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## TWENTY YEARS AFTER

### The story of the Meteorological Office Training School

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**Introduction.**—The story of the Meteorological Office Training School begins nearly 25 years ago. At that time training in meteorology of the kind which is given today was almost unknown. Some universities offered post-graduate courses leading to M.Sc. and Ph.D. degrees in meteorology, but these, mainly academic in character, were not directed towards the practical need to gear meteorology to the requirements of everyday life. Applied meteorology was neglected and the training of staff starting a career in professional meteorology had to be done by the employer.

One of the first institutions to undertake professional training was the Department of Meteorology of the California Institute of Technology in the United States in 1934. A post-graduate course lasting one year and leading to an M.Sc. degree was established. The main object of this course was to train and supply meteorologists to the rapidly developing and expanding airline companies. The course syllabus consisted of basic theoretical dynamic and synoptic meteorology which was combined with a large amount of practical synoptic chart air-mass analysis, and analysis of upper air radio-sonde ascents. Entrants to the course were restricted to graduates possessing a sound foundation in mathematics and physics.

We will not repeat here the history of the early years of training within the Meteorological Office which led to the opening of the Training School. An account of this and of the early days of the School itself has been well told by P. J. Meade, a former head of the School, in an article[1] which appeared in the *Meteorological Magazine* in May 1952.

Nevertheless it should be mentioned once again that on 15 September 1939 Professor (now Sir David) Brunt became responsible for the training of all forecasters, service and civilian, for the Meteorological Office. The date is an important one for the record because it marks the official opening of the Meteorological Office Training School, under this distinguished leadership. Although training courses had been a quite normal activity of the Office for the preceding four years, the organization under which they flourished had never before been given a separate title.

With the formal setting up of a training school on a permanent basis, the advantage of centralizing the instruction of assistants as well as forecasters was soon appreciated, and classes for synoptic assistants, airmen and civilians were arranged.

The Training School subsequently underwent a number of moves in the London Area but it was finally established at its present location at Stanmore, Middlesex in August 1951. Since that time the Training School has developed its functions and expanded its scope, both in material resources and in its methods and approach to teaching meteorology. Today, with its stimulating international atmosphere, the Training School has much in common with a small university department.

**Aim and purposes of the School.**—In the past the large majority of the professional staff of the Meteorological Office have been employed on weather forecasting duties. It is natural, therefore, that the aim of the Training School has been to produce workmanlike weather forecasters and that emphasis has been placed on synoptic meteorology and synoptic surface and upper air chart analysis. Although this somewhat limited purpose of the training effort has been maintained throughout the years as a practical working policy it has nevertheless been possible gradually to extend and expand the material covered to include topics which touch the fringe of other and more specialized branches of meteorology. In this way there has grown a departure from the turning out of weather forecasters to the training of professional practical meteorologists. Although the discipline is still practical rather than academic, emphasis being laid on the application of the science of meteorology to meet the day-to-day needs of the community, it is recognized that it is essential to base the training upon a firm scientific basis. The courses are therefore framed to include a full treatment of theoretical topics in their proper perspective so that a valid background is maintained.

**The courses.**—The training programme is conducted by means of organized courses which are offered by the School. Excluding radio-sonde courses which are given at the radio-sonde school at Hemsby, Norfolk, the major courses are as follows:

**Course for Scientific Officers.**—This is a course for newly recruited Scientific Officers who are university graduates in mathematics or physics. The course is at post-graduate level and is designed to give the young Scientific Officer a firm grasp of meteorological science. Dynamic, synoptic and physical meteorology are covered in some detail. Mornings are devoted to lectures while the afternoons are spent in analysing surface and upper air synoptic charts, upper air tephigram ascents, vertical cross-sections of various measurements, etc.: numerous class discussions of the charts are held at which the students air their views before their class colleagues and the instructor. Field exercises are occasionally carried out.

Students on this course attend regularly the Meteorological Office Monday discussions and the meetings of the Royal Meteorological Society. At the end of the course a series of colloquia are held at which each student in turn presents a piece of research he has undertaken or delivers a brief survey of current knowledge on some special topic of interest to him. The course lasts for 23 weeks.

**Initial forecasting course.**—The initial forecasting course is designed for meteorologists recruited in the Experimental Officer grade who possess as a minimum requirement the General Certificate of Education at Advanced Level in mathematics and physics. The main emphasis is on synoptic meteorology and much time is devoted to practical work in surface and upper air chart analysis. A firm groundwork of dynamic meteorology is covered, although this is at a more elementary standard and at a slower pace so that much less material is covered than on the post-graduate course. The course lasts for 16 weeks.

**Advanced forecasting course.**—This is a course for meteorologists who have already had a certain amount of practical forecasting experience. More advanced topics which are not touched upon in the initial course, such as vorticity and the development ideas of Sutcliffe, are studied. The practical work concentrates on the upper-level charts and the estimation of vorticity changes and the resultant cyclogenetic and anticyclogenetic development terms. The course lasts for four weeks.

**Course for senior forecasters.**—This is a course for senior forecasting staff who have not had a course for some years. It is designed to survey the current state of knowledge in the various specialized branches of meteorology and so bring the picture up to date. A feature of these courses is that lectures are delivered by specialist research workers from within the Office. The course lasts for three weeks.

**Course in climatology.**—This is a new course designed for the meteorologist who desires to learn something about modern climatology in its various forms. The course gives a good foundation in statistics and statistical methods as applied to meteorology. The practical work of the course includes a considerable amount of computational exercise, and each student is supplied with a calculating machine for his individual use during the eight-week course.

**Assistant course.**—The course for Assistants gives the newly recruited boy or girl who has left school with the General Certificate of Education at Ordinary Level in mathematics and science subjects an elementary but comprehensive understanding of the fundamentals of meteorology.

The course is largely practical and much importance is attached to the actual making of observations out of doors. In this way the young Assistant learns to know about the weather from his own experience. Lectures on the elementary physics of the atmosphere help to impart a scientific understanding of what the trainee sees and measures so that the data he records and plots on his charts have real meaning and interest for him.

