it was adopted at the last meeting in Brussels in March of this year. The code itself gives a very good indication of the requirements of a forecast for aviation and the code adopted in the Annex is based essentially on the code developed by the Aviation Service Division of the Meteorological Office.

The main function of the Meteorological Sub-Commission of the International Commission for Air Navigation is to secure standardization of methods. The advantage of such standardization is obvious: perhaps more obvious in Europe than in one of the great Dominions, because air navigation in Europe necessarily involves flying from country to country as distinguished from flying within the confines of a single administration.

The general practice of the Sub-Commission has been to reject proposals advanced solely on a theoretical basis and to accept and recommend to the Commission only those proposals which have been subjected to the test of experience. Up to the present the experience has been mainly that of Europe and North Africa, an area large enough to secure a reasonable representation of the more important meteorological conditions of the globe but by no means of all the conditions of importance for aviation. Moreover, experience with airships has been very limited, and it may well be that in regard to these, further extension and revision of the meteorological provisions of the Convention will be found desirable.

The recommendations of the Sub-Commission after they have been approved by the Commission are incorporated in the Official Bulletin of the Commission. Approval by the Commission is secured in practice only if (1) there is practical unanimity among the members of the Sub-Commission, (2) the proposals are of recognised value in the eyes of those concerned with the practical aspects of aviation.

After this approval has been gained the meteorological provisions secure all the advantages of the Commission's support and of its organization for bringing its resolutions to the knowledge of those concerned with aviation: and although none of the meteorological arrangements are strictly obligatory, their moral sanction is undoubtedly increased by their direct promulgation as part of the proceedings of the International Commission for Air Navigation.

So far the only representative of the British Empire on the Meteorological Sub-Commission has been a representative of Great Britain and Northern Ireland. Each Dominion is entitled to have a separate representative on the Sub-Commission. Hitherto, as the British representative, I have endeavoured to keep the Dominions' meteorological services informed of the work of the Sub-Commission, but that cannot be regarded as a satisfactory *permanent* arrangement. In the earlier years of the existence of the Commission, the Sub-Commission met at least twice a year, but recently the meetings of the Sub-Commission have tended to be not more than once a year. It seems probable that in the future the meetings will tend to become still less frequent when agreement has been reached on the main forms of presentation and exhibition of meteorological information, and it may be possible for each Dominion to send a direct representative of their own meteorological service to these less frequent meetings of the Sub-Commission. It would be of little use to have on the Sub-Commission representatives who were not meteorologists; the work, necessarily requires a thorough understanding of technical meteorological details.

It is in the highest degree desirable that the work of the Sub-Commission should be co-ordinated with the work of the International Meteorological Organization. That organization deals with International Meteorology in all its aspects while the Sub-Commission has to deal with the problems of meteorology from the point of view of its application to a specialised branch of human activity; but it is far and away the greatest application which has developed in recent years, and only to be compared in importance with those original applications to the safety of life at sea and to the economic life of man, as represented by agriculture and water supply, for which meteorology was first organized.

Air Publication 1173.

Regulations Governing the Graduation of Altimeters.

ADOPTION OF AN INTERNATIONAL STANDARD ATMOSPHERE.

1. The altimeters of aircraft are to be graduated on a uniform basis in accordance with the formulæ given below.
2. These formulæ enable values of pressure and temperature of the standard atmosphere to be calculated from height. They are approximate, as they do not allow for any local causes of variation to which the data may be subject.
3. The same formulæ will be used whenever it is necessary to convert experimental measurements made in aircraft to atmospheric conditions that make them capable of being compared with each other.
4. Altimeters having an adjustable zero are to be graduated in such a manner that the height scale is uniform.

DEFINITION OF INTERNATIONAL STANDARD ATMOSPHERE.

5. It will be assumed that the air is dry and that its chemical composition is the same at all altitudes; the composition in volume is approximately as follows: 78.03 per cent. nitrogen, 20.99 per cent. oxygen, 0.94 per cent. argon and 0.04 per cent. carbon dioxide. The value of "g" will be taken uniformly as 980.62 in c.g.s. units.
6. It will be assumed that at mean sea level the temperature is 15° C. and the barometric height, reduced to 0° C., 760 mm. of mercury.
7. Under these conditions the atmospheric pressure is 10,332 kg. a square metre (1013.2 millibars) and the weight of a cubic metre of air is 1.226 kg.*
8. It will be assumed that, for any altitude z , measured above mean sea level and between 0 and 11,000 metres, the variation of the temperature θ_z of the air is as follows:

$$\theta_z = 15 - 0.0065z.$$
9. It will also be assumed that, for all altitudes above 11,000 metres, the temperature of the air is constant and equal to -56.5° C.
10. It follows that, for any altitude z measured above mean sea level and between 0 and 11,000 metres, the barometric pressure p_z , the specific weight a_z and the specific mass ρ_z of the air will vary according to the following equations:—

$$\frac{p_z}{p_0} = \left(\frac{288 - 0.0065z}{288} \right)^{5.256}$$

$$\frac{a_z}{a_0} = \left(\frac{288 - 0.0065z}{288} \right)^{4.256}$$
 and

$$\frac{\rho_z}{\rho_0} = \left(\frac{288 - 0.0065z}{288} \right)^{4.256}$$
11. Similarly, for all altitudes above 11,000 metres, the foregoing equations will be replaced by the following:—

$$\log_{10} \frac{p_{11000}}{p_z} = \log_{10} \frac{\rho_{11000}}{\rho_z} = \log_{10} \frac{a_{11000}}{a_z} = \frac{z - 11000}{14600}$$
12. The following table shows the values of temperature, pressure and density at heights from 0 to 11,000 metres. These values are derived from the equations given in paragraph 10 above.

Temperature, pressure and density at heights up to 11,000 metres.

| Height in kilometers. | Temperature. | | | Pressure in millibars. | Density in grammes per cubic metre. |
|-----------------------|--------------------|----------------------|----------------------|------------------------|-------------------------------------|
| | Degrees, Absolute. | Degrees, Centigrade. | Degrees, Fahrenheit. | | |
| 0 | 288 | 15 | 59 | 1013.2 | 1.226 |
| 1 | 281.5 | 8.5 | 47.3 | 898.6 | 1.112 |
| 2 | 275.0 | 2.0 | 35.6 | 794.8 | 1.007 |
| 3 | 268.5 | -4.5 | 23.9 | 700.9 | 909 |
| 4 | 262.0 | -11.0 | 12.2 | 616.2 | 819 |
| 5 | 255.5 | -17.5 | 0.5 | 540.0 | 736 |
| 6 | 249.0 | -24.0 | -11.2 | 471.6 | 660 |
| 7 | 242.5 | -30.5 | -22.9 | 410.4 | 590 |
| 8 | 236.0 | -37.0 | -34.6 | 355.8 | 525 |
| 9 | 229.5 | -43.5 | -46.3 | 307.2 | 466 |
| 10 | 223.0 | -50.0 | -58.0 | 264.1 | 413 |
| 11 | 216.5 | -56.5 | -69.7 | 226.1 | 364 |

* More exactly 1.2257 kg.

C.E.M. II/1929.

APPENDIX IV.—WEATHER TELEGRAMS FROM REPORTING STATIONS.

By A. WALTER

Director, British East African Meteorological Service.

The existing international weather code for telegraphic reporting stations was drawn up, presumably, for the requirements of stations in high latitudes. Within the tropics, in East Africa at least, certain details appear to require modification and it is possible that other tropical services have experienced some of our difficulties.

In high latitudes the diurnal changes in the various elements are masked to a considerable extent by the phenomena of the weather system passing over the station; in tropical latitudes the diurnal change, in practically all elements, dominates the changes due to the weather systems. For instance, the barometric tendency, as usually telegraphed, is almost invariably the same from day to day, except in the neighbourhood of cyclonic activity. At 8h, the wind is, generally, nearly calm and hence neither the velocity nor the direction at this hour are significant. In the Highlands of East Africa visibility means very little as it changes rapidly between 8h and 10h.

The characteristics of the diurnal variation appear to be an important factor in determining the general weather type at the station of observation (apart, of course, from its position on the synoptic chart) and it is suggested that an attempt should be made to introduce two codes for telegraphic reporting stations, one applicable to high latitudes and the other to tropical latitudes, at the discretion of the directors of the services concerned. The report from tropical stations to be so devised as to give an indication of the characteristics of the diurnal variation of the previous day.

If no agreement has been reached concerning telegraphic reports of upper currents for the air services I suggest that the form which these telegrams should take should be considered. The occasional telegrams issued up to date by the East African service have been cumbersome, because the exact requirements of the air service are not known and the flying altitudes have not been communicated to us.

If this matter is to be the subject of discussion at the Conference, the telegraphic code should provide for an indication as to whether a reversed current has been observed and its probable height. Capt. Black, who recently flew over the East African route, bearing in mind the results of observations which had been communicated to him at the Nairobi station, informed me that he was able to rise out of a strong head wind into a favourable following wind.

It is, of course, possible that any predetermined code may have to be modified when more detailed results of upper air movements have been secured over the region of East Africa lying between 6° S. and 6° N., but it does not appear advisable to postpone the adoption of some measure of uniformity in the telegraphic reports for the use of the air service, which it is anticipated will commence to function some time during 1930.

APPENDIX V.—MARINE METEOROLOGY.

NOTES BY CAPTAIN L. A. BROOKE SMITH, R.N.R.,
Marine Superintendent, Meteorological Office, London.

A memorandum entitled "Marine Meteorology" dated January 15th, 1929, dealing with all items then upon the agenda concerning marine meteorology, was circulated during that month to those known to be attending this Conference.

Since then the International Conference on Safety of Life at Sea, representative of 18 maritime countries, including Great Britain, Australia, Canada, India and Ireland, has signed the International Convention for the Safety of Life at Sea, 1929.

In view of the fact that the International Commission for Maritime Meteorology meets in Copenhagen in September, 1929, it was found necessary to formulate proposals for putting into effect that part of the Convention which deals with marine meteorology.

These proposals are contained in a memorandum entitled "Marine Meteorology and Safe Navigation," dated June 4th, 1929, and a copy is attached to these notes for the information of those attending this Conference, Annex A.

For the convenience of the Conference the matters dealt with in my original memorandum dated January 15th, 1929, are set out in three notes, one for each of the three meetings allotted to Marine Meteorology.

Before proceeding may I be permitted to make a personal observation as a seaman and a Colonial by birth, charged with the duty of carrying on the work of the London Marine Division, in supervising marine meteorological work in the Merchant Navy. I realize how important the development of marine meteorology has become to the whole Empire.

It is mainly due to the voluntary work of seamen, conducted by my predecessors and Commander Maury of the United States Navy, the father of organized marine meteorology, that passages between the old country and the Dominions under sail were reduced by some 22 per cent. in time; and that with wireless communication, steamships and motor vessels navigate with the economy and safety which they now do.

It has seemed that it was not fully recognised that it was mainly due to the officers of the Merchant Navy that Great Britain has in the Marine Division the most perfect collection of marine meteorological observations over the oceans which exists; and that the officers of the Merchant Navy if properly handled will continue to provide not only written records of data, but apply the knowledge which has accrued from the work of their predecessors to navigation by means of wireless telegraphy communication, and while so doing, supply the shore services with adequate information.

Much of the data collected in the Marine Division has never been extracted and fully utilized, and remains in the logs as it was received.

It seems to me, and I plead the privilege of a Colonial in saying this, that the British Dominions may perhaps consider that the time has arrived when they can co-operate with the Home Marine Division in putting to the best use this great store of data accumulated in logs. Also in helping to organize the service of marine meteorological intelligence in all oceans which the knowledge and experience of seamen with wireless communication makes possible.

During the Conference, and particularly after each of these meetings, I hope those interested in marine meteorology will visit the Marine Division, where we will be only too pleased to show you details of our organization, and particularly the Hollerith system of extraction, computation, and printing of marine data, and also to provide each member of the Conference who requires them with a complete set of the forms used in the Marine Division and in ships at sea, including the "Meteorological Log" and the "Marine Observer's Handbook."

NOTE I.

FIRST MEETING TO BE HELD ON SATURDAY, 24TH AUGUST, 1929.

GENERAL ORGANIZATION. THE METEOROLOGICAL LOG. COLLECTION, COMPUTATION, AND EXCHANGE OF MARINE METEOROLOGICAL DATA, INCLUDING OCEAN CURRENTS.

General organization.—The Marine Division of the London Meteorological Office has been established for 75 years.

It organizes and maintains a fleet of about 500 regular observing ships, the officers of which are for the time being the Corps of Voluntary Marine Observers. (See Fleet List in the latest number of *Marine Observer*). Their activities extend wherever the British Ensign is carried at sea, and they are so selected that their sailing schedules provide as far as possible a constant network of observation over all oceans.

The functions performed are:—

- (1) The logging and return of four hourly meteorological observations, using tested instruments lent by the Meteorological Office—number, about 115 merchant ships and 10 H.M. ships;
- (2) the recording and return of weather observations made twice daily, and current and other observations made as necessary, ships' instruments being used—number about 330;
- (3) the reporting by W/T of special coded observations by North Atlantic liners to the London Meteorological Office and the United States Weather Bureau, using tested instruments lent by the Meteorological Office—number about 30;
- (4) the recording and reporting of special local observations for the purposes of forecasting, and for training young officers as marine observers, etc., using tested instruments lent by the Meteorological Office—number about 15;
- (5) the reporting by W/T of observations taken once or twice daily as a matter of routine at the same G.M.T. as those of the nearest coast, and broadcast to "all ships," and made to such National Dominion or Colonial shore services as require them. This service is performed by selected ships, that is to say, ships included in (1), (2) and (3) which have wireless telegraphy and at least a mercurial barometer of which the error is known, and which is sufficiently accurate—number at present 292, steadily increasing.

Regarding (3) and (5) an improved organization under an international scheme to conform to the Convention for Safety of Life at Sea is outlined in Appendix I.

To regulate this voluntary work and produce published results there is a Marine Superintendent who is a master mariner appointed from the corps of voluntary marine observers, and he is assisted by the following full time staff, and agents who receive small fees for occasional duties:—

Three nautical assistants, two in London, and one in Liverpool.

One professional meteorological assistant.

Twelve clerks, eleven in London and one in Liverpool.

Eleven agents (retired master mariners, specially interested in marine meteorology, seven at ports in the British Isles and four at ports in the Dominions).

Information is desired as to what extent the British Dominions and Colonies are organized for marine meteorology. Consideration is also desired as to what extent each can give assistance in furthering the work of marine meteorology, which has been instrumental in promoting safe, economical and quick communication by the British Merchant Navy between the ports of the British Empire; and which work is not only essential for this purpose, but is required to further aerial communication for the British Empire, and generally to advance meteorological science.

The first paragraph of Article 35 of the Convention for Safety of Life at Sea provides an agreement whereby it should be unnecessary for foreign meteorological services to require written returns from British ships. At present there is some duplication of work and therefore some hardship to officers of the British Merchant Navy. Copying and exchange should be effected ashore and not on board ship where the work is done voluntarily by navigating officers.

The table of the world's tonnage given in Annex A indicates, as is well known, that the tonnage registered in the British Dominions and Colonies is small. There are not sufficient Dominion or Colonial registered ships suitably disposed along the ocean trade routes for organized meteorology, and therefore a total was allotted to the British Empire as a whole, the numbers to be maintained by the Dominions being left for arrangement. If therefore, until the Dominions and Colonies have a greater tonnage, the meteorological services of the five great Dominions, with neighbouring Colonies, would undertake to maintain between them 100 of the 356 selected ships (which is the British Empire proportion) and such regular other observing ships as are necessary, from ships on their own register, and those on the Home register which are *not* required for the London Marine Division's list, there would not be the duplication of work in British ships which now exists owing to Dominions and Colonial services requesting returns from ships which are on the London list as regular observing ships.

At the present time there is not a single foreign ship left on the London Marine Division list, but there are a few British ships registered in the Dominions still on the list. The agents have been instructed to replace these on the first suitable opportunity, and to refer them to their own Dominion or Colonial meteorological service.

With the scheme outline for "selected ships" of all nations to report to all ships and selected shore stations upon a uniform plan, and with the Hollerith system of mechanical extraction, computation, and printing of marine data, all parts of the British Empire should mutually benefit by co-operating upon agreed lines in an international scheme.

Such a general organization cannot be established at a Conference, but a beginning may be made, and if the Dominion services can see their way to adopt uniform methods, where possible, an efficient general organization will be the outcome.

It should be noted that our experience is that to obtain a given number of "selected ships" about double that number of regular observing ships for all purposes is required to be maintained.

The "Meteorological Log."—This is based on international agreements, dating back to the International Conference convened at the suggestion of Commander M. F. Maury, U.S.N. in 1853, and modified by the 1874 International Conference.

The log now in use is described and illustrated in the "Marine Observer's Handbook," 4th Edition pages 77 to 82; and the Beaufort scale of wind force, Beaufort notation of weather, sea and swell and visibility scales, description and illustration of clouds, and instructions for keeping the log are also included. Special attention is invited to the Douglas sea and swell scale which is considered more suitable for sea service than the scales now in use, see Annex A.

The weather observations are entered at the relief of the officer of the watch, i.e. 4 a.m., 8 a.m., noon, 4 p.m., 8 p.m., and midnight, ship's time, which may be apparent time at ship or zone time.

These logs being the outcome of 75 years' experience form the basis on which the Hollerith data card and code has been introduced. They are the backbone of all marine meteorological work, and careful distinction is necessary between the 'Meteorological Log' and various forms used for obtaining written records of observations, and which are often erroneously referred to as 'Meteorological Logs'.

At the end of the 'Meteorological Log' specially ruled pages for the entry of routine wireless weather reports to all ships and to specified stations are provided, and this has proved invaluable in developing the "selected ship" service.

As a subsidiary, we use the 'Ship's Meteorological Reports', Form 911, based on the arrangement of the "Meteorological Log" for recording weather observations twice daily and current and other observations as necessary; also at present used by "selected ships" which do not carry Meteorological Office instruments, but have their own reliable mercurial barometers for recording routine wireless weather reports in similar columns to those provided at the end of the Meteorological Log. When the "selected ship" world-wide wireless meteorological reporting service is developed, the use of this form as it now is will be less necessary, and probably a more convenient edition of this Form will replace it.

For the instrumental equipment of observing ships see page 2 of the 'Marine Observer's Handbook.'

A special form (905) for returning observations of ships which are not regular observing ships, from the ships' deck log, when hurricanes, cyclones or typhoons are encountered is used. This is purely additional, and does not form part of the work of regular observing ships, their observations at all times being entered in the respective meteorological logs or Forms 911.

Collection, computation, and exchange of marine meteorological data.—The collection of marine meteorological data having been made for 75 years with tested instruments, there is a great store in the Marine Division, and if such of this as is entirely suitable can be extracted in such a manner that it can be made available to the meteorological services of the British Empire, reliable normals of the most important meteorological elements over all oceans would result, as well as data be provided for investigation and research.

A scheme has been worked out with this in view, and to provide ocean meteorological charts for navigation on a uniform plan and scale for all oceans, the Hollerith system being used with a special series of cards containing only the most essential elements. Up to the present, however, with the means at the disposal of the Home Service only, this valuable marine meteorological capital has lain dormant for the greater part of the North Atlantic and the North and South Pacific.

If the combined requirements of the British Empire services justify the expense of extracting and printing by the Hollerith system these data, marine meteorological charts, normals, and standard data could be made available for all oceans in about 6 years, thus giving some return to British seamen for their 75 years voluntary work, and making full use of this dormant capital.

It is highly desirable that in future, data collected should be made readily available and interchangeable, and if the information already collected up to the Great War, referred to above, is made available in working form, future accurate data collected will be more useful and productive to science.

In future collection it is desirable that as far as possible there should be uniformity in the British Empire. The use of tested instruments is necessary.

The Hollerith system of mechanical extraction, computation, and printing is strongly advocated. This method has been in use in the London Marine Division since 1921, and the Dutch adopted a similar system a year later.

As notified in the March, 1929 *Marine Observer* circulated on February 6th, 1929, and in my original memorandum dated January 15th, 1929, in agreement with Holland the code will be slightly altered on January 1st, 1930, in order that the printing of the coded observations from the cards may be free from all ambiguities.

A full description of this system, the machines, and the code at present in use is given on pages 10-14 of the January 1928 *Marine Observer*, Volume V. No. 49. In the March, 1929 *Marine Observer* pages 52 and 57 to 59, the modifications of the code to be brought into force on 1st January, 1930, are given, also a sample of the new card and of tables mechanically printed.

Ocean currents.—The collection of ocean-current data is effected by means of the 'Meteorological Log' and Form 911. This information is also broadcast by "selected ships" in their routine reports to all ships at the discretion of the Commander.

The usual observation of set and drift of current is a purely navigational matter, requiring skill, judgment and knowledge, the outcome of responsible navigational experience at sea. The set and drift is obtained by difference between observed and dead reckoning positions at the end of a run. It is not possible to fix by rule the period of observation, but usually this should be not greater than 24 hours, noon to noon; and the best results may be obtained between twilight stellar fixes. It is an advantage if the total set and drift between noon and noon, as well as the set and drift between dawn and evening stars, and evening stars and dawn, are entered.

Special attention is invited to the notes for current observation given to marine observers on the flyleaf of the 'Meteorological Log'.

Observations of currents are not punched on Hollerith cards, being few by comparison with the weather observations, and requiring special treatment. They are extracted into the data books no longer used for weather observations. For compilation they are copied on to Form 1100, specially ruled for the purpose; and carbon copies are made so that as currents are compiled and charted, the data used are made available for exchange and supply to other services requiring them.

Commencing in 1924 with the establishment of the *Marine Observer*, and using observations from 1910 to date, the currents are being charted, in sections, along all the main trade routes of the oceans; and these section charts will in time provide the roses, arrows and other graphic or tabular information of currents for making atlases on a uniform plan and a uniform scale (2 inches = 10° of longitude; arrows of roses, 2 inches = 100 per cent frequency). The year 1910 for earliest observations used was chosen because navigation had become far more accurate then, and consequently the ocean-current data are more reliable than those of earlier years.

Exhibits.—All the work dealt with in Note 1, except the actual working of the Hollerith electrical sorting, tabulating and printing machines, will be on exhibit in the Marine Division from 12.30 p.m. to 1 p.m. this day, when those desiring a sample set of forms will be supplied.

NOTE 2.

SECOND MEETING TO BE HELD ON MONDAY, AUGUST 26TH, 1929.

From 10 a.m. to 10.30 a.m. a demonstration of the working of the Hollerith machines with marine data will be given at the offices of the British Tabulating Company, General Buildings, Aldwych, W.C.2, about 100 yards from the Air Ministry and opposite Australia House.

Ships wireless weather telegraphy. The "selected ship" and organization.—Since my original memorandum of January 15th, 1929, the International Conference on Safety of Life at Sea have agreed in their Convention that the Countries parties thereto will arrange for selected ships to take and report observations to other ships and meteorological services; and will provide coast stations for the reception of these messages. They also agree to make every endeavour to obtain uniform procedure, and to refer meteorological questions to the International Meteorological Organization.

As stated in my Introductory Notes, proposals regarding the subject on to-day's agenda have been forwarded for consideration by the International Commission for Maritime Meteorology; and that part of Annex A, under the heading of "A Brief Outline of the Scheme for Selected Ships Routine Meteorological Wireless Telegraphy" on pages 5 to 10 gives concise information of what is proposed. There remains the question of the number of "selected ships" which the Dominions will maintain, and how we can assist them in organizing on these lines. It would greatly assist us if each Dominion could publish a monthly list of their "selected ships" for general information; if not, possibly we could publish supplementary lists for the Dominions at the end of our own fleet list in the *Marine Observer*. The publication for general information of all fleet lists of British Dominion and Foreign national regular observing ships is highly desirable, and it will do much to encourage good work at sea and to check duplication and unnecessary work. It will be of great assistance if the wireless stations indicated on the chart of the World as suitable for receiving routine reports from selected ships (and particularly those for C.W. reception) can be confirmed, or names and particulars of more suitable stations, suitably disposed, be provided.

One of the most difficult problems which will have to be considered in connection with selected ships is that of the code to be used in transmitting the results of the observations both to the shore and to surrounding ships. At present the London Meteorological Office has adopted a code for use on the trans-Atlantic routes but this code has not been generally adopted for selected ships, which use a plain language message in standard form. The ideal to be aimed at would be a code to be used by all classes of ships in all parts of the world, which code should, if possible, also be adapted for use in the "weather shipping bulletins" issued from the coast. The Commission for Synoptic Weather Information at their meeting in London in May, 1928, proposed a ships' code consisting of 7 five-figure groups and have circulated their proposal to the directors of the various meteorological services for consideration. This proposal will be finally considered by the International Meteorological Conference at Copenhagen. It is highly desirable that the delegates to the Conference of Empire Meteorologists should be able to have common policy when the matter is discussed at Copenhagen. In Annex B are given details of the codes at present in use.

NOTE 3.

THIRD MEETING TO BE HELD ON TUESDAY, AUGUST 27TH, 1929.

Weather shipping bulletins, wireless gale and hurricane warnings, visual gale and hurricane warnings.—In Annex A will be found Article 35 of the International Convention for Safety of Life at Sea, in paragraph (a) and (b) of which it is laid down that the countries party to the Convention will issue wireless and visual warnings of gales, storms and tropical storms, and also issue daily weather shipping bulletins forwarded to the International Commission for Maritime Meteorology, which contain guiding principles advocated after a long and continuous consultation with masters of ships trading to all parts of the world. The question of uniformity of visual gale, storm and tropical storm warnings has not been referred to in Annex A.

I beg to submit the following observations for the consideration of the British Empire Meteorological Conference.

Wireless telegraphy and wireless telephony are proving of inestimable value to shipping and seamen as a means of the communication of warnings of gales and hurricanes; but this means of signalling warnings of heavy weather can no more entirely supersede visual signalling than can the lead be superseded by the wireless direction finder, or beacon lights be superseded by radio-beacons. A wireless signal is a momentary affair and is not often used in harbour, whereas a visual gale or hurricane warning signal remains to be seen all the time it is flying.

The International Convention for Safety of Life at Sea lays down that appropriate signals should be displayed at coastal points, and in all matters regarding meteorology in safe navigation every endeavour is to be made to obtain a uniform procedure. There are a great many different systems of visual gale and hurricane warnings at present in use; some of these were established long before the use of wireless telegraphy, and go into greater detail than is now necessary; and others are inappropriate for modern requirements. The visual signals at present recommended by the International Meteorological Committee (see Annex C) are not suitable for all parts of the world.

Not only are these signals necessary for small craft but they are necessary for all types of vessels to communicate the most essential rudimentary information for navigation and pilotage, including mooring and anchoring in coastal waters. They should be such that they give brief information for the educated seaman, and constitute a warning of danger from wind to the native fisherman, amateur, or other seafarer not versed in the Law of Storms.

They should be such that the symbols are easily distinguished with the same meaning in both north and south latitudes, require a minimum number of symbols and hoists, and there should be no ambiguities regarding the directions of the wind.

With a view to showing that it is possible to devise a code of visual gale and hurricane signals for use by day to meet all the above requirements, and in the hope that it may lead to a still better code for both day and night being universally adopted, I have drawn up what I believe to be a possible code. This code was worked out in consultation with a number of masters of ships experienced in signals and the Laws of Storms in all parts of the world, and skippers of fishing craft; and can be demonstrated if desired.

In Annex D references are given to Notes, Articles, and literature regarding the subjects outlined in these notes, which it is hoped may be of assistance.

Exhibits.—From 12.30 p.m. to 1 p.m. the work of the Marine Division will be on view and a demonstration with model will be given there, for those who wish to see it, of the possible simple system of visual gale and hurricane signals for all coasts of the world referred to above.

ANNEX A.

Marine Meteorology and Safe Navigation.

MEMORANDUM prepared by Captain L. A. BROOKE SMITH, R.N.R., Marine Superintendent, Meteorological Office, London for discussion by the International Commission for Maritime Meteorology at their meeting in Copenhagen, September, 1929.

The International Conference on Safety of Life at Sea held in London, April to May, 1929, have included Articles in their convention which will, when ratified, impose greater responsibilities upon the marine meteorological services of the countries party to this convention, and the International Commission for Maritime Meteorology.

The Articles referred to are as follows:—

CHAPTER V.—SAFETY OF NAVIGATION.

Article 33.

The provisions of this chapter referring to ships, unless otherwise expressly provided, apply to all ships registered in a port of a country to which the Convention applies.

Article 34.

The master of every ship which meets with dangerous ice, a dangerous derelict, a dangerous tropical storm or any other direct danger to navigation is bound to communicate the information, by all the means of communication at his disposal, to the ships in the vicinity, and also to the competent authorities at the first point of the coast with which he can communicate. It is desirable that the said information be sent in the manner set out in Regulation XLVI annexed hereto.

Each contracting government will take all steps which it thinks necessary to ensure that when intelligence of any of the dangers specified in the previous paragraph is received, it will be promptly brought to the knowledge of those concerned and communicated to other administrations interested.

The transmission of messages respecting the dangers specified is free of cost to the ships concerned.

Article 35.

The contracting governments undertake to encourage the collection of meteorological data by ships at sea, and to arrange for their examination, dissemination and exchange in the manner most suitable for the purpose of aiding navigation.

In particular, the contracting governments undertake to co-operate in carrying out, as far as practicable, the following meteorological arrangements:—

- (a) to warn ships of gales, storms and tropical storms both by the issue of wireless messages and by the display of appropriate signals at coastal points;
- (b) to issue daily, by radio, weather bulletins suitable for shipping, containing data of existing weather conditions and forecasts;
- (c) to arrange for certain selected ships to take meteorological observations at specified hours, and to transmit them by wireless telegraphy for the benefit of other ships and of the various official meteorological services, and to provide coast stations for the reception of the messages transmitted;
- (d) to encourage all ship-masters to inform surrounding ships whenever they experience wind force of 10 or above on the Beaufort scale (force 8 or above on the decimal scale).

The information provided for in paragraphs (a) and (b) of this article will be furnished in form for transmission in accordance with Articles 31 (1), (3) and (5) and Article 19 (25) of the International Radiotelegraphic Convention, Washington, 1927, and during transmission "to all stations" of meteorological information, forecasts and warnings, all ship stations must conform to the provisions of Article 31 (2) of that Convention.

Weather observations from ships addressed to national meteorological services will be transmitted with the priority specified in Article 3, Additional Regulations, International Radiotelegraphic Convention, Washington, 1927.

Forecasts, warnings, synoptic and other meteorological reports intended for ships shall be issued and disseminated by the national service in the best position to serve various zones and areas, in accordance with mutual arrangements made by the countries concerned.

Every endeavour will be made to obtain a uniform procedure in regard to the international meteorological services specified in this Article, and, as far as is practicable, to conform to the recommendations made by the International Meteorological Organization, to which Organization the contracting governments may refer for study and advice any meteorological questions which may arise in carrying out this Convention.

The provisions of Article 34 are obligatory and are completed by regulations contained in an Annex to the Convention.

The provisions of Article 35 are for the encouragement of meteorology as an aid to navigation; and this Memorandum is submitted with a view to assisting the International Commission for Maritime Meteorology, in its forthcoming deliberations, to obtain a uniform procedure with regard to the International Meteorological Services specified in the Article.

REFERRING TO ARTICLE 35.

THE COLLECTION AND EXCHANGE OF MARINE METEOROLOGICAL DATA.

The collection of standard marine meteorological data is effected by the "Meteorological Log," with tested instruments lent for the purpose.

The arrangement of the columns of the log is based on the original drawn up at Brussels in 1853 modified by the International Maritime Meteorological Conference in London in 1874, with times of observation corresponding to those of the relief of the officer of the watch.

This arrangement is entirely satisfactory and a great store of reliable marine meteorological data has been accumulated by those countries which have adhered to it, continuing the use of tested instruments.

The international scales and notations for wind, weather and visibility are satisfactory. The scales for sea and swell require improvement, and it is suggested that the Douglas sea and swell scale, as under, be adopted:—

Admiral Douglas's Scale for Sea and Swell.

| SEA | SWELL | | | | | | | | | |
|---------------------|----------|------------------|------|----------|---------|------|-------|---------|------|------------|
| | No Swell | Low | | Moderate | | | Heavy | | | Con- fused |
| | | Short or Average | Long | Short | Average | Long | Short | Average | Long | |
| | | | | | | | | | | |
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0 Calm | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 |
| 1 Smooth | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 2 Slight | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |
| 3 Moderate | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 |
| 4 Rough | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 |
| 5 Very Rough | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 |
| 6 High | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 |
| 7 Very High | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 |
| 8 Precipitous | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 |
| 9 Confused | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 |

A short swell means a swell where the length or distance between each successive top of swell is small.

A long swell means a swell where the length or distance is large.

A low swell means a swell where the height between the lowest and the highest part of the swell is small.

A heavy swell means a swell where the height is great.

This scale was devised for use both with log books and wireless reports.

Exchange of marine meteorological data has been made easier by Great Britain and Holland by means of cards, upon which the observations from meteorological logs are punched mechanically. From these cards the observations can be mechanically computed and the observations can also be mechanically printed in code, so providing copies.

The arrangement of the elements on the cards is in accordance with the columns of the meteorological log.

Referring to Sections (a) and (b).—During the great developments which have taken place in the last 10 years in wireless gale, storm and tropical storm warnings, and in wireless weather bulletins, some cases have been brought to my notice by masters and officers where ambiguous or misleading wireless weather messages were alleged to have led to risk of safety, damage, or loss of ships. Clearness and precision are necessary.

I beg therefore to submit for consideration the following as necessary guiding principles.—

(1) That in all cases, clear, concise descriptions of weather signals be suitably published for the information of shipping and seamen; and that ample notice be given by means of Notice to Mariners of changes, before they are made.

Wireless gale, storm, and tropical storm warnings for shipping.—(2) That in the case of gales and storms in middle and high latitudes, a clear concise message should be used, specifying as far as possible the nature of the depression, its locality and movement, the wind direction, with changes, and a broad estimation of force, over the area or areas warned, distinction being made between a gale of force 8 and one of force 10 and upwards.

(3) That in the case of tropical storms, i.e., hurricanes, tropical cyclones, and typhoons, a clear concise message should be used, specifying as far as possible the latitude and longitude in whole degrees of the centre, its movement, and intensity of the storm. Such messages should clearly indicate when any parts of the information contained therein is based on deduction, without sufficient actual reported observations to verify position, movement, or intensity.

Routine wireless weather bulletins for shipping. (4) That these should be clear and concise, and that when practicable they should contain actual observations of a limited number of suitably disposed coast stations, salient points used for landfall being preferred.

The elements included should only be those necessary for the mariner. Information of visibility to seaward from the station in the International Scale in parts of the world where conditions of visibility vary, and those elements which are necessary for the construction of a simple weather chart in conjunction with "selected ships" reported observations, and for general information for safe navigation.

These elements are generally:—

Station, distinguishing number.

Wind, true direction and force.

Barometric pressure.

Weather.

Visibility.

Barometric tendency (change of barometer).

On coasts within the tropics, visibility may often be replaced with advantage by departure from the barometric normal for the time of day.

In addition to these actual observations, short-period forecasts for defined areas of wind and one or two other elements (preferably visibility) necessary for information in navigation are desirable.

A general statement of prevailing conditions, with general idea of pressure distribution, is an advantage.

A small selection of well disposed ships' reports repeated after the bulletin is useful. Brevity is necessary in all wireless weather signals.

Referring to Section C and § 4. (Priority of ships' weather reports).—The international organization of "selected ships" for routine wireless meteorological telegraphy has been the subject of study and report by General Delcambre's Sub-Commission (of which I am a member).

Since his report dated May, 1928, and the report of the Commission for Synoptic Weather Information, also of May, 1928, much further experience with "selected ships" in all oceans has been obtained, and study of this experience indicates that a definite schedule for the transmission of ships' routine meteorological reports is necessary, also that Resolution No. 3 of Paris Meeting and No. 5 of London Meeting (p. 17 of M.O. 309) concerning wireless apparatus of "selected ships" and the frequency of their reports may require modification before adoption by the International Meteorological Committee.

With a view to showing clearly the need for the proposed schedule, it is desirable to re-state in outline the scheme, with modifications found necessary.

A Brief outline of the Scheme for Selected Ships' routine meteorological wireless telegraphy.—This scheme provides on a voluntary basis for an international system under which selected ships, when at sea, make meteorological observations at fixed times G.M.T., and subsequently report these observations at fixed times G.M.T., to certain coast stations and to all ships; the main principles being that:—

(a) *Selected Ships* fitted for long-range transmission to address their reports to the appropriate shore station and use the wave-length allotted to that station; Berne and all concerned being notified that the information may be intercepted and used by all ships.

(b) *Selected Ships* not fitted for long-range transmission to address their reports to C.Q. (all ships) using wave length 600 metres spark, shore stations within range intercepting them as required.

(c) *Selected Ships* be limited to a certain total, the complement to be maintained by each maritime country party to the Convention on Safety of Life at Sea to be according to their proportion of the world's tonnage, steam and motor, of vessels of over 100 tons.