**Optional subjects.**—During the past year the length, scope and content of the courses have all been expanded and reorganized in order to enable the Training School to fulfil its true aim and purpose of being able to offer a really comprehensive training programme. One of the objects of the replanning has been to insert certain optional subjects into the main training courses. The object of including these additional subjects is to permit them to be taken separately, if desired, by overseas students or by Meteorological Office staff who do not require the full course. The optional subjects are:

*Instrument maintenance.*—Elementary instrument maintenance forms part of the Assistant course and lasts a week. Advanced instrument maintenance lasts for two weeks and forms part of the initial and advanced forecasting courses and of the course for Scientific Officers. These subjects are essentially practical and a well equipped instrument workshop including a small wind tunnel has recently been established for the purpose. The aim is to give meteorologists of all grades an insight of the design and operation of the various instruments which the meteorologist so often takes for granted but which give him the tools of his trade in the form of the raw data he requires. The Assistant, in particular, learns how to care for and maintain the basic instruments and is imbued with a sense of responsibility in handling them.

*Mediterranean meteorology.*—This is a special subject for Meteorological Office staff who may be called upon to work in the Mediterranean region. It will also be useful to students from countries in that area. Lectures are supported by practical analysis of surface and upper air synoptic charts which illustrate synoptic patterns which are typical of the Mediterranean.

*Tropical meteorology.*—For many years there has been a demand for instruction in tropical meteorology. The requirement has come from Meteorological Office staff who have to maintain forecasting offices in tropical regions and also, but to an even more marked extent, from overseas trainees attending the standard courses at the School. Analysis and forecasting techniques are so different in the tropics that the usual temperate zone procedures may be of little help. The practical work includes streamline analysis by the isogon, isotach and pseudo-geostrophic methods.

*Numerical prediction.*—This advanced course forms part of the course for Scientific Officers. It is given in the Napier Shaw Laboratory at Dunstable by expert research staff. The students are given the opportunity of working with the electronic computer.

The latter three subjects each last for two weeks.

**Synoptic chart analysis.**—It has already been said that practical surface and upper air chart analysis forms an important part of the basic courses. The availability of the necessary data provides a problem which can be solved in two ways. Either continuous use can be made of current teleprinter data or printed examples can be produced in quantity. Both methods are used at the School.

The introductory period of the basic training courses is devoted to the analysis of printed examples. These take the form of a number of sequences of developing synoptic situations which have been specifically selected for their training value. The sequences consist of about a dozen consecutive six-hourly synoptic charts, unanalysed, but with surface and upper air observations already printed on them. The students do not have access to the next instalment following on the particular chart upon which they are working until after a class discussion on that chart has been held. However, a carefully analysed master copy of each full sequence is held under lock and key and this is produced for inspection prior to the class proceeding to the next chart. The sequences cover Mediterranean and tropical situations for the optional subjects as well as the normal temperate situations of north-west Europe and the eastern Atlantic.

During the final few weeks of the course for Scientific Officers and the initial forecasting course the trainees change over from sequence work to current weather. Teams are formed, each of which is composed of a surface analyst and forecaster and an upper air analyst. This period simulates the normal routine of a forecasting office.

A number of teleprinters are installed at the School. These are linked to the Central Forecast Office at Dunstable and they pour out a continuous stream of data from midnight until 5.30 p.m. during the week. The immediate availability of such current data is essential on any course in synoptic meteorology and full use is made of it.

About 4.30 p.m. daily during these final periods of the course the above mentioned teams of trainees assemble in one of the briefing rooms for the daily chart discussion. This is the climax of several months of hard work both for the trainee and for the instructing staff who have been responsible for the day-to-day running of the course. Each trainee opens his briefing with a descriptive account of his analysis and of the associated weather. He proceeds to discuss the forecasts he has prepared as assigned earlier in the day by his instructor. He is then cross-examined at some length by the class instructor and by other members of the staff of the School who are present at these sessions. In some cases the briefings and subsequent discussion are tape recorded so that the trainee may listen to his style of presentation and pick out his faults. At the end of the course each member of the class should have acquired a confidence and ease of manner in delivering forecasts which are well phrased and technically sound.

**The School as an international training centre.**—A small number of students from overseas have attended courses at the School for many years. They have been accepted, subject to vacancies being available, along with Meteorological Office staff. No special arrangements were made for them.

In the autumn of 1957 it was becoming clearly evident that the number of overseas students was increasing to such an extent that the full capacity of the School was being taxed to its limit to absorb them. Numbers had doubled within a year. There were two courses of action open. Either the flow of these trainees would have to be seriously restricted or alternatively special arrangements would have to be made to encourage and welcome them. The latter choice was decided upon as a matter of policy. As a result of this a plan was submitted which proposed a reorganization of the Training School programme. The plan embodied a substantial expansion of the course programme both in the number and content of courses. Some of the new courses were specifically designed to meet the needs of overseas students (for example, Mediterranean meteorology and tropical meteorology). Others extended their scope to improve the training programme of British staff as well. The plan proposed some new features. One of these was the idea of awarding a "Certificate of Competence" to overseas students who had successfully passed a course at the School. Another was the proposal to publish an annual School prospectus or calendar for distribution to overseas meteorological services and international agencies such as the World Meteorological Organization.

The proposals were formally adopted and the doors of the School were opened officially to the students of other nations. The only restriction is that any person who is enrolled must be sponsored by a meteorological service or by the authorities administering an international fund.

The new course programme came into operation in April of this year. Applications for enrolment have been received from a number of countries, including those as far away as Burma, Japan, Korea, Taiwan and Venezuela. The majority of applications, however, are received from Commonwealth countries.

**The future.**—The School is now entering a new phase of its history. This year marks the 20th anniversary of its coming into being as a separate organization, the "Meteorological Office Training School". During this period many thousands of trainees have passed through its doors. It has extended its activities, expanded its accommodation and acquired considerable material resources, as well as an international atmosphere. Most of all there has grown a team spirit of stimulating enthusiasm, backed by hard work, among the members of the staff which would be hard to beat. The future success of the School depends to a great extent on these intangible attributes.