Since the report, the world's tonnage has somewhat altered, and the following table gives the latest information, together with the proportionate number of selected ships for each nation, including those not in the Convention.

The main points for consideration are as follows:—

(1) The number of messages required for this service is comparatively small, if efficiently organized.

(2) If not efficiently organized and limited the result has proved to be congestion of communication, wasted energy, expense, and consequent loss of efficiency.

(3) The marine meteorological code or form of message used must be universal throughout this marine meteorological service, simple and concise, giving only essential information. Masters of ships have not time to make and code such elaborate reports as are made by meteorologists.

(4) There are two classes of "Selected Ships" to be considered—

(a) Ships fitted with long-range, Type A1 apparatus, mostly mail liners, sailing and arriving at dates fixed by mail contract; termed "A Selected Ships."

(b) Ships fitted with short-range A2 or type B apparatus, including many passenger and cargo liners sailing according to an advertised programme; also a number of cargo vessels whose movements are irregular, termed "B Selected Ships."

(5) It is proposed that "A Selected Ships" should work a definite schedule under the control of specified coast wireless stations in parts of the world where there is congestion.

(6) The movements of a number of "B Selected Ships" are uncertain, and in some areas there will be more than are required to report. Control from coast wireless stations is impracticable; moreover, in some areas where there is not a great deal of shipping, and in certain seasons, it will be necessary for *other ships as well as "selected ships"* to make reports, and this applies particularly to hurricane, cyclone and typhoon regions, such as in the neighbourhood of Mauritius and Fiji.

TOTAL MERCHANT TONNAGE APPROXIMATE (STEAM AND MOTOR) OF THE WORLD (Vessels over 100 Tons Lloyds Register Book, July, 1928) AND NUMBER OF "SELECTED SHIPS" REQUIRED FOR MAKING W.T. WEATHER REPORTS, IN ALL OCEANS, WORLD WIDE.

| Country | Steamers and motor vessels | | Percentage of world tonnage | Number of selected ships required | Number of ships fitted for C.W. transmission |
|---|----------------------------|------------|-----------------------------|-----------------------------------|--|
| | Number | Gross tons | | | |
| Great Britain and Ireland .. | 7,810 | 19,754,001 | 31.7 | | |
| Australia and New Zealand .. | 613 | 709,030 | 1.1 | | |
| Canada (excluding Lakes) .. | 579 | 871,985 | 1.4 | | |
| Hong Kong | 124 | 309,376 | 0.5 | | |
| India and Ceylon | 138 | 175,400 | 0.3 | | |
| South Africa | 122 | 69,922 | 0.1 | | |
| Other Colonies* | 340 | 298,336 | 0.5 | | |
| Total | 9,726 | 22,188,050 | 35.6 | 356† | 182 |
| Argentina | 252 | 264,898 | 0.4 | 4 | — |
| Belgium | 230 | 488,219 | 0.8 | 8 | 6 |
| Brazil | 344 | 542,092 | 0.9 | 9 | 5 |
| Chili | 116 | 159,568 | 0.3 | 3 | — |
| Danzig | 33 | 127,568 | 0.2 | 2 | — |
| Denmark | 627 | 1,042,209 | 1.7 | 17 | 6 |
| Finland | 239 | 213,991 | 0.3 | 3 | — |
| France | 1,482 | 3,255,832 | 5.2 | 52 | 12 |
| Germany | 2,053 | 3,738,067 | 6.0 | 60 | 32 |
| Greece | 515 | 1,187,508 | 1.9 | 19 | — |
| Holland | 1,270 | 2,809,375 | 4.5 | 45 | 24 |
| Italy | 1,142 | 3,348,732 | 5.4 | 54 | 23 |
| Japan | 2,048 | 4,139,815 | 6.6 | 66 | — |
| Norway | 1,765 | 2,953,944 | 4.7 | 47 | 6 |
| Portugal | 169 | 219,337 | 0.3 | 3 | 10 |
| Russia (Soviet Union) | 349 | 373,836 | 0.6 | 6 | — |
| Spain | 789 | 1,137,813 | 1.8 | 18 | 17 |
| Sweden | 1,239 | 1,411,730 | 2.3 | 23 | 4 |
| Turkey | 179 | 159,836 | 0.3 | 3 | — |
| United States of America (excluding Lakes) .. | 3,104 | 11,249,288 | 18.0 | 180 | 88 |
| Yugo Slavia | 145 | 260,912 | 0.4 | 4 | — |
| Other Countries | 908 | 1,117,130 | 1.8 | 18 | 3 |
| | | | | | Not classified |
| | | | | | 5 |
| Total | 28,724 | 62,389,750 | 100.0 | 1,000 | 423 |

* Including Dominion of Newfoundland.

† The Number of "Selected Ships" in the British Empire to be allotted amongst Great Britain and the Dominions by arrangement.

All that can be said is that on the most frequented mail-liner routes, notably the trans-North Atlantic, no routine wireless meteorological reports are necessary from "B selected ships," except in cases of urgency. In the North Atlantic, it has been suggested that "B selected ships" between the parallels of 40° and 60° N. should be under this restriction.

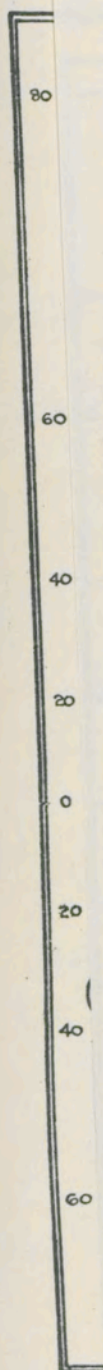
There may be other places where similar restrictions will be desirable.

In all other parts of the world which cannot be adequately served by "A selected ships," "B selected ships should broadcast their reports to C.Q. (all ships) on 600 metres spark at schedule times.

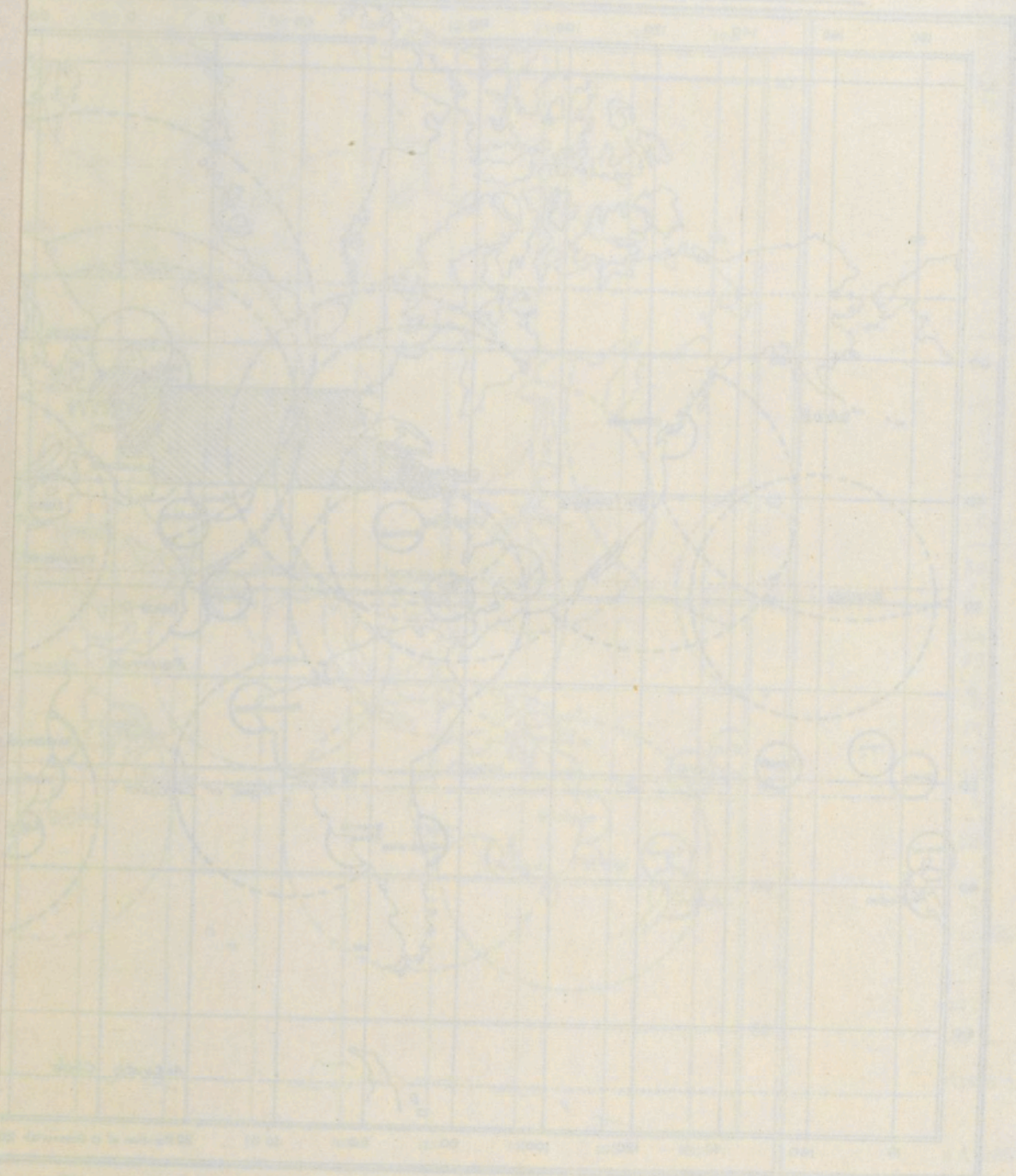
This may result in interference, but at least ships and stations which are anxious to obtain information at no great range will be able to receive it, for obviously those on the spot will arrange matters of communication within the schedule times laid down, and when reports are not received, repetition will be asked for as necessary.

This broadcasting by "B selected ships" on 600-metres spark, of routine meteorological reports has its weak points, but there is no alternative; and it is of the utmost importance that reports from selected ships should be available to all ships and meteorological centres through certain stations in all parts of the world, particularly in the hurricane regions, and in the regions of heavy weather on the less frequented trade routes of the Southern Ocean.

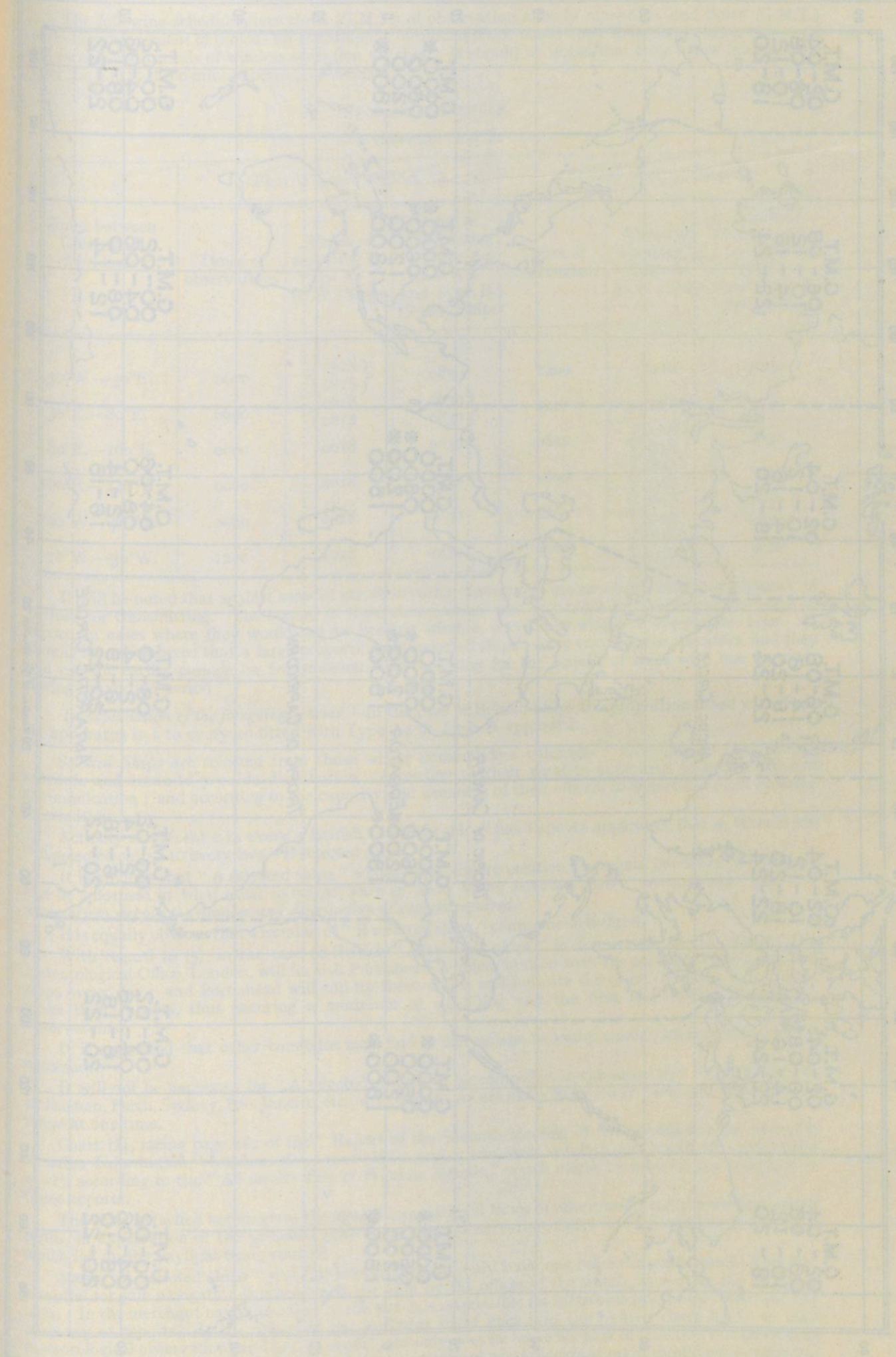
CH



STATIONS FOR RECEPTION OF SHIP



The shaded circle indicates the area in which British ships would report to London. The shaded circle indicates the area in which British ships would report to London. The shaded circle indicates the area in which British ships would report to London.



The shaded circle indicates the area in which British ships would report to London. The shaded circle indicates the area in which British ships would report to London. The shaded circle indicates the area in which British ships would report to London.

The following schedule gives times (G.M.T.) of observation already agreed to, and times (G.M.T.) of the commencement of periods for transmission of these reports, based upon these observation times and the established periods of wireless operation watches. It should be noted that they follow immediately after the S.O.S. three-minute periods of silence.

PROPOSED SCHEDULE.

All times are G.M.T.

| Zones between Greenwich Meridians | First Weather Report. | | | Second Weather Report. | | |
|-----------------------------------|-----------------------|--|--|------------------------|--|--|
| | Times of observations | Times of reporting by Type A1 (C.W.) Ships | Times of broadcasting by Type A2 (I.C.W.) and Type B (Spark) Ships | Times of observations | Times of reporting by Type A1 (C.W.) Ships | Times of broadcasting by Type A2 (I.C.W.) and Type B (Spark) Ships |
| 30°W.—30°E. | 0600 | {0618 0818} | 0830 | 1200 | 1212 | 1230 |
| 30°E.—80°E. | 0600 | {0618 0818} | {0630 0830} | 1200 | 1218 | 1230 |
| 80°E.—160°E. | 0000 | 0018 | 0030 | 0600 | {0618 0818} | 0830 |
| 160°E.—140°W. | 0000 | 0018 | 0030 | 1800 | {1818 2018} | 2030 |
| 140°W.—70°W. | 0000 | 0018 | 0030 | 1800 | {1818 2018} | {1830 2030} |
| 70°W.—30°W. | 1200 | 1218 | 1230 | 1800 | {1818 2018} | 2030 |

It will be noted that against some of the observation times there are two times of commencement of periods for transmitting. The second of these times, where two occur, are for single-operator ships to report, in cases where they would not be keeping wireless watch following the observation hour. It should be remembered that a large proportion of "selected ships" carry two or three operators, and they will use the earlier periods for transmission, also repeating for the benefit of ships with one operator during the second period.

In explanation of the foregoing scheme.—In the case of British Ships the proportion fitted with Type A1 apparatus is 1 to every 20 fitted with Type A2 or Type B apparatus.

Selected Ships are selected from those whose commanders volunteer; according to their sailing schedule and trade to provide distribution; according to their wireless apparatus to ensure efficient communication; and according to the capacity and keenness of their officers to ensure the most accurate information.

Actually at present 1 in every 3 British "selected ships" has Type A1 apparatus, that is, there is one "A selected ship" to every two "B selected ships."

It is obvious that "A selected ships" whose approximate position on certain dates can be foreseen, can be informed in what order to report, when in areas where there are more "selected ships" than are necessary to supply the number and distribution of reports required.

It is equally obvious that a number of "B selected ships" cannot be so treated.

With regard to (5), in the case of British "A selected ships" in the eastern North Atlantic the Meteorological Office, London, will furnish Portishead Wireless Station with the names of chosen selected ships every day; and Portishead will call up those ships, and indicate the order in which they should make their reports, thus ensuring a minimum of signalling and the best distribution of reported observations.

It is suggested that other countries may find it convenient to make similar arrangements where necessary.

It will not be necessary for "A selected ships" to be controlled in the same way by such stations as Durban, Perth, Sydney, Rio Janeiro, etc., where there are not likely to be many "selected ships" within range at one time.

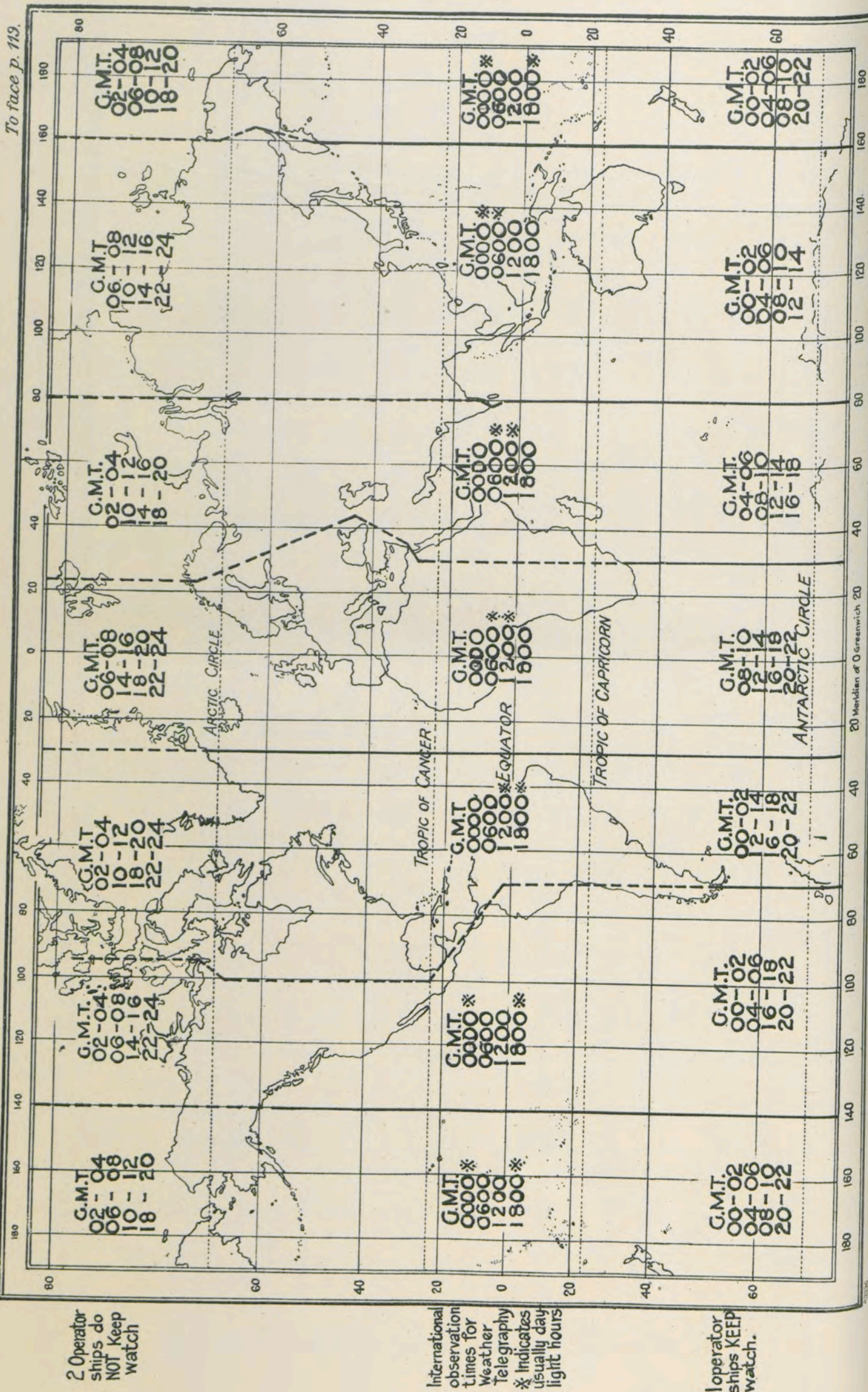
Chart III, facing page 182 of the "Report of the Seventh Meeting of the Commission for Synoptic Weather Information," London, May, 1928 (M.O. 309), gives coast wireless stations in all parts of the world, according to the "Admiralty List of Wireless Signals," which might be used for the reception of these reports.

The chart attached hereto gives the agreed international times of observation and the wireless watch zones, in explanation of the proposed schedule; those observation times in each wireless watch zone which fall during daylight being starred.

Many "A selected ships" and "B selected ships" only have one officer in each watch. The first essential for safe navigation is a good look out kept by the officer of the watch, as well as the look-out men. In the merchant navy the officer of the watch is responsible for meteorological observation and the accuracy of reports. If the officer of the watch at night goes into the lighted chart house to take meteorological observations and draft a report, not only does he leave his post of look out, but he returns to the bridge momentarily blinded. Hence wireless meteorological reports at night should not be required as a matter of routine.

To face p. 119.

CHART II.



There are a number of selected ships which carry two watch-keeping officers for each watch, and arrangements can be made as is now done with certain large liners, for observation to be made and reported at the times shown on the chart, not starred, and not shown in the schedule.

The proposed schedule has been worked out in consultation with wireless experts to overcome the present confusion, jamming and waste, which disheartens all concerned. It is not necessary that reporting ships only should know when to signal meteorological reports, but that all ships should know when to listen and when to refrain from communication which jams them.

In British "selected ships," it is the custom to report to all ships the set and drift of current, with the positions between which this was experienced, at the discretion of the master when he considers these observations reliable. This information is proving of value to safe navigation, and it is submitted that this practice should be provided for in the international scheme.

ANNEX B.

KEY TO THE CODE NOW IN USE IN THE BRITISH NORTH ATLANTIC SERVICE FOR REPORTING TO THE LONDON METEOROLOGICAL OFFICE AND THE WASHINGTON U.S.A. WEATHER BUREAU.

PQLLL III GG BBDDF wwVKd xxxxx yyyyy CNWUy TTty. A word is added if the wind force is above nine, thus for force 10, gale; force 11, storm; force 12, hurricane.

| | |
|-------|--|
| P | = Day of week. |
| Q | = Quarter of the globe. |
| LLL | = Latitude to nearest 1/10th of a degree. |
| lll | = Longitude to nearest 1/10th of a degree. |
| GG | = Mean Civil Greenwich time |
| BB | = Barometer, in millibars. |
| DD | = Wind direction, true. |
| F | = Wind force. |
| ww | = Present weather. |
| V | = Visibility. |
| K | = Sea and swell |
| d | = Swell direction, true. |
| xxxxx | = Check group. |
| yyyyy | = Check group. |
| C | = Cloud predominating. |
| N | = Cloud amount. |
| W | = Past weather. |
| U | = Unusual phenomena. |
| y | = Check figure. |
| TT | = Air Temperature. |
| tt | = Sea temperature. |
| y | = Check figure. |

KEY TO CODE PROPOSED BY THE INTERNATIONAL SYNOPTIC WEATHER COMMISSION, MAY, 1928
RESOLUTION XVI.

| | |
|---|---|
| PQLLL III GV BBDDF wwNKd CCTTd _t CiWIII d _s cbN _h h. | |
| P | = Day of the week. |
| Q | = Quarter of the globe. |
| LLL | = Latitude to nearest 1/10th of a degree. |
| lll | = Longitude to nearest 1/10th of a degree. |
| G | = Standard hour of observation. |
| V | = Visibility. |
| BB | = Barometer. |
| DD | = Wind direction, true. |
| F | = Wind force. |
| ww | = Present weather. |
| N | = Cloud amount. |
| K | = Sea and swell. |
| d | = Swell direction, true. |
| CC | = State of sky and evolution of cloud. |
| TT | = Air temperature. |
| d _t | = Difference between air temperature and sea temperature. |
| Ci | = Specification of cirrus. |
| W | = Past weather. |
| III | = Special distinguishing number of ship. |
| d _s | = Rough course of ship in cardinal or quadrantal points. |
| c | = Characteristic of barometric tendency. |
| b | = Amount of barometric tendency. |
| N _h | = Amount of predominating type of low cloud. |
| h | = Height of base of lower predominating cloud. |

ANNEX C.

International Storm Warning Signals.

The system of local day storm signals adopted and recommended at the Ninth Meeting of the International Meteorological Committee in Berlin in 1910, and modified by the International Meteorological Committee in 1926, is as follows:—



Single Cone, point upward—
Gale commencing with wind in the NW. quadrant.



Single Cone, point downward—
Gale commencing with wind in the SW. quadrant.



Two Cones, one above the other, both points upward—
Gale commencing with wind in the NE. quadrant.



Two Cones, one above the other, both points downward—
Gale commencing with wind in the SE. quadrant.

One flag displayed with any of the above signals indicates that the wind may be expected to *veer* during the gale.

Two flags displayed with any of the above signals indicates that the wind may be expected to *back* during the gale.



Black ball signifies—

Atmospheric disturbance, be alert and look out for further information.

Force 8 on the Beaufort scale should be the inferior limit of wind strength for which a storm signal (except the ball) should be hoisted, unless local circumstances ask for 7 as a limit

NIGHT SIGNALS.

By night the following signals to be hoisted:—

| Signal. | Meaning. |
|--------------------------------------|---|
| Two white lights vertical | Gale commencing with wind in SW. quadrant. |
| Two red lights vertical | Gale commencing with wind in NW. quadrant. |
| A white light over a red light | Gale commencing with wind in SE. quadrant. |
| A red light over a white light | Gale commencing with wind in NE. quadrant. |
| One red light | Indicates atmospheric disturbance; be alert and look out for further information. |

ANNEX D.

References which may be of assistance in connection with the subjects of the Agenda.

GENERAL ORGANIZATION. THE METEOROLOGICAL LOG. COLLECTION, COMPUTATION, AND EXCHANGE OF MARINE METEOROLOGICAL DATA, INCLUDING OCEAN CURRENTS.

| | Marine Observer. |
|---|----------------------------|
| Marine Meteorology and the British Merchant Navy | Pages 72-74, Volume VI. |
| The Conduct of the Work | Pages 25-26, Volume V. |
| Marine Meteorology, Wider Application at Sea | Pages 60-61, Volume V. |
| The Wind Systems of the Oceans | Pages 82-83, Volume V. |
| The Oldest Branch of the Work | Page 52, Volume VI. |
| The Extraction and Compilation of Marine Meteorological Data by Mechanical Methods. | Pages 10-14, Volume V. |
| Proposed Improvements in Mechanical Extraction and Compilation of Data to overcome Ambiguities in Printing. | Pages 57-59, Volume VI. |
| Work of the Year | Pages 117-121, Volume VI. |
| A Plea for a suitable division of Routine Voluntary Marine Meteorological Work at Sea. | Pages 167-169, Volume VI. |
| Information of Current and Safe and Economical Navigation | Pages 189-190, Volume VI. |
| List of Voluntary Observing Ships. | The last number published. |
| The Marine Observers' Handbook, fourth Edition. | |

SHIPS' WIRELESS WEATHER TELEGRAPHY AND THE "SELECTED SHIP."

The Selected Ship *Marine Observer*.
 Intelligence of Weather, Tide, Current, and Ice, and Safety of Life at Sea .. Pages 149-150, Volume V.
 Wireless and Weather, an Aid to Navigation. .. Pages 197-199, Volume V.

"WEATHER SHIPPING" BULLETINS, WIRELESS GALE AND HURRICANE WARNINGS. VISUAL GALE AND HURRICANE WARNINGS.

British Weather Signals Page 28, Volume VI.

The "Marine Observers' Handbook," The *Marine Observer*, and "Wireless and Weather, an Aid to Navigation," are published and sold by H.M. Stationery Office.

Forms for use on board ship.

| Form No. | Description. |
|----------|--|
| Form 134 | .. Cadets' meteorological log (for use in Officers' Harbour Training Ships of the Merchant Service). |
| " 138 | .. Ships' W/T weather report register (for use in selected North Atlantic liners only). |
| " 138A | .. International code for W/T reports (varnished card). |
| " 139 | .. Ships' W/T report pad (Weather, London). |
| " 139A | .. Ships' W/T report pad (Government Observer, Washington). |
| " 684 | .. Special observations of sea and swell (measurements). |
| " 854 | .. "Weather shipping" bulletin (decode form). |
| " 905 | .. Cyclone report. |
| " 911 | .. Ships' meteorological report. |
| " 912 | .. Ice report. |
| " 913 | .. Barometer test card (blue post card). |
| " 914 | .. Coast station report. |
| " 915 | .. Ships' meteorological log. |
| " 916 | .. Original note book. |
| " 917 | .. Lighthouse register. |
| " 955 | .. Drift bottle paper. |
| " 1089 | .. Outline chart of North Atlantic, for making weather charts at sea. |
| " 1245 | .. Outline chart of North-East Pacific, for making weather charts at sea. |
| " 1246 | .. Outline chart of North-West Pacific, for making weather charts at sea. |
| " 1253 | .. Outline chart of South-West Pacific, for making weather charts at sea. |
| " 1254 | .. Outline charts of West Indies and U.S.A. (east coast), for making weather charts at sea. |
| " 1268 | .. Outline chart of Australia, for making weather charts at sea. |
| " 1269 | .. Outline chart of South Africa, for making weather charts at sea. |
| " 1290 | .. Outline chart of South America, for making weather charts at sea. |
| " 1297 | .. Outline chart of the Bay of Bengal and Arabian Sea, for making weather charts at sea. |
| " 1973 | .. Outline chart of North Atlantic and Mediterranean, for making weather charts at sea. |

Forms used for working agencies.

| Form No. | Description. |
|----------|---|
| Form 104 | .. Proposal for supply of instruments. |
| " 110 | .. Inspection of instruments. |
| " 111 | .. Advice to agents re movements of ships (postcard). |
| " 118 | .. Agent's quarterly return of instruments. |
| " 906 | .. Tally for P.M.O. and agent's comparison of barometer. |
| " 907 | .. Receipt for instruments. |
| " 909 | .. Advice of transmission of log to Meteorological Office. |
| " 910 | .. Agent's account of fees and allowances. |
| " 920 | .. Instructions for the guidance of agents. |
| — | .. Muster of Instruments |
| — | .. Particulars for application by intending marine observers. |
| — | .. Quarterly demand for forms and stationery. |

Forms for use in Marine Division.

| | |
|----------------|---|
| A.M. Form 789 | Hollerith card. |
| " 953 | Test sheet for logs. |
| " 983 | Index correction for barometer. |
| " 1011 | Marsden chart. |
| " 1100 | Tabulation of surface current (for computation and exchange). |
| " 1197 | Record of observers (index card). |
| " 1218 | Tabulation of wind direction and force. |
| " 1266 | Marine data (copy of log or Form 911, etc.). |
| M.O. Form 112A | Data extraction book (now used for currents only). |
| " 151 | Wind rose skeletons. |

Note.—Copies of all the above forms were supplied to each of the delegates.

C.E.M. 6/1929.

APPENDIX VI.—THE METEOROLOGICAL REQUIREMENTS OF THE ARMY WITHIN THE BRITISH EMPIRE

By D. BRUNT.

(Army Services Division, Meteorological Office).

The peace-time requirements of army units are normally limited to occasional forecasts of general weather conditions, and to information as to winds and temperature in the upper air for the use of Artillery units. In addition to these, the development of the tactical use of smoke screens for obscuring operations has led to a demand for a further type of information.

Forecasts of general weather conditions should usually include wind, weather, cloud, visibility, air temperature, and ground temperature. They do not demand anything outside the ordinary scope of a forecasting service, and no difficulty would be experienced in meeting this requirement.

Telegrams for artillery.—Of more importance in peace-time are the requirements of artillery units, who require information as to the upper winds, temperatures, and humidities in a form suitable for ready application in the ranging of their guns. The form of telegram developed during the Great War, which is always referred to as the "meteor telegram", has been adopted as a universal practice in the British Army. The height which a projectile attains is specified by its time of flight. If the time of flight is t seconds, the maximum height attained is $4t^2$ feet, to a reasonably close approximation. The "meteor telegram" gives a weighted mean of the wind, and a *ballistic temperature*, for times of flight of 5, 10, 20, 30, 40 and 50 seconds, in addition to the mean-sea-level pressure. In peace-time practice the message may not be required to go beyond 30 seconds.

A pamphlet has been prepared and published by the Stationery Office, entitled "The Supply of Meteor Reports to Artillery Units". M.O. 317. This pamphlet gives full particulars of the method adopted in the preparation of "meteor telegrams", with tables of the appropriate weighting factors, and some rules as to the procedure when actual observations of temperature are not available. No attempt will, therefore, be made to summarise this pamphlet in the present memorandum, but it may be mentioned that the observations which are necessary are:—

1. Upper winds up to the highest point attained by the projectile.
2. Temperature and humidity up to the same height.
3. Pressure at mean sea level.

When these observations are available, the computation of the message in the form required by the gunner is a very simple operation, and can be completed in 10 minutes. A pilot-balloon form has been specially prepared for making this computation. Tables of multiples of the wind weighting factors and a table for converting components of wind into resultant wind velocity and direction, are reproduced on the back of this form, while the front page provides for the computation of observations of pilot balloons with tails attached. This form has been drawn up largely with a view to use "in the field", and its use is by no means essential to the computation of meteor telegrams. Attention is directed to the units used by Artillery.

Pressure is measured in inches of mercury.

Temperature .. degrees Fahrenheit.

Height .. feet.

Wind velocity .. feet per second.

Wind direction .. degrees from true north (E. = 90° W. = 270°).

Time of flight .. seconds.

Range .. yards.

These units are somewhat different from those normally used in meteorology, but it is not considered practicable at present to modify these units, since the Range Tables have all been based on these units.

The method of dealing with the requirements of Artillery has been brought before the Empire Conference in the hope that all the meteorological services within the Empire will undertake to supply "meteor telegrams" when requested to do so by Artillery units in their neighbourhood. Further, it is highly desirable that the dominions which maintain artillery units of their own should adopt the same procedure. Copies of M.O. 317 have been supplied to some of these dominion units, and further copies could be supplied if required. This pamphlet is printed for official use only, and is not for sale to the general public. It is issued on the distinct understanding that no copy shall be shown to persons outside official services of the British Empire.

It is found that in very few cases are Artillery units of the British Army posted abroad out of reach of a meteorological service. The question of the supply of meteorological information to most of these units has been raised by correspondence with the individual services concerned. The outstanding cases where no arrangement has hitherto been possible are Aden, Bermuda and Gibraltar. It is hoped that a small conference of representatives of the services mainly interested in Observations at Aden may meet to discuss the possibility of setting up a meteorological station at Aden, to provide for the requirements of Artillery and aviation, and to arrange who shall accept responsibility for conducting this station. It is further hoped that at Bermuda a meteorological station may be set up by the local authorities. Gibraltar offers peculiar problems whose investigation falls upon the home meteorological service.

The use of smoke screens.—The increasing importance of the use of smoke screens for hiding military operations has made it essential that wherever possible meteorological information as to the possible use of such screens for tactical purposes should be collected and summarised for the use of military units. It has been found that it is not possible to set up such screens in very light or very strong winds, or when the lapse-rate exceeds the adiabatic. In order to determine whether a smoke screen can be used it is therefore necessary to have available estimates of the wind direction and velocity, and of the distribution of temperature in the vertical. Some idea of the stability of the vertical conditions may be gained from the gustiness of the wind trace. The Meteorological Office has been asked by the fighting services to

make every possible effort to collect information of this nature from all parts of the Empire. The type of information which is of value is exemplified in the attached reproductions of wind and temperature records taken at Ismailia in Egypt, Figs 1 and 2. It will be noted that there is a marked sea breeze, which sets in at about 15 30 G.M.T. and which blows as a steady northerly wind for 7 hours. This wind is very stable, having initially a small lapse rate, later becoming an inversion as shown by the temperature records. The stability is also shown by the steadiness of the anemometer trace.

Similar information for other localities would be of great value, and would fill a gap in our existing knowledge. At the present moment there is no collected body of information available as to such diurnal changes of wind. It happens also that precisely the same information would be of considerable value to airships.

We would therefore ask all British meteorological services to supply us with information of this character. Unfortunately, it is improbable that the variation of temperature with height in the lowest layers has been recorded in many places, but the stability of the wind can probably be inferred from the steadiness of the wind traces. It is possible that some information of this character has already been published. References to the appropriate publications would be helpful in such cases.