Several projects are either in an active state of preparation or are in the planning stage. One of these, the inclusion in the Assistant course syllabus of practical instruction in making observations at night, commenced in October of this year. In the near-distant future, the School will take up its new premises in the new Meteorological Office Headquarters building in Bracknell. There, the proximity of so much of the operational and research facilities of the Meteorological Office will open up vistas to inspire future students which were undreamed of on that September day twenty years ago when the first Meteorological Office Training School was first established.

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## A QUICK METHOD OF ALLOWING FOR TRAJECTORY CURVATURE WHEN ESTIMATING THE GRADIENT WIND FROM FORECAST CONTOUR CHARTS FOR WESTBOUND NORTH ATLANTIC FLIGHTS

By F. E. LUMB, M.Sc.

**Introduction.**—When making quick estimations of the gradient wind from contour charts, it is customary to use the approximate form of the gradient wind which is obtained by taking the curvature of the contours to represent the trajectory curvature. This is equivalent to assuming that the speed of movement of the contour patterns is small compared with the gradient wind. This assumption is usually satisfactory, particularly in the vicinity of the level of maximum wind speed, that is, at 300 and 200 millibars (see for example Zobel[1]), but it is not necessarily valid for mobile ridges and troughs.

Whether the geostrophic wind or the approximate form of the gradient wind is a better approximation to the true gradient wind will depend on the speed of movement of the contour patterns. This question will first be examined theoretically. The practical application of the theory to the task of drawing isotachs on forecast contour charts for westbound North Atlantic flights will then be considered. Finally the operationally important case of east winds on the north side of an upper low will be discussed.

**Theory.**—The following symbols will be used:

$r_c$ = radius of curvature of contour

$r_t$ = radius of curvature of trajectory

$v$ = speed of movement of the contour pattern

$\psi$ = angle between the direction of movement of the contour pattern and the tangent to the contour drawn in the direction of the geostrophic wind

$G$ = geostrophic wind speed

$V$ = gradient wind speed

$V_0$ = approximation to the gradient wind speed ($V$) by correcting the geostrophic wind speed ($G$) for contour curvature (that is, assuming $v = 0$).

The relationship between the curvature of the trajectory and of the contour at any point in balanced flow is given by the equation[2]

$$\frac{1}{r_t} = \frac{1}{r_c}\left(1 - \frac{v}{V}\cos\psi\right). \qquad \text{............(1)}$$

Consider the case of a simple ridge–trough contour pattern, with the axes of the ridge and trough aligned north–south, moving east with speed $v$. Along both the ridge and trough axes $\cos\psi = 1$, and equation (1) becomes

$$\frac{1}{r_t} = \frac{1}{r_c}\left(1 - \frac{v}{V}\right). \qquad \text{............(2)}$$

Also at the trough and ridge axes (see, for example, Brunt[3])

$$V_0 - G = \pm\frac{V_0^2}{\lambda r_c} \qquad \text{............(3)}$$

$$V - G = \pm\frac{V^2}{\lambda r_t}, \qquad \text{............(4)}$$

where $\lambda = 2\,\omega\sin\phi$. The positive sign applies to the ridge, the negative sign to the trough.

If $G$ is a better approximation to $V$ than $V_0$,

$V - G < V_0 - V$ at the ridge axis

and $G - V < V - V_0$ at the trough axis.

Using equations (3) and (4) with the appropriate sign these inequalities both transform to the single inequality

$$\frac{2V^2}{r_t} < \frac{V_0^2}{r_c} \qquad \text{............(5)}$$

Substituting for $r_t$ from equation (2) the condition that $G$ is a better approximation to $V$ than $V_0$ becomes

$$2V^2\left(1 - \frac{v}{V}\right) < V_0^2$$

$$\text{or } v > V - \frac{V_0^2}{2V}. \qquad \text{............(6)}$$

From equations (2), (3) and (4) it is seen that as $r_c \to \infty$, $V_0 \to G$ and $V \to G$. Consequently, as $r_c \to \infty$, $(V - V_0^2/2V) \to \frac{1}{2}G$, that is, the critical value of $v$ approaches $\frac{1}{2}G$ as $r_c \to \infty$.

At the ridge axis $G < V_0$ so that if $G$ is to be a better approximation to $V$ than $V_0$

$$V < \tfrac{1}{2}(G + V_0) < V_0$$

$$\text{and therefore } V - \frac{V_0^2}{2V} < \tfrac{1}{2}(G + V_0) - \frac{V_0^2}{2V_0}$$

$$\text{that is, } V - \frac{V_0^2}{2V} < \tfrac{1}{2}G. \qquad \text{............(7)}$$

At the trough axis $G > V_0$ so that if $G$ is to be a better approximation to $V$ than $V_0$

$$V > \tfrac{1}{2}(G + V_0) > V_0$$

and therefore $$V - \frac{V_0^2}{2V} > \tfrac{1}{2}(G + V_0) - \frac{V_0^2}{2V_0}$$

that is, $$V - \frac{V_0^2}{2V} > \tfrac{1}{2}G. \qquad \text{...........(8)}$$

Since the critical value of $v$ approaches $\frac{1}{2}G$ as $r_c \to \infty$, inequalities (7) and (8) show that $\frac{1}{2}G$ is the upper limit of this critical value at the ridge axis, and the lower limit at the trough axis.

In other words, at the ridge axis if $v > \frac{1}{2}G$, $G$ is always a better approximation to $V$ than $V_0$, whereas at the trough axis unless $v > \frac{1}{2}G$, $G$ can never be a better approximation to $V$ than $V_0$.

**Application to forecast contour charts for westbound North Atlantic flights.**—The relationship derived above between $v$ and the validity of $G$ as an approximation to $V$ has a useful application when drawing isotachs on forecast contour charts for westbound North Atlantic flights, bearing in mind that it is important not to under-estimate headwinds (west). In order to draw the isotachs it is first necessary to evaluate the gradient wind at numerous points on the contour chart. At an operational station the time available for drawing the isotachs is limited by flight-planning requirements, so that the use of Gilbert's diagram or tables [4] for calculating $V$ from trajectory curvature is impracticable, even if the over-all standard of accuracy of the forecast contour charts would justify their use. However, $r_c$ and $G$ being known, $V_0$ can be determined in a matter of seconds, for any given latitude, from a set of correction curves, and in practice it is sufficient to know whether the best approximation to $V$, without incurring the risk of under-estimating headwinds, is obtained by making the full correction, half the correction, or no correction to $G$ for curvature of the contours; or, in symbols, whether the best approximation is given by $V_0$, $\frac{1}{2}(G + V_0)$, or $G$.

The relationship derived above shows that for ridges and troughs which are expected to be slow-moving relative to the geostrophic wind ($v < \frac{1}{2}G$), a suitable approximation to $V$ is $V_0$ at the ridge axis and $\frac{1}{2}(G + V_0)$ at the trough axis, for all values of $r_c$. For fast-moving ridges and troughs ($v > \frac{1}{2}G$), a suitable approximation to $V$ is $\frac{1}{2}(G + V_0)$ at the ridge axis and $G$ at the trough axis, for all values of $r_c$.

**East winds to the north of upper lows.**—Consider an upper low moving east with speed $v$. To the south of the centre $\cos\psi = 1$, so that what has been deduced already for a trough axis applies also to the south of the low. To the north of the centre $\psi = 180°$ and $\cos\psi = -1$. Equation (1) then becomes

$$\frac{1}{r_t} = \frac{1}{r_c}\left(1 + \frac{v}{V}\right). \qquad \text{...........(9)}$$

Substituting for $1/r_t$ in equation (4) taken with the negative sign we get

$$G - V = \frac{V^2}{\lambda r_c}\left(1 + \frac{v}{V}\right) \qquad \text{...........(10)}$$

whence $$\frac{\partial V}{\partial v} = -\frac{V}{2V + \lambda r_c + v}. \qquad \text{...........(11)}$$

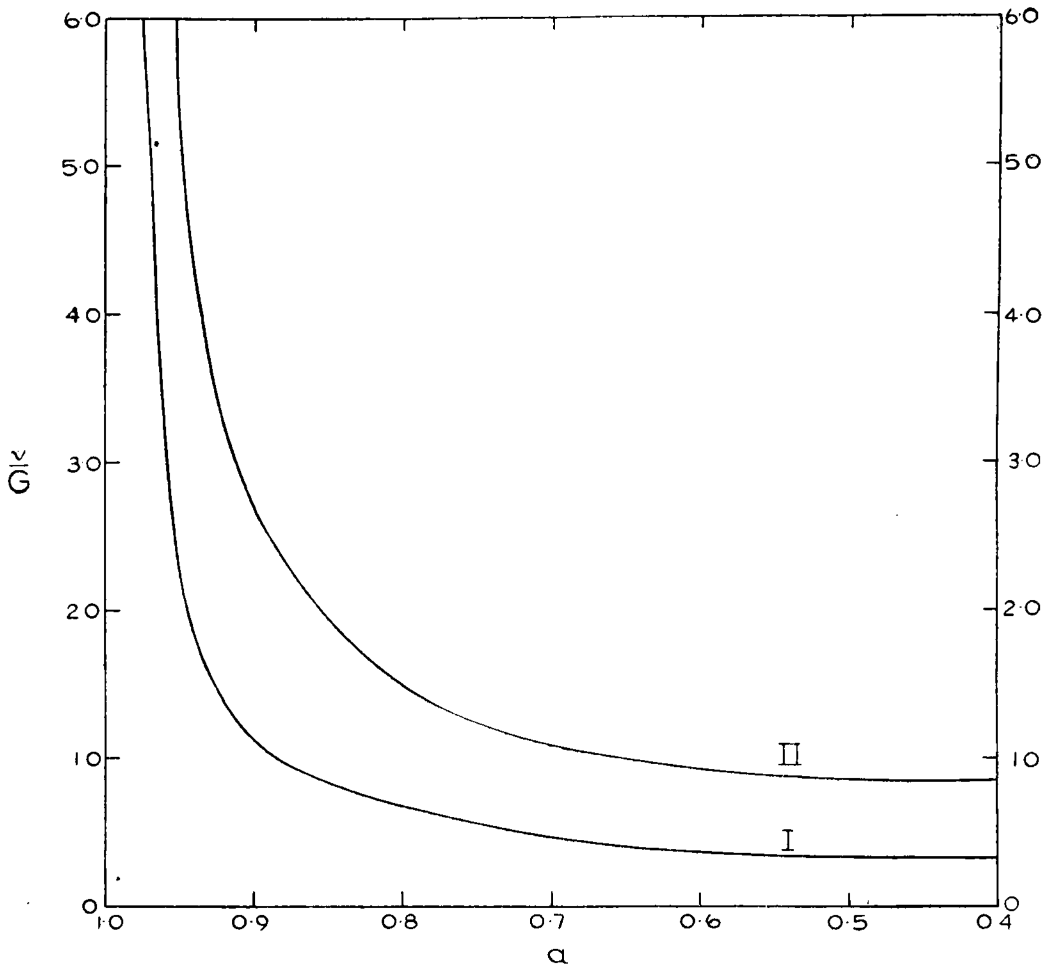


FIGURE 1—CURVES SHOWING VARIATION OF $v/G$ WITH $a$
$a = V_0/G$; $b = V/G$; curve I: $a-b = 0 \cdot 1$; curve II: $a-b = 0 \cdot 2$

$\partial V/\partial v$ is therefore negative. When $v = 0$, $V = V_0$. Consequently, for an eastward-moving low, $V$ is always less than $V_0$ and the difference $(V_0 - V)$ increases as $v$ increases. It follows that to the north of an eastward-moving low $V_0$, although a better approximation to $V$ than $G$, still over-estimates the speed of the east wind. For westbound flights this is equivalent to an under-estimate of headwinds. It is therefore important when drawing isotachs on forecast contour charts for westbound North Atlantic flights to reduce $V_0$ by an amount sufficient to avoid the risk of over-estimating the speed of the east wind. For practical purposes it is sufficient to know by what fraction of $G$ (in tenths) $V_0$ should be reduced in order to ensure a safe estimate of $V$. A solution to the problem in these terms can readily be obtained as follows:

Substituting for $r_c$ from equation (3) in equation (10) we get

$$G - V = \frac{(G - V_0)\ (V + v)\ V}{V_0^2}. \qquad \text{..........(12)}$$

Put

$$V_0 = a\,G$$

$$V = b\,G.$$

Then equation (12) becomes

$$\frac{v}{G} = \frac{a^2 (1 - b)}{b (1 - a)} - b \qquad \text{............(13)}$$

and $0 < a < b < 1$.