The Superintendent of the Airship Services Division has already asked that we might be supplied with wind summaries giving ten minute means of wind velocity and direction ending at the exact hour, and the highest gust in the 60 minute interval centred at the exact hour. These summaries will meet the requirements of both airships and army. In addition to these summaries, we desire to know some of the characteristics of the wind, particularly the salient features of the diurnal changes. It is of extreme importance to obtain information as to such diurnal changes as those shown in the attached anemometer chart, such as the setting in of a stable current which persists for some hours. It is realised that these features can not readily be summarised, and it is asked that any service which has observations likely to be of interest in this connection would lend us 1 year's charts from each station. We can undertake to examine the charts and return them without delay.

We have been urged by the three fighting services to take all possible steps to collect information bearing on the use of smoke screens. The character of the information required has been indicated above. The only additional factor of importance is humidity, which has a considerable influence upon the effectiveness of some types of screens. It is therefore requested that those services which lend us anemometer charts would at the same time lend their hygrograph charts.

In searching through published records for information bearing on the possible use of smoke screens, it is found that the most serious defect is the absence of measurements of the lapse rate in the lowest few hundred feet. This is unfortunately a difficult quantity to measure with accuracy. Efforts have been made in England, mainly at Porton and Leafeld, to measure the lapse-rate up to heights of 300 feet, by means of resistance thermometers. An analysis of the observations at Porton, with descriptions of the apparatus, will be found in M.O. *Geophysical Memoirs* No. 46 by N. K. Johnson. It is urged that similar observations should be made in different parts of the Empire, as they provide information of practical value, as well as of considerable theoretical interest.

Meteorological services in war time.—Soon after the end of the Great War it was laid down that all meteorological work for Government departments should be performed by one service, the Meteorological Office, which was then transferred to the Air Ministry. At the same time it was arranged that the Air Ministry should also undertake the responsibility of providing for all meteorological services in war time.

The meteorological requirements of the Army and Air Force in a war have been laid down, and in order to provide the personnel required, a meteorological section of the Royal Air Force Reserve has been formed. A number of officers and men have now been enrolled, most of them members of the staff of the Meteorological Office.

In each of the last three years the section has been called up for a fortnight of collective training in uniform. The training has consisted in carrying out all kinds of meteorological observations under conditions similar to those which would hold in war, together with the preparation of forecasts, of coded "meteor telegrams" to Artillery and of messages giving upper wind information to the Royal Air Force. Both officers and men have undergone some general training in the customs of the Air Force, with drill and parades. Though the section is as yet small numerically, it forms a highly efficient nucleus of a war-time service.

In the event of war, the section would be immediately mobilised, ready to proceed with an expeditionary force to the theatre of war.

THE WAR OFFICE, LONDON, S.W.1.
6th June, 1929.

The Secretary, The Air Ministry, W.C.2.
Sir,

I am commanded by the Army Council to inform you that during last year meteorological observations made in Egypt on wind direction and strength, temperature, and humidity, have yielded valuable information regarding the possibilities of using smoke clouds in the Nile Delta.

It will be appreciated that it is of great importance to have available information of this nature when preparing schemes of military operations, whether for offence or defence in any particular locality; and that, therefore, it is highly desirable to collect similar meteorological observations, from all parts of the British Empire where they are available.

The Council are aware that an Imperial Conference of Meteorologists is to take place this summer in London in August. I am therefore to ask if the Air Council could take steps to put before this Conference the desirability of their supplying similar data to those recorded in Egypt whenever available.

I am further to suggest that it might be possible in such cases where no records are available, to urge upon the Dominion or Colonies concerned, the importance of such records being obtained.

(Sgd.) A. E. WIDDOWS.

ANEMOGRAM 5th-6th AUG., 1928.

ISMAILIA.

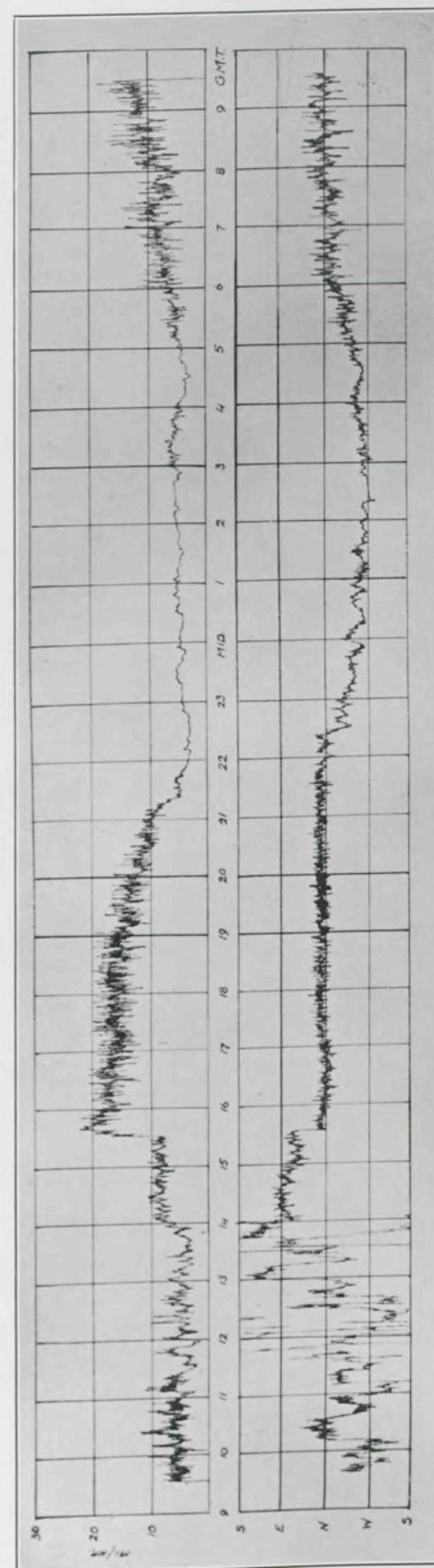


FIG. 1.—A good example of thermal swinging and nightly sea breeze.

C.E.M. 7/1929.

APPENDIX VII.—MEMORANDUM ON FLEET METEOROLOGY.

By COMMANDER L. G. GARBETT, R.N. (RETD.).
Superintendent, Navy Services Division, Meteorological Office.

Introduction.—The convening of this Conference of Empire Meteorologists affords an opportunity for indicating to the representatives of the meteorological services of the various British Dominions, Colonies and Mandated Areas, the extent to which meteorology is now utilised in the Royal Navy and for formulating a request for the active co-operation of these services in the meteorological work of the Fleet. Fleet meteorology on the more distant stations has not yet been organized to the same degree that it has been organized on the Home and Mediterranean stations but there are likely to be considerable developments in the immediate future, and the co-operation of local meteorological services in such developments will be essential.

Before means of co-operation between the Navy and local meteorological services are discussed in detail, it is desirable that some general information regarding meteorological work in the Fleet should be given. This memorandum is divided therefore into four main parts:—

- I. The present Meteorological Organization of the Fleet.
- II. Meteorological Factors of Special Importance to the Navy.
- III. Co-operation between the Navy and Local Meteorological Services.
- IV. Co-operation between the Meteorological Services of the Empire and the British Meteorological Service on matters affecting Fleet Meteorology.

I. The Present Meteorological Organization of the Fleet.—(a) *Headquarters organization of Fleet meteorology.*—The increasing importance of meteorology in the Navy is fully recognized by the Admiralty and in 1928 the Board appointed a *Fleet Meteorological Committee* to consider the meteorological requirements of the Navy and the policy to be adopted to satisfy them. This Committee, which comprises representatives of the Meteorological Office and Chemical Warfare Committee as well as the heads of various Admiralty departments, has now been constituted a standing committee.

The Navy Services Division is the division of the Meteorological Office which deals with meteorology for the Navy. The division works in close co-operation with the Hydrographic Department of the Admiralty, the Hydrographer of the Navy being immediately responsible to the Board of Admiralty for the meteorological organization of the Fleet.

It is the duty of the Superintendent, Navy Services Division, to advise the Hydrographer on all matters connected with Fleet meteorology and to arrange for such services as are required from the Meteorological Office and its branch offices to meet the meteorological needs of the Fleet. The Division is responsible for the provision of meteorological information for naval authorities, for supervising the meteorological equipment of H.M. ships and for the special meteorological training of naval officers. The Superintendent keeps in close personal touch with all officers undertaking meteorological duties in H.M. ships and the Division endeavours to assist these officers in every possible way.

From its inception the Navy Services Division has been intimately connected with the development of meteorology in the Fleet and one of its most important duties is to bring to the notice of the Hydrographer and the Fleet Meteorological Committee possible future developments in the meteorological organization of the Fleet. The most important development possible at the present time being the organization and co-ordination of the meteorological work of the Fleet on stations abroad, considerable attention has been given to this subject in the Division and the opportunity of preliminary discussion of the matter at this Conference is welcomed.

(b) *Performance of meteorological duties in the Fleet.*—The Master of the Fleet or squadron navigating officer on each station is responsible for co-ordination and supervision generally of the meteorological work of the Fleet on the station and in each ship an officer is appointed to carry out meteorological duties.

The officer responsible for meteorology in each of H.M. ships (except Fleet carriers) is the navigating officer. These officers receive a certain amount of meteorological training in the navigation course and are able to prepare a synoptic chart and make a rough forecast. The navigating officer qualifies at H.M. Navigation School, Portsmouth, and, in order that the meteorological portion of the course may include modern developments in meteorological practice, arrangements have been made for officers on the staff of the Navigation School to undergo a short course of instruction in this subject at the Meteorological Office. As the officers on the staff of the Navigation School change fairly frequently this arrangement ensures also that in a few years time about half the navigating officers of the Fleet will have taken this short course as a supplement to their ordinary meteorological training.

In addition to taking this formal course, navigating officers are encouraged to visit the Meteorological Office whenever it is possible for them to do so in order to keep in touch with latest meteorological developments.

The development of the Fleet Air Arm has led to a demand for officers trained to deal with the more specialised meteorological requirements of aircraft. The officers undertaking meteorological duties in aircraft carriers are selected naval observers (i.e., executive officers qualified for observing duties in aircraft) who have undergone a special three months' course in meteorology at the Meteorological Office. All naval observers qualify in meteorology as part of the observers' course but the special three months' course is devoted mainly to forecasting and modern methods of analysis of charts.

The meteorological officers in aircraft carriers keep in close touch with the Navy Services Division by correspondence and by personal visits and after about two years afloat in a carrier, each officer attends a refresher course at the Meteorological Office; this gives him an opportunity of discussing his practical problems with experts at Headquarters.

In addition to the navigating officers and naval observers of the Fleet, the hydrographical surveyor is intimately concerned with meteorology. From the nature of his work he is keenly interested in local meteorology and forecasts based upon synoptic charts assist him to arrange his surveying programme. A short course in modern meteorology for surveying officers has been instituted at the Meteorological Office, Air Ministry and eventually all surveying officers will have been through this course.

ISMAILIA.

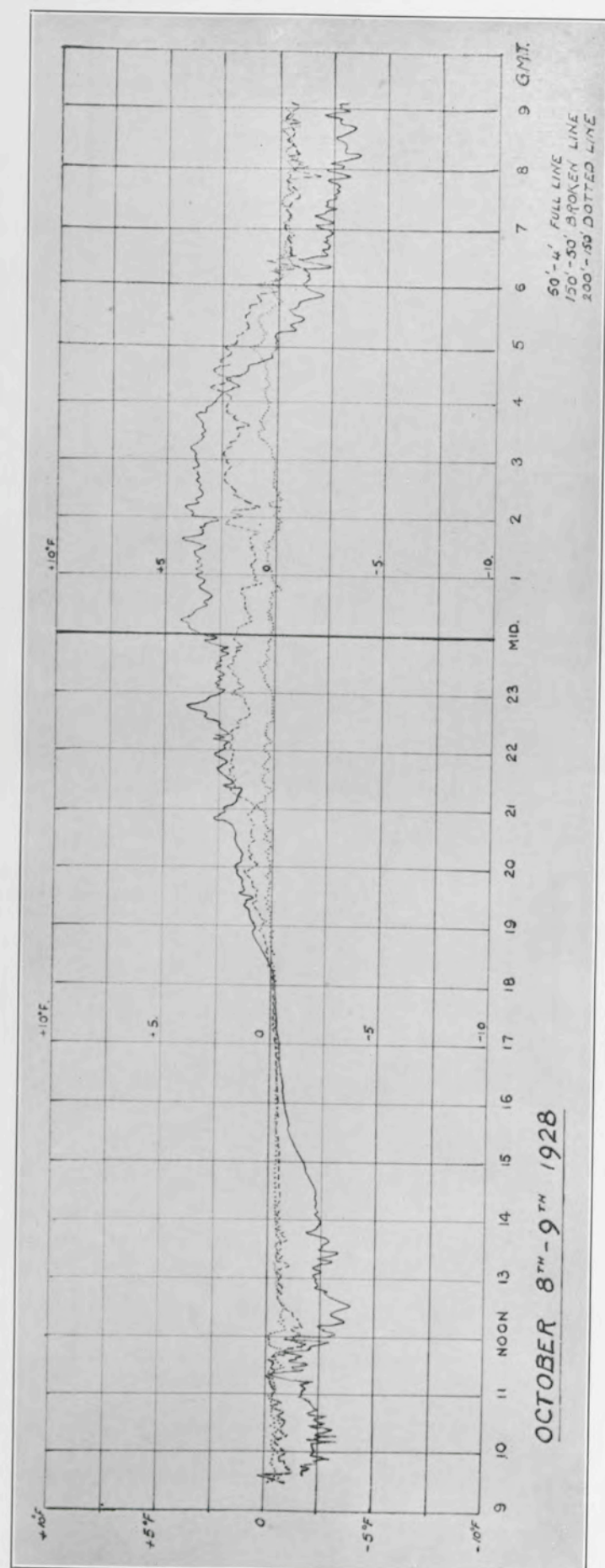


FIG. 2.—Record of vertical temperature gradient.

It will be seen from the above that although there are no professional meteorologists in the Navy, the officers undertaking meteorological duties have had special training and are conversant with modern developments, practical and theoretical, of the subject.

(c) *Meteorological equipment of H.M. Ships.*—H.M. ships of the sloop class and above are each equipped with Kew pattern marine mercurial barometer, aneroid barometer, barograph, wet and dry bulb thermometers and thermometers for sea temperatures. Surveying ships are equipped with electrical cup anemometers also. Mercurial and aneroid barometers are graduated in millibars, the former being fitted with a Gold slide for reduction of pressure to M.S.L. Thermometers are graduated in degrees Fahrenheit.

Aircraft carriers, in addition to the instruments mentioned above, have a distance-reading thermograph, hygrograph, whirling psychrometer, Finemann nephoscope, strut psychrometer and aeroplane aneroid barometer (for upper air work). Some carriers having masts are also equipped with a diaphragm wind-speed recorder and a Baxendell wind-direction recorder. All aircraft carriers are now fitted with a special meteorological office and eventually all flagships will be so equipped.

Thirty-seven of H.M. ships, including all the aircraft carriers, are also equipped with instruments for the observation of upper winds by means of pilot balloons.

The meteorological officer in one of H.M. ships is provided therefore with sufficient instruments to enable him to make the customary meteorological observations and in an aircraft carrier he has also autographic recording instruments for the most important meteorological elements.

The instruments at present issued to H.M. ships, are generally of the same type as those issued to land stations, only slight modifications being made. This practice may easily fail to give the best results, for the mounting of an instrument necessary for most efficient use at sea may be quite different from that required in a land instrument. Hitherto little attention has been given to the design and mounting of the meteorological instruments for use in H.M. ships, but this matter is now being investigated in the Meteorological Office, and it is hoped that the efficiency of meteorological equipment in the Navy will be increased as a result of the investigation.

(d) *Meteorological work in the Fleet.*—The meteorological duties in one of H.M. ships include the care of instruments, the taking of observations and the keeping of the ship's special meteorological log, when one is carried. When no such log is carried, meteorological phenomena of special interest are noted in the "Navigating Officer's Remark Book". The meteorological officer is responsible also for the reporting of the observations made at fundamental hours to local meteorological services on shore, when arrangements exist for the exchange of such information. The preparation of weather maps and the issue of forecasts are not necessarily routine duties but are carried out in many ships.

In a ship equipped for the observation of upper winds by means of pilot balloons the meteorological officer is responsible for this work also. The methods of observation used at sea are described in Form 2086. The Admiralty and the Meteorological Office are co-operating in this investigation with a view to the preparation of charts of wind roses for various levels over sea areas, the data being classified in the form recommended by the I.C.A.N. The distribution of ships (including aircraft carriers) undertaking the observations is at the present time that shown below, but alterations in the allocation are made from time to time.

| | |
|---|----|
| Home Station | 6 |
| Mediterranean Station | 10 |
| East Indies Station | 5 |
| China Station | 5 |
| America and West Indies Station | 5 |
| Africa Station | 3 |
| Australia Station (R.A.N.) | 3 |

In an aircraft carrier, owing to the special importance of meteorology to aircraft, the meteorological duties are more onerous and the officer responsible for them requires special training. In addition to the duties enumerated above, the daily routine includes the preparation of two synoptic charts and the issue of general forecasts based upon them. On the Home and China Stations these forecasts are broadcast for the benefit of the Fleet generally.

In addition to these routine forecasts the meteorological officer has to make special forecasts to individual pilots (corresponding more or less to the route forecasts of a civil aviation service), and is responsible also for the issue of gale warnings and the notification of deterioration of visibility, shifts of wind, etc., to aircraft.

Records of upper air temperatures are taken from aeroplanes whenever possible. Observations of upper winds by pilot balloons or smoke shell are taken daily when flying is in progress. The necessity of a knowledge of the prevailing wind conditions to pilots proceeding on reconnaissance at dawn has led to the development of methods of obtaining upper winds at night and night pilot-balloon ascents are now regularly carried out. This information regarding temperatures and winds in the upper air is utilised occasionally by gunnery officers.

Apart from what may be termed these routine duties, the meteorological officer in the Fleet carrier is becoming recognized as the meteorological expert in each Fleet and therefore is called upon to carry out any special meteorological investigation that may be required.

Special investigation work for the Meteorological Office is also performed in H.M. ships, mainly on the Home Station at present. Trials of new instruments and new methods of observation have been made and series of observations of special phenomena have been obtained for the Meteorological Office. Owing to the attention recently drawn by the Fleet Meteorological Committee to the importance of special investigation of the problems of marine meteorology, a considerable increase in this branch of the work is to be expected.