The curves I and II of Figure 1 show the variation of $v/G$ with $a$ for values of $a$ between 1·0 and 0·4 when $(a-b)=0\cdot1$ and 0·2 respectively. $a$ is the ratio of $V_0$ to $G$ and is therefore a function of $\lambda$, $r_c$ and $G$. The range of $a$ from 1·0 to 0·4 comprises at latitude 55°N. all values of $r_c$ from $\infty$ to 100 nautical miles, and all values of $G$ up to 180 knots, and therefore caters for all values of $V_0/G$ which are of practical importance.

Curve I shows that the lowest value of $v/G$, to the first place of decimals, is 0·3 when $(a-b)=0\cdot1$, that is, when $V=(V_0-0\cdot1\ G)$. Hence if $v < 0\cdot3\ G$ a suitable approximation to $V$ which does not incur the risk of over-estimating the speed of the east wind is $(V_0-0\cdot1\ G)$. Similarly, curve II shows that if $0\cdot3\ G < v < 0\cdot9\ G$ a suitable approximation to $V$ is $(V_0-0\cdot2\ G)$.

The speed of movement of almost all upper lows is in the range $0 < v < 0\cdot9\,G$. Hence a suitable approximation to the gradient wind to the north of the centre is $(V_0-0\cdot1\ G)$ for lows which are expected to be almost stationary and for more mobile systems, $(v > 0\cdot3\ G)$, a suitable approximation is $(V_0-0\cdot2\ G)$.

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## METEOR


By E. KNIGHTING, B.Sc.


A Ferranti Mercury computer has been installed at Dunstable for the purpose of research into numerical forecasting and is known as METEOR. In order to convey some idea of how its highly complicated circuitry is used to carry out the elaborate arithmetic needed for numerical forecasting it is helpful to consider a simple analogue of some of the operations that the computer can carry out.

Suppose we have a calculating system set up in the following way. There are 32 slates, equally accessible, laid out on a desk and numbered from 0 to 31. Each slate is divided by painted horizontal lines into 32 compartments, numbered from 0 to 31. Each of the compartments is identifiable by an "address" made up by giving first the slate number and then the compartment number on that slate, so that the address of the first compartment on slate 0 is numbered 0·0, the third compartment on slate 5 is named 5·2, the 21st compartment on slate 26 is named 26·20 etc., the last compartment of all being 31·31. Numbers may be written in chalk in any compartment. There is also another slate with a single compartment similar to all the rest and this compartment is named A (or Accumulator).

The man carrying out the computations, or the computer, has no memory apart from what is written on the slates. He is only able to carry out arithmetical working on the partially empty slate containing A; the arithmetic must concern the number written in A and perhaps other numbers and the answer is written in A after the previous number there has been rubbed out. For example, suppose that the required computation is to add the numbers in compartments 5·3 and 26·21. The computer must copy the number from 5·3 into A, add the number in 26·21 to that in A and finally write the answer in A, having rubbed out what was there; in this process the numbers written in 5·3 and 26·21 are undisturbed. The computer can copy the number in any compartment into A and *vice versa* but not directly from one compartment to another.

Not only does the computer not have any memory of his own; he does not know what he is doing and so has to be instructed in detail. These instructions are written on the slates in a shorthand form which enables two instructions to be written in any compartment and the computer knows that he has to follow the instructions sequentially.

Consider now the series of instructions which have to be given to add together the squares of the integers from 10 to 20. First of all the numbers from 10 to 20 must be written in eleven separate compartments, say from 6·2 to 6·12 (the third to thirteenth compartments on slate number 6), and this has already been done. The instructions would be:

| *Instruction* | *Result* |
|---|---|
| Copy the contents of 6·2 into A | 10 into A |
| Multiply A by the contents of 6·2 | $10\times 10$ in A |
| Copy the contents of A into 6·1 | $10\times 10$ in 6·1 |
| ⎧ Copy the contents of 6·3 into A | 11 into A |
| ⎨ Multiply A by the contents of 6·3 | $11\times 11$ in A |
| ⎨ Add contents of 6·1 to A | $10\times 10+11\times 11$ in A |
| ⎩ Copy the contents of A into 6·1 | $10\times 10+11\times 11$ in 6·1 |
| Etc. | |

with the answer appearing in 6·1, and there would be $10 \times 4 + 3 = 43$ instructions in all, taking up $21\frac{1}{2}$ compartments. These orders may be written anywhere where they do not interfere with the numbers which are used in the computation, say on slate 8.

The first point to be noted about these instructions is that they are written on the slates just as the numbers are. The second point to be noted is that the instructions are concerned not with the numbers themselves but with the contents of the compartments and the same set of instructions would suffice to add the squares of any eleven numbers, providing that they were written in the compartments 6·2 to 6·12. The third point to be noted is that the number of elementary instructions is large. However, the last four instructions in this example form a cycle, and instead of repeating them ten times, the instructions denoted above by etc. would be replaced by:

repeat the last four instructions after adding 1 to the compartment number, stopping when the compartment number reaches 6·12.

For many calculations the number of compartments available for writing numbers will not suffice. Imagine in the corner of the room slates similar to those on the table but attached to a vertical axis about which they can turn, like the shop fitting on which picture postcards are displayed. There are four such vertical axes and each has 128 slates attached to it, and the slates are numbered 0 to 511. The numbers on these slates cannot be transferred to A, as can those numbers on the slates on the table. All the numbers on any given slate in the corner can be copied on to any given slate on the table and *vice versa*, but no selection can be made and every one of the numbers on the given slate must be copied. These 512 slates are a good deal less convenient to use than the 32 on the table because the time required for access to the numbers in the compartments is much larger. Suppose that the numbers 10 to 20 are not written in the compartments on slate 6 but in the compartments of corner slate 120. Then the instructions written above would have to be preceded by the instruction:

Copy corner slate 120 to slate 6.

METEOR, the Ferranti Mercury electronic digital computer which has been installed at Dunstable, is rather like an electronic counterpart of the slate system. It has an *arithmetic unit* which carries out the actual computations, corresponding to the blank space below A where the slate computer did his working and an *accumulator* corresponding to A. There is a *high-speed store* of 1,024 locations, each capable of containing a number, and conveniently divided into 32 pages each of 32 numbers, corresponding to the 1,024 compartments on the slates on the table. Finally there is a large *magnetic-drum store* consisting of four drums each containing the equivalent of 128 pages of numbers or information, corresponding to the banks of slates in the corner.

**The representation of numbers in METEOR.**—A number in METEOR is represented in binary form and the elementary unit is 10 binary digits (contracted to "bits"). Thus numbers up to 1,023 can be represented and as an example in the usual notation

637 is 1001111101 or $512+64+32+16+8+4+1$,
and 59 is 0000111011.

It is often more convenient to allow the numbers so represented to run from $-512$ to 511 instead of from 0 to 1,023, since this allows for negative numbers. Then the first of the ten bits gives the sign of the number, 0 if the number is positive, 1 if the number is negative; the rule is that if a number commences with 1 (and so is negative), 512 is subtracted from the positive number represented by the remaining digits, for example,

1 000 000 000 is $-512$
and 1 111 111 111 is $-1$.

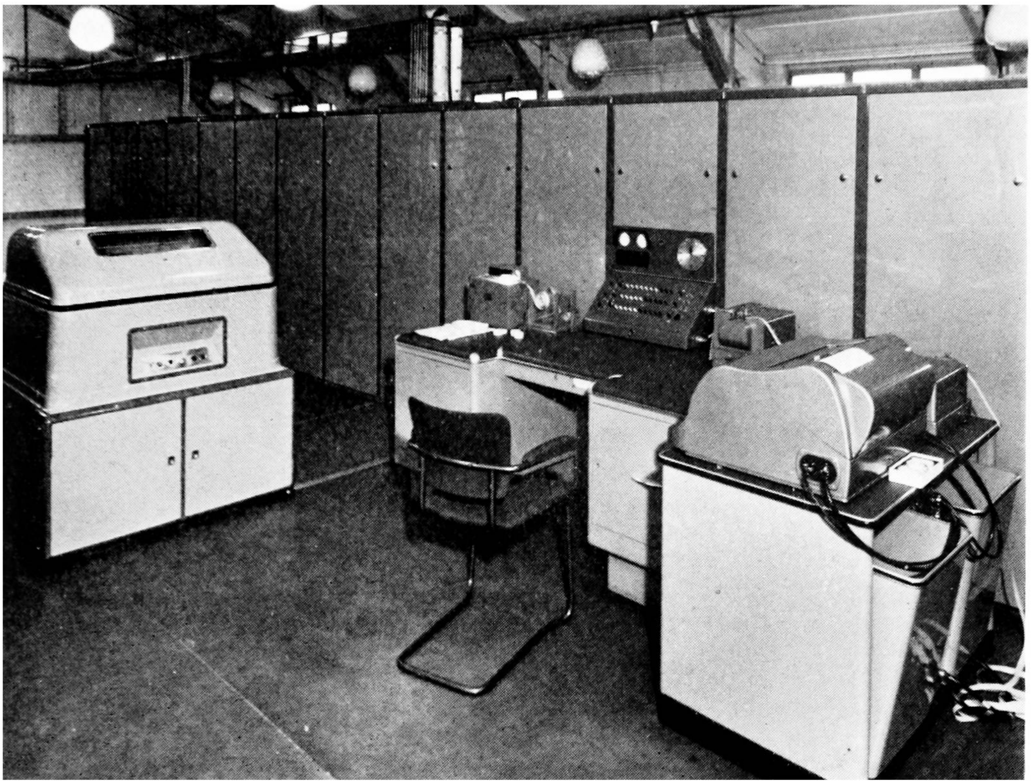
Four of these elementary blocks of ten bits represent a number in the form $2^n \times m$, where $n$ ranges from $-256$ to 255 and $m$ is a signed fraction (expressed in binary scale), so that METEOR can deal with numbers of the order of $10^{\pm 80}$, with an accuracy of about 1 in $10^9$.

The instructions are also in binary form but require only two blocks of ten bits.

**The arithmetic unit.**—The arithmetic unit carries out the operations of addition, subtraction and multiplication, writing out the answers in the accumulator A, which is a special 40-digit register capable of taking a number of the form $2^n \times m$. Most of the arithmetic operations involve two numbers and one of them must first be placed in the accumulator.

**The high-speed store.**—The high-speed store is capable of storing 1,024 40-binary digit numbers of the form $2^n \times m$, similar to that of the accumulator, and may be thought of as 32 pages of 32 numbers each. Since instructions require only 20 binary digit numbers, the high-speed store will accommodate

[*To face p*. 268





METEOR, THE FERRANTI MERCURY COMPUTER INSTALLED AT DUNSTABLE

Equipment from left to right: line printer, tape reader, control desk, punch and teleprinter.
(see p. 269)



METEOR, THE FERRANTI MERCURY COMPUTER INSTALLED AT DUNSTABLE

At the end of the row of cabinets are the four cabinets containing the magnetic drums.
(see p. 269)

2,048 instructions. The high-speed store is physically composed of ferrite rings which have two states of magnetization corresponding to the digits 0 and 1.

**The magnetic-drum store.**—The magnetic-drum store is physically made up of four rotating drums which have magnetic surfaces, each divided into 128 sectors capable of being magnetized to correspond with any page in the high-speed store and *vice versa*, so that 32 numbers (or 64 instructions) may be transferred from page to drum and *vice versa*.

**The control unit.**—Finally it is necessary to have a control unit which selects the next instruction to be observed and interprets it. There are nearly 100 different instructions, some of the most important being those which add to, subtract from or multiply the number in the accumulator by the number in a location or compartment, and those which transfer control to some selected instruction which is not the next in sequence.