II. *Meteorological factors of special importance to the Navy.*—Although general forecasts, gale warnings, etc., are of utility to the Navy certain meteorological elements are of particular importance, and the forecaster pays a corresponding amount of attention to them. From the point of view of operations the most important element is *visibility*, and a meteorological officer forecasting for the flagship, for instance, would have to give prominence to this factor. An investigation of visibility at sea is now to be undertaken by the Meteorological Office in co-operation with the Admiralty, and it is hoped that the result will lead to greater accuracy in the forecasting of visibility changes.

Another meteorological factor of tactical importance is the *lapse-rate in the lower layers* of the atmosphere. The success of smoke-screens depends upon the stability of these lower layers; these particular operations are more dependent upon the meteorological factor than any other operation. The subject was dealt with in detail by Superintendent, Army Services Division, and it is not necessary to add anything to his remarks.

To the aircraft carrier also visibility changes are extremely important, and in this case vertical as well as horizontal visibility must be considered. In addition, owing to the fact that there is at present no really satisfactory method of determining wind speed from a machine flying over sea, the accurate forecasting of *changes of wind* is of vital importance to naval aircraft, the times as well as the nature of the changes being specified.

The importance of accurate wind forecasts for naval aircraft cannot be over-emphasised, for success in finding the aircraft carrier on return may depend solely upon the accuracy of the information on this point in the possession of the navigator.

The difficulty of the problem confronting the naval meteorologist is increased by the fact that observations at hand when a forecast is required may be very few or even, in time of war, non-existent. The meteorological officer is then in the position of the *single-observer forecaster*, forecasting from the observations available in the ship and his knowledge of the general meteorological situation. Considerable attention is therefore being devoted to this problem of single-observer forecasting in the Navy Services Division and in aircraft carriers.

III. *Co-operation between H.M. Navy and local meteorological services.*—(a) Although the Navy has a meteorological organization of its own, it is of course dependent for the preparation of its synoptic charts upon collective messages, etc., issued by shore meteorological services and, usually, for its information regarding local conditions, upon the experience of the staff of the local meteorological service. Further, the Navy is in a position to assist meteorologists generally by furnishing weather reports, etc., from regions in which other reports cannot be obtained, and by undertaking special investigational work which can be combined with a ship's routine duties.

It is extremely desirable, therefore, that there should, whenever possible, be close co-operation between the Fleet and the meteorological services of the Dominions and Colonies. As previously stated, such co-operation already exists between the Navy and the Meteorological Office on the Home and Mediterranean Stations, and it is desired that other stations should be organized in a similar way, on the basis of an exchange of services.

(b) *Co-operation on Home Station.*—In addition to the close liaison maintained between the Admiralty itself and the Meteorological Office, there is considerable co-operation between the Atlantic Fleet and Naval Shore Establishments and the Meteorological Office.

Certain ships and establishments receive daily the printed *Daily Weather Reports* of the Meteorological Office and arrangements exist for the supply on request of special forecasts to any H.M. ship or dockyard (the latter usually in connection with docking or towage operations). Gale warnings are passed to certain naval centres direct from the Meteorological Office.

Meteorological officers in H.M. ships requiring synoptic data for the construction of a chart can intercept any of the collective issues made by the Air Ministry and by other European meteorological services, so that a special collective issue for the benefit of the Fleet has not been arranged.

In order that navigating officers may have a means of checking from time to time the accuracy of the mercurial barometers installed in their ships, special barometers have been issued by the Meteorological Office to certain dockyards for use as standards for comparison. The scheme is described in "Navy Meteorological Services Memo 8/28". It is important, from the point of view of the Meteorological Office, to ensure that H.M. ships' barometers are indicating accurately or ships' weather reports become misleading.

An increasing number of meteorological memoranda, etc., are prepared in the Navy Services Division and are issued to H.M. ships for the information of officers undertaking meteorological duties. In this manner it is hoped to bring these officers in touch with the developments in meteorological practice or organization that may prove of benefit to the Fleet.

H.M. ships render valuable assistance to the Meteorological Office by furnishing weather reports when in wireless touch with Great Britain, in accordance with the scheme outlined in Form 185. On the average two reports *per diem* from ships in the Bay of Biscay and off the coast of Spain are received now the scheme is in full operation. Upper air temperatures are reported by aircraft carriers when in wireless touch with Great Britain (see Memorandum 10/29).

These routine services are of course additional to the special investigational work undertaken for the Meteorological Office.

(c) *Co-operation on the Mediterranean Station.*—The Meteorological Office, Malta, is established partly in order to meet the needs of the Fleet in these waters.

The arrangements with regard to supply of information, etc., are very similar to those on the Home Station. Weather reports and upper air temperature reports are made to Malta in a similar manner to those made to London. These reports are especially valuable to Malta on account of its isolated position.

Owing to the difficulties experienced by H.M. ships in obtaining data for the preparation of synoptic charts, collective messages for Europe and North Africa are issued twice daily by Malta. These are referred to as the "Mediterranean Fleet Synoptic Messages" and are fully described in Form 190. General forecasts for areas in which H.M. ships are known to be cruising are appended to the synoptic message, for the use of H.M. ships which do not prepare synoptic charts.

(d) *Co-operation on other stations.*—On some of the other stations, although co-operation has not yet been officially developed to the extent that it has been on the Home and Mediterranean Stations, there is already a considerable exchange of services between the Navy and local meteorological services. The co-operation that exists between the Royal Observatory, Hong Kong and the Fleet on the China Station is an example of this.

The Fleet Meteorological Committee consider that the time has now come when co-operation between the Fleet and the local meteorological services on each station should be placed upon a more official basis. It has been recommended therefore that the Commander-in-Chief on each station (except the Home and Mediterranean Stations) should call a conference to discuss the organization and development of Fleet Meteorology on the station; it is expected that these conferences will be held early in 1930. Besides dealing with internal organization, these conferences will specify in detail ways in which assistance can be rendered by the local meteorological services. The general nature of the mutual services that can be rendered will have been gathered from Sections III (b) and III (c) of this memorandum. Thus they include—

(i) the issue, by the local meteorological office, of a special collective message for the benefit of the Fleet or the modification, when necessary, of existing collective issues to meet naval requirements.

(ii) provision for the immediate supply of special forecasts for naval authorities when required, including the issue by W/T of special forecasts for areas in which H.M. ships are cruising, ships' positions being ascertained from the weather reports which they furnish.

(iii) the development and improvement of the hurricane and gale warning service in those regions where no adequate service exists. Arrangements would be made for the special notification to naval authorities of all warnings issued.

(iv) the provision for naval meteorological officers of information regarding local meteorology. This might be done by personal conversation, by lecture, or by the circulation of notes and memoranda. Meteorological officers in H.M. ships are rarely forecasting for the same area for any length of time, and thus are not in a position to acquire a detailed knowledge of local effects. The provision of such information by the local meteorological office would be a very valuable service.

(v) the provision of means of checking the accuracy of the barometers of H.M. ships on the station (on the lines of Navy Meteorological Services Memo. 8/28).

(vi) the organization of a system of coded meteorological reports to shore stations from H.M. ships at sea. The system may provide for reports of weather and the usual meteorological elements, reports of upper air temperatures and, probably, reports of pilot-balloon ascents from H.M. ships, if required.

(vii) the joint investigation of local meteorology, on lines laid down by the local meteorological service. H.M. ships would readily co-operate in an investigation of the local peculiarities of visibility on the station, for instance.

There are two points in connection with the organization of Fleet meteorology on stations abroad which require emphasis. The first is the need for uniformity of practice on all stations with regard to such arrangements as those suggested in (i), (ii), (iii), (v), and (vi) of above. Both officers and ships change from station to station fairly frequently and it is very desirable, therefore, in the interests of smooth working that the arrangements on all stations should be as similar as possible. For instance, H.M. ships now make weather reports to London and Malta in the International Ships Code and adoption of this procedure on all other stations would be distinctly advantageous.

The Superintendent, Navy Services Division, will probably be present at each of the conferences called by the commanders-in-chief of the various stations, and will endeavour to ensure such uniformity of practice and organization and co-ordination of the meteorological work of the Fleet on all the stations.

The second point is the necessity of really close liaison between the meteorological services of the Dominions and Colonies and the Fleet. This liaison will undoubtedly be established officially in connection with the conferences mentioned above, but it is essential that it should be continued, both personally and officially, for the success of any scheme of extensive co-operation depends upon it. Arrangements such as those outlined in (iv), (v), and (vii) above certainly could not be worked without close personal liaison between the staffs of local meteorological services and meteorological officers of the Navy.

IV. Co-operation between Dominion and Colonial Meteorological Services and the Meteorological Office, Air Ministry, (Navy Services Division).—It will not be inopportune to mention, in concluding, a few ways in which the meteorological services of British Dominions and Colonies can co-operate with the Meteorological Office (Navy Services Division) for the benefit of the Fleet.

The preparation of the charts of wind roses for selected levels will involve the incorporation of a large amount of data from coastal meteorological stations and island meteorological stations. Dominion and Colonial meteorological services will be able to assist materially by providing such data.

Assistance could be rendered similarly in connection with the tabulation and possibly the charting of the distribution of elements such as visibility, cloud height and amount, etc.

The Conference will doubtless be familiar with the publications known as the "Admiralty Pilots" or "Sailing Directions". Each of these publications includes information on the meteorology of the region covered by the "Pilot" and the Meteorological Office is responsible for the production and revision of this portion of the text. Although there is usually sufficient statistical data available for the compilation of an account of the general climatology of the region, it is considered that these "Pilots" should contain as much information as possible about local conditions and peculiarities which can only be furnished satisfactorily by the local meteorological service itself. It is proposed, whenever possible, to forward relevant portions of the text to the appropriate local meteorological service for revision and it is hoped that all services will co-operate with the Meteorological Office, Air Ministry, in an endeavour to make these reliable and popular publications valuable handbooks of local meteorology also.

The Superintendent, Navy Services Division, being present at the conference held on each station for the organization of Fleet meteorology on the station the Division will be intimately connected with the initiation of the various schemes, and it is considered that this connection should be continuously maintained, in view of the responsibility resting upon the Meteorological Office of advising the Hydrographer and the Fleet Meteorological Committee on such matters. It is desirable therefore that the Superintendent, Navy Services Division be kept informed (through the Director, Meteorological Office, Air Ministry) of any proposed developments or alterations in the meteorological routine of a Dominion or Colonial meteorological service that will affect Fleet meteorology on the station. Similarly the Meteorological Office will inform each Dominion or Colonial meteorological service co-operating with the Fleet of developments on other stations.

Such an exchange of views and information between the Headquarters organization and local meteorological services will tend to maintain uniformity of practice and organization on all stations and will therefore considerably facilitate smooth working of the arrangements on individual stations.

C.E.M. 18/1929.

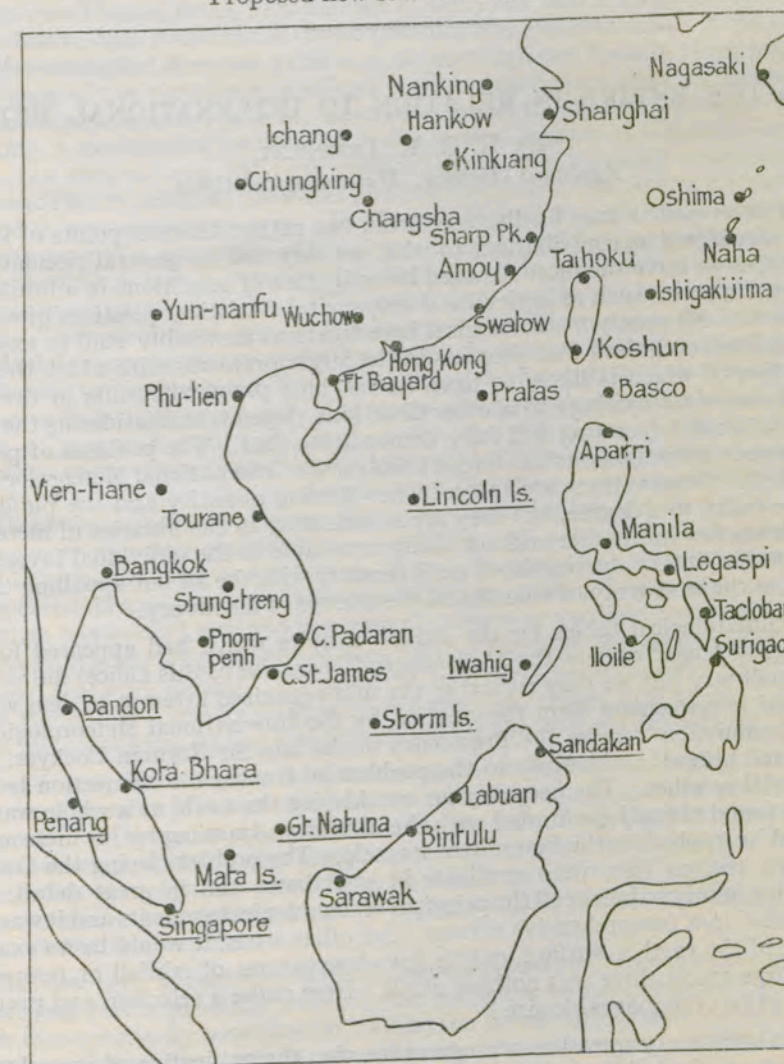
APPENDIX VIII.—PROPOSED ESTABLISHMENT OF THIRTEEN NEW METEOROLOGICAL STATIONS IN THE SOUTH CHINA SEA.

By T. F. CLAXTON,
Director, Royal Observatory, Hong Kong.

In a memorandum on the subject for discussion at this Conference I have recommended the establishment of 13 new stations in the South China Sea and surrounding countries. Their positions are shown on the diagram.

These stations are required for improving the Hong Kong forecast service and for special aviation forecasts. I should be glad of the support of the Conference and of the Air Ministry in connection with this recommendation.

MAP OF THE FAR EAST SHOWING PROPOSED RÉSEAU OF METEOROLOGICAL AND AEROLOGICAL OBSERVING STATIONS.
Proposed new stations underlined.



C.E.M. 17/1929.

APPENDIX IX.—NOTE ON ANEMOMETERS.

By T. F. CLAXTON,

Director, Royal Observatory, Hong Kong.

In connection with climatological summaries of wind velocity, we are asked to give the mean velocity for the last 10 minutes of every hour. I think that in place of making recompilations, or in the case of near stations making special compilations for this epoch, it would suffice if the ordinates of mean monthly curves were measured at the 55th minute of each hour.

We are told that the instrument used is the Dines pressure-tube anemograph. I should like to inquire whether exhaustive comparisons have been made in this country between the Dines and the cup anemometers.

The comparisons made at Hong Kong show large variations from month to month, and even year to year, in the factor between the two instruments, in spite of very careful tending, cleaning, oiling, etc. The pens of the Dines instrument are brought to zero every 6 hours and base lines drawn through the zeros so obtained. These base lines are by no means straight when the wind velocity is variable. As regards time scale the pens are lifted from the paper for 3 minutes at each hour by the mean time clock.

I would suggest that both a Dines and a cup anemograph be installed at all first-order stations and their records compared. By so doing we may be able to form some opinion as to the merits of each for climatological purposes.

C.E.M. 19/1929.

APPENDIX X.—MINIMUM WET-BULB THERMOMETERS.

By A. J. BAMFORD,

Superintendent, Colombo Observatory.

The present custom appears to be to use vertical thermometers for wet bulbs. The effect is that dry and wet readings are all eye observations and do not include a minimum wet.

In places where there is a marked difference between day and night humidities there appears to be a case for standardising a horizontal thermometer as the wet bulb.

C.E.M. 13/1929.

APPENDIX XI.—THE EMPIRE IN RELATION TO INTERNATIONAL METEOROLOGY.

By R. G. K. LEMPERT,

Assistant Director, Meteorological Office.

Meteorological observations may be discussed from two rather different points of view. On the one hand they may be considered as contributions to what we may call the general circulation of the atmosphere and on the other we have the more detailed investigation of conditions in a limited area and their correlation with other matters such as agricultural crops, vital statistics, questions of water supply and a host of other subjects. All purely meteorological investigations inevitably tend to expand in area and meteorologists have long recognised that progress in the larger problems with which they are confronted, the successful solution of which is likely to have far-reaching practical results in the improvement of long-period or short-period forecasting and in other directions, depends on considering the world as a whole. Our discussion on seasonal forecasting will fully demonstrate that. The problem of providing material in suitable form for such investigations has forced itself on the International Meteorological Organization from the earliest days. Observations are taken in bewildering quantity and the publications in which they are set out are bulky to a degree, but they are stored away in the libraries of meteorological offices and Societies which are few in number and not easily accessible to the individual investigator, and even if he has access to such a library he was faced until recently with the all but appalling task of extracting his raw material from the vast array of volumes on the shelves of his library.

The monthly climatological tables for the British Empire which had appeared for many years in *Symons's Meteorological Magazine* (now the *Meteorological Magazine* of this Office) did something to meet the demand in a small way but we may regard as the first organized attempt to deal with the problems of providing material in convenient form the creation by the International Meteorological Committee in 1903 of a "Solar Commission" under the Presidency of the late Sir Norman Lockyer. Lockyer, as we all know, had devoted himself assiduously to the problem of tracing the connection between solar phenomena and terrestrial weather. The necessity for considering the world as a whole was obvious to him as to others, but he found himself confronted with the difficulty of coming by his meteorological material in suitable form and he applied to the Committee for help. The problem facing the Commission was no easy one. For some regions data were available in abundance and in great detail. The first-order observatories provided hourly values of all the principal meteorological elements and it was quite impossible to include all the detail in a comprehensive survey. For other areas, it would be no exaggeration to say for the greater part of the earth's surface, only a few observations of rainfall or temperature might be available, and for large tracts there was nothing at all. How make a selection and produce a survey of the whole that should be of manageable size?

The Commission ultimately agreed on a programme, viz., the production of annual volumes in which each "ten-degree square" of the earth's surface should normally be represented by data from two selected stations. The month was taken as the appropriate unit of time, and data were confined to the

elements, pressure, temperature and rainfall. By such means it was hoped to keep the enterprise in manageable proportions. A specimen of such a publication for the month of January, 1905, was prepared in the Meteorological Office from the data available in the Office library and was submitted to the International Meteorological Committee at its meeting in Berlin in 1910. It is printed as an appendix to the official report of that meeting and gives the mean pressure, mean temperature and rainfall for the month for 278 stations distributed over 169 "squares." When possible the differences from normal and information about the extreme values were also given.