**Input and output.**—It must be possible to put the numbers representing the instructions and the data into the computer and to get the results out of the computer. Numbers or letters which are to be entered into the computer are punched on teleprinter tape and fed into the tape reader which senses photo-electrically the punched holes, recording the numbers in the computer's store. There are two ways of extracting numbers from METEOR. In the first an instruction is obeyed which causes numbers to be punched on a teleprinter tape which can then be used to give a teleprinted copy. In the second method the instructions set up numbers in line on a printer which is capable of printing the whole line of numbers almost simultaneously.

**Some characteristics of METEOR.**—Electronic computers work at very high speeds and METEOR is one of the largest and fastest computers manufactured in England. Some of the times of operation are:

| | |
|---|---|
| Transferring a number from a location to the accumulator | 120 microseconds |
| Multiplying the number in the accumulator by the number in a location | 300 microseconds |
| Adding a number to that in the accumulator | 180 microseconds |
| Transferring a sector from the magnetic drum to a page in the high-speed store | 16 milliseconds |
| Reading a teleprinter tape | 200 characters per second |
| Punching a teleprinter tape | 33 characters per second |
| Line printing, 92 characters per line | 150 lines per minute |

There are about 5,000 thermionic valves and 3,500 crystal diodes.

This means that METEOR can perform about 8,000 additions per second and 3,000 multiplications per second. There are many other operations which take only 60 microseconds and a numerical forecast which involves several million operations is carried out in about 30 minutes. The computer itself is housed in metal cabinets each 6 feet 3 inches high and 15 inches deep and the row of cabinets is about 40 feet long. Additionally, there are four large cabinets which contain the drums and a large motor-alternator which supplies the power rated at 45 kilowatts. Refrigeration is required at certain points to prevent overheating.

The photographs between pp. 268–269 show two views of the computer and its allied equipment. The series of cabinets have the control desk almost in the middle with the tape reader on the left, the punch and teleprinter on the right; in the middle of the room is the line printer and at the end of the row of cabinets are the four cabinets containing the magnetic drums.

# AN ATTEMPT AT NUMERICAL ASSESSMENT OF DIVERGENCE AT SINGAPORE

By K. BRYANT

In recent years many meteorologists have suggested that convergence and divergence could explain, or explain away, the weather of the tropics, and Kindle[1] derived a table of values showing the rates of convergence or divergence to be associated with various weather phenomena, see Table I. Grimes[2] and others have suggested that such areas of convergence or divergence can readily be found by inspection of the streamline charts, but there is no general agreement on this point due possibly to the somewhat subjective method of drawing streamlines in an area where there is a poor network of upper winds. Forsdyke[3] made some progress towards numerically mapping the field of divergence but his method using winds from pilot-balloon stations some hundreds of miles apart is, as he has stated, open to doubt as the errors in wind measurement could give rise to errors greater in magnitude than the expected divergence or convergence.

TABLE I—KINDLE'S VALUES FOR DIVERGENCE AND ASSOCIATED WEATHER PHENOMENA

(For the tropics using high average humidities)

| Divergence $sec^{-1}$ | Approximate weather |
|---|---|
| $-10^{-4}$ | heavy precipitation |
| $-10^{-6}$ to $-10^{-5}$ ... ... | light precipitation |
| $-10^{-8}$ ... ... | very little weather |
| $+10^{-8}$ ... ... | very light subsidence |
| $+10^{-6}$ to $+10^{-5}$ ... ... | moderate subsidence |

Singapore is an island of approximately 170 square miles some 100 miles north of the equator, where the Coriolis force can be considered almost zero, lying at the southern extremity of the Malay Peninsula and with little or no high ground in the immediate vicinity. Despite these advantages, areas of convergence or divergence are not easily found by inspection, especially in airstreams where wind direction shows little change, and very little advancement of forecasting technique using values of convergence or divergence has been made since the war.

An attempt to find whether divergence or convergence could readily be obtained from pilot-balloon data (thus helping the forecaster) was made using the results of an intensive programme of 17 half-hourly pilot-balloon ascents to 10,000 feet (cloud permitting) from five stations within Singapore Island, carried out on 4 February 1958 between the hours of 0730 and 1530 local time (0001 to 0800 G.M.T.) during the height of the north-east monsoon. Three of the stations used in the programme were the normal Air Ministry observing stations at Royal Air Force stations Changi, Seletar and Tengah; an Air Ministry mobile unit was also used at the old airport of Kallang and a further mobile unit at Tanjong Kling was supplied by the Director of the Malayan Meteorological Service who co-operated in the "upper air" day. The position of the stations used in this programme are shown in Figure 1.

An arithmetical analysis was made of the total "inflow" and "outflow" of wind over a given area at any one level, using the mean winds at that level

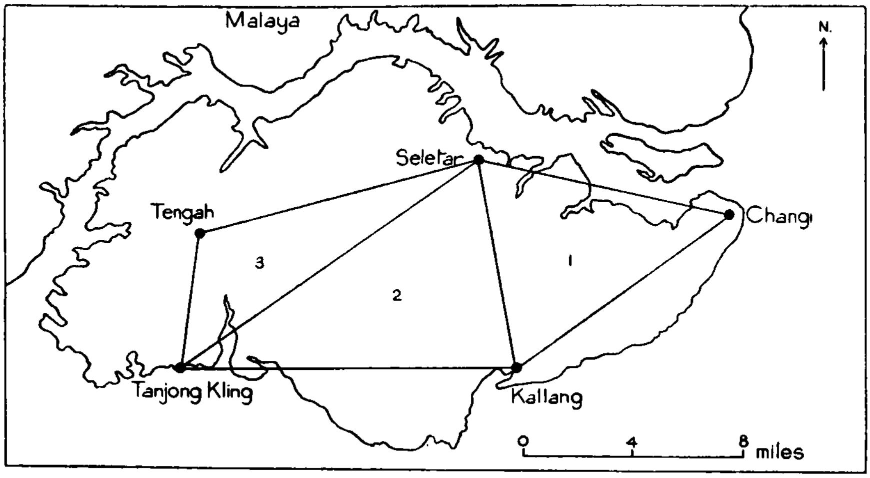



FIGURE I—SINGAPORE ISLAND

blowing into or out from the triangles formed by the pilot-balloon stations. The results of this analysis were checked by planimetric analysis on the lines suggested by Saucier,[4] and found to be in good agreement. This analysis of a relatively dense network of wind data has shown that computed values of rates of convergence or divergence are mainly at the extremes of the limits quoted by Kindle for "moderate subsidence to heavy precipitation", but the variations with time and height above 1,000 feet were almost completely random, on occasions the sign and amount changing through the full range of Kindle values within either half an hour or 1,000 feet.