The general form of the proposed publication was thus settled, but the arrangements for its regular compilation and for printing had still to be worked out. I need not go into details of that. Suffice it to say that ultimately Sir Napier Shaw, the former Director of our Office, who had succeeded Sir Norman Lockyer as President of the Solar Commission was able to arrange for that duty to be undertaken by the Meteorological Office. A start was made with the compilation of data for 1911, the manuscript of which was completed in the early part of 1914 just as the war broke out. At first it looked as though the enterprise would be brought to nought, but somehow the printing was accomplished during the days when "business as usual" was the prevailing slogan and then a catastrophe occurred. The whole edition was destroyed in an accidental fire in the warehouses of the printer who had the work in hand. The manuscript and proofs were fortunately still available and in 1917 the *Réseau Mondial*, 1911 was at last printed and distributed. Since that time 12 further volumes have appeared, dating back to 1910, that for 1923 is now ready for press and the work in compiling 1924 is well in hand. The volume for 1922 contains data for 452 stations of which no less than 176 are in the British Empire. There are also included marine data for six ocean "squares." The International Commission which still supervises the work has changed its name and has now become the Commission for the *Réseau Mondial* and Dr. Simpson is its President. It is perhaps not in order to invite criticisms from a conference of Empire delegates on an enterprise which is conducted in some respects under international auspices, but I think I may invite delegates who may not be familiar with the volumes to examine them and make suggestions for extending the network of stations to regions at present unrepresented. There may be such regions not actually under the British Flag, in which British influence is strong, in which stations already exist or could be started. I have in mind more particularly isolated islands in the ocean wastes and the desert or polar regions of the earth which from the meteorological point of view are perhaps even more important than the areas where civilization thrives. The *Réseau Mondial* is fast becoming a powerful instrument of meteorological research, whose importance increases with each year that is added to the collection. Who knows but what it will form the means for making advances which may have the most far-reaching practical consequences in the applications of meteorology?

Turning now to the other aspect of meteorological work, the collection of data for the more detailed study of conditions over limited areas, I should like to say a few words about the system that has grown up for publishing observations from British Crown Colonies and Protectorates. If one turns to the reports of International Meteorological Meetings of 20 and 30 years ago one finds in them numerous resolutions urging the importance of the systematic publication of meteorological data for distant regions. These resolutions were in large measure, I believe, directed at us of the British Empire. It is true that the practice of including meteorological summaries in the annual reports of Colonial Governments, the so-called blue books, is a very old one, but such publications are not generally available, and they for the most part fail to reach meteorological institutes and observatories. Moreover, the statistics given in the early days followed no recognisable system. The British Meteorological Committee early in the present century brought the matter to the notice of the Colonial Office and in 1906 a dispatch was issued by the Earl of Elgin, the then Secretary of State for the Colonies, inviting Colonial Governments to adopt certain forms for their meteorological statistics. The forms were closely similar to those which Dr. Brooks is bringing before us. They were those used in this country and followed the standard international forms very closely. Colonial Governments were further asked to provide 100 reprints of their meteorological tables for transmission to the Meteorological Office, London, for distribution among the meteorological institutes and observatories with which our Office maintains an exchange of publications. By this means the large amount of meteorological work done in the outlying parts of the Empire has been made generally available to meteorologists and others interested in the applications of meteorology to other subjects. The demand for these reprints has been so great that the number supplied has had to be increased to 200 copies. About the same time arrangements were made for the Crown Agents for the Colonies to submit indents for meteorological equipment to our Office and to draw their supplies as far as possible from the stock of instruments held by the Office. It may be that to some this action on the part of the London Office appeared as a piece of gratuitous interference, but I think that on the whole we may claim that the system has worked well and has been the means of avoiding many mistakes.

In other respects also we hope that our Office has been able to give assistance to those engaged in organizing meteorological work abroad. For example, it has been our endeavour to give in the "Meteorological Observer's Handbook" and its companion volume the "Observer's Primer" concise instructions for the layout of a meteorological station and for conducting the routine of observing.

A further step in co-ordination has been taken more recently. On looking through the statistics one noticed that in a number of cases information regarding the height or position of stations, the conditions of exposure, or hours of observation and other details which the meteorologist finds useful or even indispensable when applying the results were not stated. Arrangements have therefore been made for the circulation of a questionnaire asking for such information to be given for each station that appears in the summaries. The replies are gathered together and published in an Introduction which is distributed with each batch of reprints.

The system has now been in operation for about 20 years and the reproach that the Empire does not make its meteorological results generally available can no longer be sustained, but the present is the first occasion on which those primarily concerned in making the arrangements work have had any opportunity of discussing them and of drawing attention to possible further improvements. The Office would welcome comments on the system or on the details which Dr. Brooks will bring before us.

APPENDIX XII.—THE COLLECTION, TABULATION AND PUBLICATION OF CLIMATOLOGICAL DATA.

By C. E. P. BROOKS,
Superintendent, General Climatological Division, Meteorological Office.

1. **The elements required for climatological purposes.**—We may take as a broad definition of climate the aggregate of atmospheric conditions and processes which affect human health and activities. The climatic elements include temperature, humidity, cloudiness and sunshine, rainfall, wind, snow, hail, thunder, and other phenomena. For agricultural purposes soil temperature and soil moisture are also important. Pressure at moderate elevations does not directly affect human activities, and unless pressure is required for synoptic weather reports, it should only be observed at selected stations, including all first order observatories. The requirements as regards each element are first, accuracy, and secondly, comparability with other parts of the world. The requirement of accuracy is discussed later (section 4). The requirement of comparability involves comparable instruments, comparable methods of exposure and comparable hours of observation.

The methods of exposure have been standardised; they are fully set out in the "Meteorological Observer's Handbook," and more concisely, for temperature and rainfall only, in the "Observer's Primer." It is now recognised that even in tropical countries the best form of exposure is the Stevenson screen, but it is important that the screen should be constructed according to standard specifications. The stand may be constructed of iron, painted white, instead of wood, in order to avoid damage by rot and insects. The site, both for thermometer screen and for rain-gauge, should be level and open; the rain-gauge should be at least ten feet from the screen, and its distances from neighbouring objects such as building and trees should be at least twice the heights of those objects.

The current practice in the British Isles is to fix the rain-gauge with its rim one foot above the level of the ground which should be covered with short grass. If the rim is at a greater height the gauge records less than the true rainfall, some rain-drops which should fall in the funnel being carried past it by eddies of wind. If the height is less than one foot, there is some risk that part of the rain-drops falling outside the funnel will splash into it. In this country it is probably extremely rare for rain to fall with sufficient force for any appreciable amount of water to splash from grass turf to a greater height than one foot, but if the ground is bare, smooth and hard, such a source of error is appreciable even in this country, and in some tropical countries this may be serious. In some tropical countries the winds accompanying rain are usually less strong than in Britain and there the best policy may be to raise the rims to a greater height than one foot to avoid insplashing, but where any appreciable part of the rain falls with strong winds, for example during the passage of hurricanes, raising the rim will probably introduce a considerable error. Whatever height be adopted, it will be necessary to keep the vegetation near the gauge cut very short.

The container used for the water of the wet-bulb thermometer may be important in hot dry climates, as a wide-mouthed container may lower the temperature in the screen appreciably by evaporation, and it is desirable that some definite pattern of container, such as that employed at Meteorological Office stations in Egypt, should be adopted as a standard.

The observations of wind, both direction and force or velocity, often present difficulty, and the type of exposure of an anemometer in forest country especially requires discussion. Records of anemometers in sheltered situations should not be published without comment among the regular meteorological observations. It is better to give Beaufort estimates than results derived from anemometers of which the calibration constants are unknown, or which are badly exposed.

Observations of solar radiation are becoming increasingly important but present difficulties. The old "black bulb in vacuo" is of little use as an instrument of precision, but the modern pyrhemometers require skilled observers. A pyrhemometer should form part of the equipment of first order stations; a suitable instrument is that designed by Dr. C. G. Abbot.

The Abbot Silver Disc Pyrhemometer is an instrument for determining readings proportional to the intensity of solar radiation. The radiation is absorbed by a silver disc, its increase of temperature being measured by a mercurial thermometer. The disc is bored radially with a hole to admit the cylindrical bulb of the thermometer which is bent at a right angle. To assist the transfer of heat to the thermometer bulb, the hole is lined with steel and filled with mercury. The disc is supported in a cylindrical copper box, the latter being in a wooden box. A tube with a number of diaphragms fits into the copper box. The aperture of the diaphragm nearest the disc is smaller than the others and limits the cross section of the beam. Shutters for cutting off the sunlight are provided. The instrument is mounted equatorially on a stand and the tube is pointed at the sun. To obtain absolute values of the solar constant the pyrhemometer must first be standardised. The Abbot Pyrhemometer is not at present made commercially, but instruments are constructed by the Smithsonian Institution as required, the cost being about 200 dollars.

2. **The hours of observation.**—The regular meteorological observations fall into two groups, (1) those in which the value observed is the *instantaneous* value of the element, such as the pressure, and the dry and wet bulb thermometers at 9h. (2) those in which the information obtained refers to some preceding interval, usually 24 hours, ending at the time of observation, e.g. the readings of the rain-gauge and the self-registering maximum and minimum thermometers.

The second group of observations is taken at one of the hours allocated to the first group, and as there are in most meteorological services a number of third order and rainfall stations where observations are taken once only, at a morning hour, it is preferable for the sake of uniformity, that the rain-gauge and self-registering thermometers should be read at the morning hour at all stations. In that case the rainfall and the maximum temperature are regarded as belonging to the preceding day, but the minimum

temperature, which usually occurs about or shortly before sunrise, is regarded as belonging to the day of reading. There is no theoretical objection to these readings being taken in the evening, in which case they are all entered to the day of reading.

The mean of the mean daily maximum and mean daily minimum temperatures for the month is often taken as the mean temperature of the 24 hours. This practice is convenient, and gives results which are roughly comparable, but it suffers from certain disadvantages. The mean of the mean daily maximum and minimum is generally above the 24 hour mean by about one Fahrenheit degree, but the difference varies from one place to another and often from one month to another. A more serious objection in hot countries is the liability of spirit thermometers to develop errors, due especially to the condensation of spirit in the upper part of the stem. Where no adequate system of inspection or checking is in operation, such errors may continue for many months or even years before being discovered, and in the past long series of observations have often been vitiated from this cause. Mercury thermometers are much less liable to error, and if a suitable combination of hours can be selected, readings of the dry bulb thermometer of the first or *instantaneous* group give a more reliable measure of the average temperature. The readings of the dry and wet bulb thermometers at the same combination of hours will also give a good representation of the average relative humidity.

Observations once a day are however not very satisfactory for this purpose. The best hour is 9h when temperature and humidity are passing through their average for the day, and theoretically readings at 9h. should give a good measure of average conditions, but at this hour both temperature and humidity are changing most rapidly, and small unpunctualities, the use of zone time for local time, and the difference between apparent and mean time, have their greatest disturbing effect. For this reason observations of temperature and humidity once a day may not be readily comparable. It will be seen later, however, that dry bulb readings at the hour of reading the self-registering thermometers are valuable for purposes of checking.

When observations are taken twice daily one of two alternative systems may be adopted. The first selects two observation-hours twelve hours apart, and both near the times of average conditions, i.e. 9h. and 21h. local time. A small departure, such as the use of zone time, if applied equally to morning and evening observations, raises the temperature at one observation hour and lowers it at the other hour by almost equal amounts, thus having little effect on the mean. The combination $\frac{1}{2}(9h. + 21h. + \text{max.} + \text{min.})$ gives a good representation of the daily mean temperature if the readings of the maximum and minimum thermometers are reliable. The alternative system is to take observations near the time of maximum and minimum temperature, a convenient combination being 7h. and 15h. This has the additional advantages that it gives the relative humidity in the afternoon, when it is lowest, and that it avoids observations after dark, an important consideration at some stations. The combination 9h. and 15h. gives a very good representation of pressure, but not of temperature or humidity.

Undoubtedly the best combination is given by observations three times a day, at 7h., 13h. or 14h. and 21h. Using the symbols I for the morning observation (7h.), II for the midday observation (13h. or 14h.) and III for the evening observation (21h.), a very good representation of the 24 hour means of temperature and humidity is given by the combination $\frac{1}{3}(I + II + 2 \times III)$. The observations at the individual hours also show the diurnal variation clearly. The International Meteorological Conference recorded the opinion that a general approach to the adoption of these hours (7h., 14h., 21h.) is in the highest degree desirable.

The necessity for systematising the hours of observation to improve comparability is shown by the fact that at present about 36 different hours or combinations of hours are in use at stations in the Empire.

3. **The form of the network of stations.**—The International Meteorological Congress classifies stations as follows:—

A station of the first order is an observatory in which meteorological observations are conducted on a great scale, i.e., either by hourly readings or by the use of self-recording instruments.

Stations of the second order are stations where complete and regular observations (at approved hours) of the usual meteorological elements, viz., pressure, temperature, and humidity of the air, wind, cloud, rain and hydrometeors, etc., are conducted.

Stations of the third order are the observing stations, where only a greater or less portion of these elements are observed.

A fourth class may be added, *rainfall stations*.

Stations of the first order will require the full-time services of a trained meteorologist. Without a competent observer the instruments are useless. At stations of the second order it is desirable that the observer should have received some training and that the observations should be recognised as part of the regular work for which he receives payment. Stations of the third order and rainfall stations would in general be maintained by voluntary observers.

The ideal system to be aimed at is as follows:—

(1) A first-order station in each of the climatic provinces of the Empire. In practice this would mean one or more first-order stations for each of the larger Colonies, and one for each territorial group of the smaller Colonies.

(2) One or more representative second-order stations observing temperature, rainfall and weather.

(3) A closer network of voluntary stations observing temperature, rainfall and weather.

(4) A still closer network of rainfall stations.

The localities of (3) and (4) will naturally depend on the presence of suitable voluntary observers.

4. **Improving the accuracy of the observations.**—The only satisfactory way of maintaining the accuracy of meteorological observations is by systematic examination of the returns at headquarters, combined with regular inspection of the stations by a trained meteorologist.

If regular inspection is impracticable, something may be done to facilitate the discovery of the most frequent errors by insisting on the comparison of the maximum and minimum thermometers after setting with the dry bulb. Experience has shown that a simple instruction to make the comparison is insufficient, and that some method is required by which the observer actually reports to headquarters the result of such a comparison. It is suggested that a small printed form be inserted with each sheet of the monthly return, or printed on the latter, containing space for such a comparison once a month immediately before the monthly return is despatched to headquarters:

| Date. | Dry Bulb. | After setting Maximum. | After removal of muslin Minimum. | Wet bulb. |
|-------|-----------|------------------------|----------------------------------|-----------|
|-------|-----------|------------------------|----------------------------------|-----------|

The provision of the last column will ensure that the muslin of the wet bulb is changed at least once a month. This method of checking would supplement the usual examination to verify that the maxima are not lower and the minima and wet-bulb readings not higher than the dry-bulb readings.

Readings of pressure and rainfall can only be satisfactorily checked by systematic plotting of the monthly means or totals.

5. **The form of publication.**—Publication of daily observations *in extenso* appears to be impracticable at present. Where practicable, it is highly desirable that daily observations should be published for selected stations. The form of publication of monthly summaries has become far more systematic of recent years than at one time, but there is still a large amount of divergence. The form which is recommended is that of forms 3211 and 3215 employed by the Meteorological Office.

The general tendency is towards the use of millibars and tenths for barometric pressure and it is desirable that these units should be adopted when changes are being made or new services initiated. The head of the column must always contain a statement of the corrections which have been applied. The corrections for attached thermometer reading and for gravity should always be applied.

Average temperatures should be in degrees and tenths on the Fahrenheit scale.

Extreme temperatures should be in whole degrees. Amounts of rainfall should be in inches and hundredths or in millimetres and tenths.

C.E.M. 12/1929.

APPENDIX XIII.—DIURNAL VARIATION OF METEOROLOGICAL ELEMENTS.

By A. WALTER,

Director, British East African Meteorological Service.

Sufficient attention does not appear to have been paid to the diurnal variation of the various elements in the tropics.

For general climatic purposes the averaging of hourly values by the inclusion of all types of days may be advantageous, especially in high latitudes, but there can be no doubt that this procedure is masking many of the processes of meteorological changes in the tropics. Two noteworthy instances may be cited in the rainfall and temperature changes in East Africa. In certain regions the rains are of the monsoonal type and fall almost entirely, for days on end, in the early morning; instability rains, on the other hand, fall during the late afternoon. If these two types are averaged into monthly hourly values they shew two maxima; a phenomenon which has no climatic significance whatever.

Again, the daily range of temperature on days falling outside the rainy seasons in East Africa is very large, amounting to as much as 30 degrees or 35 degrees Fahrenheit. During the rains this daily change drops to 5 degrees Fahrenheit and even less. When the rains break in the middle of a month and all days are averaged, a result is obtained which also has no counterpart in nature.

C.E.M. 3/1929.

APPENDIX XIV.—A PRELIMINARY NOTE ON THE RAINFALL OF WEST AFRICA.

By N. P. CHAMNEY, B.Sc.,

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The object of this paper is to show broadly what is known about the distribution of rainfall in West Africa and to indicate what further information is necessary and what records appear to the writer to be desirable.

It was originally intended that a map of isohyets should accompany this paper but, owing to lack of information in certain areas, there does not appear to be sufficient justification at this stage. There are sufficient points of interest in the records examined to justify careful investigation in the future and, later on, the publication of this map together with the basal records.

The area dealt with.—Artificial limits had to be set with regard to the area to be studied, and these were finally fixed at the eastern side of the French mandated sphere of the Cameroons to the northern edge of Senegal.

The northern limit inland was roughly that shown in the geographical maps of West Africa which include a portion of the French Soudan.

Recording stations.—The total number of rainfall recording stations in this area appears to be large but, relative to the range of country covered, is by no means sufficient for accurate, large-scale plotting of isohyets. As far as information has been obtained from various sources, there are not less than 342 stations, either recording at present, or from which past records are available.

These stations are distributed over West Africa as follows:—

| | Stations. |
|---|-----------|
| 1. Mandated sphere of French Cameroons | 6 |
| 2. Nigeria and British mandated Cameroons | 50 |
| 3. Dahomey and French mandated Togoland | 33 |
| 4. Gold Coast and British mandated Togoland | 91 |
| 5. Ivory Coast | 26 |
| 6. Liberia | 2 |
| 7. Sierra Leone | 11 |
| 8. French Guinea | 26 |
| 9. Gambia | 2 |
| 10. Senegal | 28 |
| 11. French Soudan | 32 |
| 12. Haute Volta | 18 |
| 13. Mauretania | 11 |
| 14. Niger District (French) | 8 |
| | <hr/> 342 |

Records are available from the majority of these stations except those in the French Territories, where published information is very scanty. This is unfortunate, as records from the Ivory Coast, French Guinea and Dahomey form links between various British Colonies, and are of great importance in designating the paths of the isohyets which are more complicated in this coastal region, than in the hinterland. Liberia has only two stations one of which is operated by French observers and the other by American missionaries.

The importance of rainfall records.—Apart from the academic interest of rainfall records to the meteorologist and scientific workers, such records are of definite value to the agriculturist, medical officer, engineer and also to the statesman.

In tropical countries, rain is the limiting factor in agriculture and determines the boundaries of development of the various crops. From this point of view the administrator must also have knowledge of rainfall distribution in order to formulate policy and to make the best of his country's resources.

The wealth of the West African Colonies lies largely in their agricultural produce, and therefore accurate information from well distributed sources, is a matter of importance.

The agriculturist is concerned with question as to whether there is sufficient total rainfall to grow the particular crop he desires in his district. He will also wish to know the distribution of this precipitation over the year since different crops need rain at different periods. Variations from year to year and the chances of drought are other figures which should be available to him.

The statesman is chiefly interested in the broader aspects such as the map of isohyets which limits the development of the country and the most paying export crops and what areas are merely suited for food production for their population or are adapted for irrigation in extreme necessity.

Zones of total rainfall.—The average annual precipitation of stations in West Africa varies between wide limits. In the neighbourhood of the Cameroon mountain an annual fall of 400 inches is common. In the hinterland near Timbuku only eight inches is recorded. The majority of stations, however, record between 20 and 150 inches.

West Africa may be divided roughly into sections according to the angle at which the SW. monsoon (the rain-bearing wind) strikes the coast line. Where this is at right angles, it is usual to find a heavy precipitation, but where the coast line is more or less parallel to the direction of the wind the precipitation is much less.

The areas of heavy rainfall are:—

- (1) French Guinea, Sierra Leone and Liberia.
- (2) Part of the Ivory coast and the south-west of the Gold Coast.
- (3) Southern Nigeria and Cameroon.

The areas of light rainfall are:—

- (1) The majority of the Gold Coast coast line.
- (2) Dahomey.
- (3) The northerly portion of the coast including the Gambia and Senegal.
- (4) The hinterland.

The former area corresponds with the equatorial climatic zone and is mainly covered with forest and crops which require forest conditions, such as cacao, coffee, oil-palms, etc. The latter area corresponds to the tropical zone and is covered with savannah or desert. Crops are confined to food production or occasionally cotton, shea nuts and ground nuts. The remainder is transitional and may, according to local conditions of rainfall carry either food crops or forest crops.

Distribution of rainfall.—The annual distribution of rainfall is governed by the apparent "passage" of the sun towards the solstices. Those parts of the area under consideration which lie along the coast and below the tenth degree of latitude have a definitely defined double rainy season which has two peaks. The first of these occurs just after the sun "passes" towards the north and the second just after the "passage" south. As one proceeds in a northerly direction the peaks are reversed from a major peak in the early part of the year and a minor peak later to a minor early peak and a late major one. Further north only one peak occurs in or about September. This fact severely limits the agricultural possibilities of the hinterland and also the coastal area lying above 15° N. latitude.

Annual variation and periodicity.—The variation in annual precipitation from the mean is large over the majority of the area. This is important from many points of view, especially from that of the engineer responsible for the construction of roads, bridges, etc.

To quote figures from several stations may be of interest in illustrating this point.

TABLE I.

| Country. | Station. | Mean annual rainfall. | High extreme. | Low extreme. |
|----------------|-------------|-----------------------|---------------|--------------|
| | | in. | in. | in. |
| Gold Coast .. | Axim .. | 76.29 | 109.65 | 47.64 |
| " .. | Kintampo .. | 70.75 | 100.58 | 48.87 |
| " .. | Bekwai .. | 63.51 | 104.90 | 46.21 |
| " .. | Aburi .. | 47.79 | 73.16 | 32.09 |
| Nigeria .. | Forcados .. | 142.20 | 249.21 | 106.29 |
| " .. | Lokoja .. | 48.40 | 73.64 | 34.76 |
| " .. | Lagos .. | 71.40 | 115.49 | 40.50 |
| Sierra Leone.. | Bonthe .. | 138.56 | 192.21 | 123.98 |

This variation does not appear to occur in regular cycles nor in the whole of one area at once. The writer has plotted many curves of total rainfall for various districts in West Africa, and has failed to find definite indications of similarity in curves in most districts. The so-called dry and wet years do not appear to be marked over large areas and droughts are of very local occurrence. The influence of local conditions appears to govern these variations rather than broad relationships of climatic origin.

Periodicity curves for all stations with records going back over a fair period have been worked out but fail to show marked periodicity unless the rhythm of recurrences is a long one like that exhibited by Brückners 35-year cycle. In connection with this is the apparent diminution of rainfall on the coast between Sierra Leone and Senegal. Whether this is part of a major period or is a separate phenomenon is not yet known, but it is definitely taking place over a probably larger area than can be identified by the available information. The table set out below shows instances of this apparent diminution.

TABLE II.

| Freetown. | | St. Louis. | |
|-----------|-----------|------------|-----------|
| Years. | Rainfall. | Years. | Rainfall. |
| | in. | | in. |
| 1882-91 | 166.67 | 1830-40 | 23.62 |
| 1892-1901 | 166.15 | 1841-60 | 17.32 |
| 1902-1911 | 156.00 | 1861-94 | 15.91 |
| 1912-1921 | 122.66 | 1895-1902 | 15.75 |
| | | 1903-1916 | 9.36 |

In addition to the figures given above there are records to show that, in the past 40 years, Bathurst (Gambia) has experienced a diminution of ten inches when the records are grouped in decades. Records from Tamale and Kintampo on the Gold Coast show similar but less marked diminution, but on the other hand Nigerian figures from the Northern Province have not shown this tendency.

The system of shifting cultivation adopted by the African races leads to much deforestation, and combined with a diminishing rainfall would present a very real problem to administrators in the future.

Additional records and their value.—It is obvious to anyone acquainted with the rate of precipitation of tropical rain, that a mere measure of total rainfall does not give an accurate idea of the value of that rain to crops. In addition, the engineer has no idea of the allowances he has to make for the heavy precipitation of sudden storms.

It is therefore essential that additional records should be published for meteorological stations in the tropics to amplify the record of total rainfall.

The measurement of "effective" rainfall is outside the scope of any ordinary station as so many factors have to be taken into account and require both complicated and expensive apparatus. These factors include:—

- (1) Rate of precipitation.
- (2) Interference by trees, shrubs, etc.
- (3) Run-off.
- (4) Evaporation.
- (5) Drainage.
- (6) Type of soil.

These vary in every locality and at different times in the year, and to determine factors for calculation of the loss of rainfall due to each is a very long and difficult piece of work. These will probably have to be worked out at certain stations to give a rough idea at least of the "value" of these factors. In the meantime, however, records can be kept at each station as is done in the Gold Coast of the time over which rain falls and the number of days on which measurable fall is recorded. It is probable that these records are kept in other countries but unfortunately are rarely published and possibly not always kept after the annual figures have been extracted. The records of these observations gives an approximate idea of the value of the annual rainfall which is nearer the truth than the total precipitation. The present system does not differentiate between a fall of two inches in an hour and a fall of two inches spread over say twelve hours.

Chipp's formula, whereby the degree of wetness of a station is arrived at, is a step towards a truer picture of the effectiveness of rainfall. This formula is $(\text{rainfall} \times \text{number of wet days}) \div 100$.

In conclusion the writer wishes to thank the Director and staff of the Meteorological Office for much valuable help and also to express a hope that by co-operation between observers in various parts of West Africa and the addition of such records, as are detailed above, a reliable and instructive account of the rainfall of West Africa may soon be able to be prepared.

C.E.M. 2/1929.

APPENDIX XV.—ON LONG-RANGE FORECASTING.

By PROF. SIR GILBERT WALKER.

Late Director-General of Observatories, India.

In response to a request from Dr. Simpson I am attempting to describe the methods which seem to hold out most hope of foreshadowing seasonal rainfall. Those which have been used in the past depend on (a) relations with sunspots, (b) strict periodicities, (c) "surges," (d) motion of the belts of high pressure, and (e) relations with previous weather conditions in various parts of the world. Now while the effect of sunspots should always be examined it is in general only on temperature in the tropics that it is considerable; the correlation coefficients (in future denoted by c.c.) of the seasonal values hitherto examined and published by me⁽¹⁾ only exceed .4 for temperatures at Batavia and Samoa. Periodicities have frequently been tried, and have in almost every case been discarded. Both methods (a) and (b) may, if examination proves them worthy of employment, be combined with (e), for in (a) the sunspot curve and in (b) the harmonic curve given by periodogram analysis may be treated as if these were curves of a "centre of action." The rainfall of Sweden and of Java appears to tend to be in excess for a time and then to be in defect for a time; so that forecasts have been made by plotting these swayings. If for instance a minimum period has been passed and rainfall has become normal it might be justifiable to forecast an excess. But instead of plotting the curve exhibiting the surge, and estimating the resulting forecast by inspection we might more readily get it by calculation, working out the c.c.'s of the season to be forecasted with seasonal values on the surge curve one, two, three, four . . . quarters, half-years or years previously. Thus (c) is a special case of (e)⁽²⁾. Colonel Rawson's idea of motion of the belts of high pressure is attractive, but I have given reasons for rejecting it in para. 68, pp. 123-4 of *World Weather I*.⁽³⁾ Anyhow the position of the belt can be estimated by the pressure at a few selected stations, and so (d) also is in reality included in (e).

Regarding (e) a general account of seasonal relations is attempted in an address of 1928⁽⁴⁾ and the detailed tables will be found in *World Weather II*⁽⁵⁾ and *World Weather III*⁽¹⁾.

2. The first step in examining variations of rainfall is clearly to tabulate it: and it is doubtful whether records of less than 20 years are worthy of inclusion. We must divide up our region into rainfall divisions small enough to be reasonably homogeneous, work out the rainfall of each and ascertain by actual correlation with world centres which of these divisions are similar enough to be combined, and which must be kept separate. For the rainfall of a division during n years it is not usually satisfactory to take the average rainfall over the division and its departures from the normal got by adding up the n years and dividing by n ; for as the number of stations grows it may be that either the wet or the dry areas become more

⁽¹⁾ *World Weather III, Memoirs of the Royal Meteorological Society*, No. 2, 17, 1928. See also Chapter I, pp. 77-87, of Vol. XXIV, Pt. IV of the *Indian Meteorological Memoirs*, a paper which may be called *World Weather I*.

⁽²⁾ Thus for Australia the formula season's rain = .11 (rain of previous year) — .22 (rain 2 years before) + .21 (rain 3 years before) gives $R = .39$; the region of Australia referred to is that of para. 2 below.

⁽³⁾ See footnote ⁽¹⁾.

⁽⁴⁾ *Q.J.R. Meteor. Soc.* 54, April 1928, pp. 79-87.

⁽⁵⁾ *Ind. Met. Mem.* 24, Pt. 9, 1924.

fully represented, and this fact alone will produce a change in the average rainfall. A better plan is to work out the normal rainfall for each station separately, and its departures from normal for each season; then the departure from normal of the divisional rainfall during any season is the mean of the departures of the separate stations during that season. It would be even better to work with percentage departures but this refinement is probably not necessary. In India we employed 33 rainfall divisions⁽¹⁾ though probably 15 would have sufficed; and the labour was justified as it showed us that rain in some areas varied inversely with that in others, so that it was absurd to include both in the same prediction formula; it showed us that decidedly better forecasts for north-west India, the Peninsula and north-east India could be made than for India as a whole, and that for Malabar we could do nothing. In South Africa and Australia there are obviously considerable diversities. In each there is a south-western region of cold weather rainfall, while to the north-east the rains come in the summer; also recent work shows that in South Africa the summer rainfall of Natal is largely different from that of the region to the west of it, as also is the rainfall of Southern Rhodesia. For this interior region of South Africa a preliminary forecast with a c.c. of .72 follows at once, while in Australia for the fairly homogeneous region of the Kimberley Division (Western Australia), Northern Territory and Queensland a c.c. of .79 is readily found. Either of these could be modified by including stations whose records extend over 23 and 28 years respectively; but as the data used cover about 45 years and the improvement in R would be small, it is safer to wait until the series is longer.

3. A further question is that of the labour involved and the reduction of its amount where this can be done without sensible loss of accuracy.

I have discussed (*Q.J.R. Meteor. Soc.* 52, pp. 74-6, 82-4, 1926) the limits of the accuracy which it is worth while to attempt, and shown that the accuracy required for observatory records is far in excess of that wanted for the purpose of correlating. When the departures have been reduced and entered in slips the working out of a c.c. involving 45 years can be completed in a minute. The gist of the matter is that it is enough to choose the unit of measurement so large that the departures will only range from about -12 units to +12 units and to ignore fractions of a unit. The standard deviation will then be about $\sqrt{20}$ units and most of the figures will lie between -7 and +7 so that multiplication in the head can be very rapidly done.

4. The quarterly departures of 32 world centres and of some other meteorological factors have been tabulated for rapid calculation with $\sqrt{20}$ as their standard deviations and it would certainly be worth while for any office desirous of carrying out investigations of this character to have copies of the slips on which these are entered. In return they might consider themselves pledged to tabulate their rainfall by divisions, and publish the monthly and seasonal values (Dec.-Feb., Mar.-May, June-Aug., Sep.-Nov.) as soon as they conveniently can. I would suggest further that they prepare corresponding seasonal values of the pressure and temperature of a selection of their best and oldest observatories. The discovery of new relationships over the world would be greatly facilitated if the question of the existence of a connection between two series could be settled within a minute.

5. I would like to suggest a point for consideration. I hold that in the present state of knowledge it is better to make forecasts that rainfall will be "in excess" or "in defect." If on any occasion we issue a more vague forecast such as "normal or in excess" and there is a defect of 18 per cent. it may be that such a defect was classed by us as "normal," but the public would, I think, accuse us of unfairness if we claimed success and it would really count as a failure. If this view is accepted it follows, as I have shown in *Q.J.R. Meteor. Soc.* 52, pp. 77-9, that predictions with a 4.1 chance of success can only be made when the indicated departure exceeds a definite limit. I therefore prefer to speak of "fore-shadowing" seasons, rather than use the word "forecasting" which has more ambitious associations.

APPENDIX XVI.—ARRANGEMENTS FOR THE SUPPLY OF METEOROLOGICAL STORES TO THE COLONIES.

By E. G. BILHAM,

Superintendent, Instruments Division, Meteorological Office.

The following arrangements are in operation :

A. Colonies for whom supplies are arranged by the Crown Agents for the Colonies.—(1) A Colony in this category requiring meteorological instruments, or equipment associated with the installation and maintenance of meteorological instruments, forwards to the Crown Agents for the Colonies an indent, giving particulars of the supplies required. When doubt exists as to the exact type of instruments required, the Colony should give particulars of the purpose for which the supplies are required and instruct the Crown Agents for the Colonies to consult the Director of the Meteorological Office as to the pattern to be supplied.

(2) Upon receipt of the indent, the Crown Agents for the Colonies forward it to the Meteorological Office requesting that recommendations be made as to the issue of invitations to tender.

(3) If the stores required are available for supply from the stocks held in the Instruments Division of the Meteorological Office, a priced copy of the indent is returned to the Crown Agents for the Colonies with a covering letter stating that the instruments will be supplied by the Meteorological Office. When charts for use on self-recording instruments are involved, supply by H.M. Stationery Office is arranged through the Instruments Division. This arrangement does not, however, apply when forms other than those standardised by the Meteorological Office are required. In all cases, responsibility for shipment rests with the Crown Agents for the Colonies, but when mercurial barometers or other fragile instruments are involved, arrangements for placing them on board ship may be made by the Meteorological Office.

⁽¹⁾ *Ind Met. Mem.* 23, Pt. 2, 1922.

(4) When the indent refers to instruments or equipment which are not available for issue from stocks held by the Meteorological Office, the names and addresses of firms who should be invited to tender are forwarded to the Crown Agents for the Colonies. Any specifications and/or drawings that may be necessary for ensuring the supply of satisfactory instruments are forwarded to the Crown Agents for the Colonies with the recommendations.

(5) Upon receipt of the tenders referred to in paragraph 4 they are submitted by the Crown Agents for the Colonies to the Meteorological Office for recommendations as to the placing of contracts. In forwarding its recommendations, the Office calls attention to any matters requiring special consideration.

(6) Inspection services relating to instruments referred to in paragraph 4 are performed by the Meteorological Office or, in the case of thermometers, barometers and other instruments for which special test facilities exist at the National Physical Laboratory, by the National Physical Laboratory. The fees for these services are payable direct by the Crown Agents for the Colonies in the case of satisfactory items and by the contractor if the supplies in question fail to pass the tests.

B. Self-Governing Dominions.—Arrangements on generally similar lines to those described in Section A are in operation, the High Commissioner for the Colony acting in the same capacity as the Crown Agents for the Colonies.

It should be emphasised that smooth and satisfactory working of the system is largely dependent upon the maintenance of a close liaison between the Colony and the Meteorological Office. Unless there is special urgency and the supplies are of a simple and normal character, much subsequent correspondence may be avoided by a preliminary discussion with the Meteorological Office as to the quantities and types of instruments to be supplied. In some cases, special provision may be necessary for the installation of the instruments. This applies in particular to pressure tube anemographs. To overcome the effect of obstacles such as trees and buildings, a mast of more than ordinary height or of special construction may be necessary. If full particulars are given, the Instruments Division can normally make provision for the supply of suitable equipment.

Official correspondence relating to the supply of instruments, damage, deficiencies, etc., should be conducted through the Crown Agents for the Colonies, or through the High Commissioner in the case of self-governing Dominions, but preliminary correspondence relating to design, etc., should be carried on with the Meteorological Office direct.

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APPENDIX XV—ARRANGEMENTS FOR THE SUPPLY OF METEOROLOGICAL STATIONS TO THE COLONIES

BY THE METEOROLOGICAL OFFICE

The following are the arrangements:

1. Colonies for which regular reports are required are the Crown Agents for the Colonies—by a Colony in the ordinary course of meteorological work, the Colony is supplied with the necessary instruments and materials, and the necessary arrangements are made for the supply of the Colony. The Colony is supplied with the necessary instruments and materials, and the necessary arrangements are made for the supply of the Colony.

2. Colonies for which regular reports are required are the Crown Agents for the Colonies—by a Colony in the ordinary course of meteorological work, the Colony is supplied with the necessary instruments and materials, and the necessary arrangements are made for the supply of the Colony.

3. Colonies for which regular reports are required are the Crown Agents for the Colonies—by a Colony in the ordinary course of meteorological work, the Colony is supplied with the necessary instruments and materials, and the necessary arrangements are made for the supply of the Colony.

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