TABLE II—EXAMPLES OF COMPUTED VALUES OF DIVERGENCE

| Height *feet* | Triangle | Time G.M.T. 0001 | 0030 | 0100 | 0300 | 0330 | 0430 | 0730 | 0800 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | $sec^{-1}$ ($\times 10^{-4}$) | | | | |
| 1,000 | 1 | +1·33 | +2·24 | +2·77 | +1·85 | +3·36 | +2·39 | −6·30 | +4·66 |
| | 2 | +0·37 | −0·62 | +1·25 | +0·58 | +0·48 | +0·34 | +0·39 | −5·59 |
| | 3 | −3·46 | −0·95 | −1·00 | −2·62 | −2·07 | −4·07 | −4·79 | −1·56 |
| 2,000 | 1 | +0·26 | +3·0 | +0·81 | +2·36 | −1·42 | +1·93 | +2·20 | +8·04 |
| | 2 | −1·67 | +1·36 | −1·25 | −0·47 | −0·67 | +1·81 | −2·79 | −1·03 |
| | 3 | −0·84 | −1·12 | −3·72 | +1·85 | −1·29 | +2·03 | −3·67 | −6·64 |
| 3,000 | 1 | +0·23 | −0·45 | +0·73 | +0·12 | +2·05 | +1·21 | −1·25 | +4·96 |
| | 2 | −1·90 | −0·18 | +0·37 | −2·79 | +1·83 | +3·50 | −1·41 | +2·69 |
| | 3 | −3·01 | +0·02 | −0·71 | −0·26 | −1·58 | −3·72 | no reading | +1·13 |

Table II shows examples of the values obtained in various areas of the Island using the triangles formed by the base lines of the pilot-balloon stations, triangle I being the eastern, triangle 2 the middle and triangle 3 the western triangle. Synoptic observations over Singapore Island during the period of the ascents showed that the weather in the areas was as follows:

(*a*) Triangle 1, fair or fine throughout the period.

(*b*) Triangle 2, fair to cloudy with only scattered light showers during the afternoon.

(*c*) Triangle 3, fine becoming fair to cloudy by late morning with moderate showers and an isolated thunderstorm during the afternoon.

The only general agreement with Kindle's relation between the weather and the computed values was obtained when mean values for all ascents up to 5,000 feet were used. Table III shows the figures obtained and the number of observations used. (It should be noted that with marked convergence in any area there is a tendency for cloud cover to increase and thus for the number of high-level wind observations to decrease, which would therefore give a bias to the present series of observations in favour of divergence.)

TABLE III—MEAN VALUES OF DIVERGENCE AT ANY LEVEL BETWEEN 1,000 AND 5,000 FEET

| Triangle | Value $sec^{-1}$ | No. of observations |
|---|---|---|
| 1 ... ... ... | $+1 \cdot 8 \times 10^{-5}$ | 55 |
| 2 ... ... ... | $+1 \cdot 6 \times 10^{-6}$ | 46 |
| 3 ... ... ... | $-4 \cdot 2 \times 10^{-5}$ | 41 |

Fine-scale gridding on the lines suggested by Forsdyke showed general changes from divergence north to convergence south of the Island but, however, with no clearly defined areas. In no case was there any reasonable continuity from chart to chart and the subjective element in the drawing of these charts was considerable.

It is clear that the errors involved by using normal pilot-balloon reports (where in addition to casual errors the rates of ascent are subject to variations) are of the same order of magnitude as the actual convergence or divergence taking place and that, even with frequent observations in a far closer network than is possible on a routine basis, it is not possible to compute reliable values of convergence or divergence directly from the observed winds. If, therefore convergence or divergence are to be used for forecast purposes in the tropics some method other than the direct approach using observed winds must be found.

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2. GRIMES, A.; Equatorial meteorology. Compendium of meteorology, Boston, Mass., 1951, p. 881.
3. FORSDYKE, A. G.; Weather forecasting in tropical regions. *Geophys. Mem., London,* No. 82, 1949.
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## MEASUREMENT OF TURBULENCE IN THE FREE ATMOSPHERE

By C. S. DURST, B.A.

The paper below was written in 1942 and was discussed by the Meteorological Research Committee in 1943. I have now been asked to submit it for publication in the *Meteorological Magazine* and it is presented without alteration except for the brief introduction below. There is also added a comment which Mr. W. Swinbank supplied which brings out what the physical meaning of the swings may be.

When wind finding by radio techniques was first devised by the British in 1939 the observations were made by direction finding with loop aerials from two ground stations on a radio-sonde carried by a balloon. The sonde was suspended by its aerial, and the direction observed at any instant was that of the point of intersection of the line of the aerial with the ground. Thus the direction was continually varying about the true value with the swinging of the sonde on its suspension. (At an early stage the loop aerials were replaced by a type in which this "polarization error" did not occur, and the number of direction-finding stations was increased to three.)

During the course of conversation in August 1941 between Dr. Hopkins of the National Physical Laboratory, Mr. A. C. Best and the writer, Dr. Hopkins stated that he believed the swing of the can of a radio wind-finding balloon might give a measure of the disturbance due to eddies and he also stated that the swing of the can was measured in the early ascents observed with a loop aerial. To test how far the observations showed real swinging of the can, some of the early records were examined and it was found that the magnitudes of the simultaneous swings observed at two independent stations were closely correlated on some occasions, though on others there appeared to be considerable differences which were believed to be due to some observers being less expert than others. On one occasion when two ascents were made within $1\frac{1}{4}$ hours of each other the swing appeared to die down at about the same level on both occasions and to increase to a maximum at about 22,000 feet in both ascents.

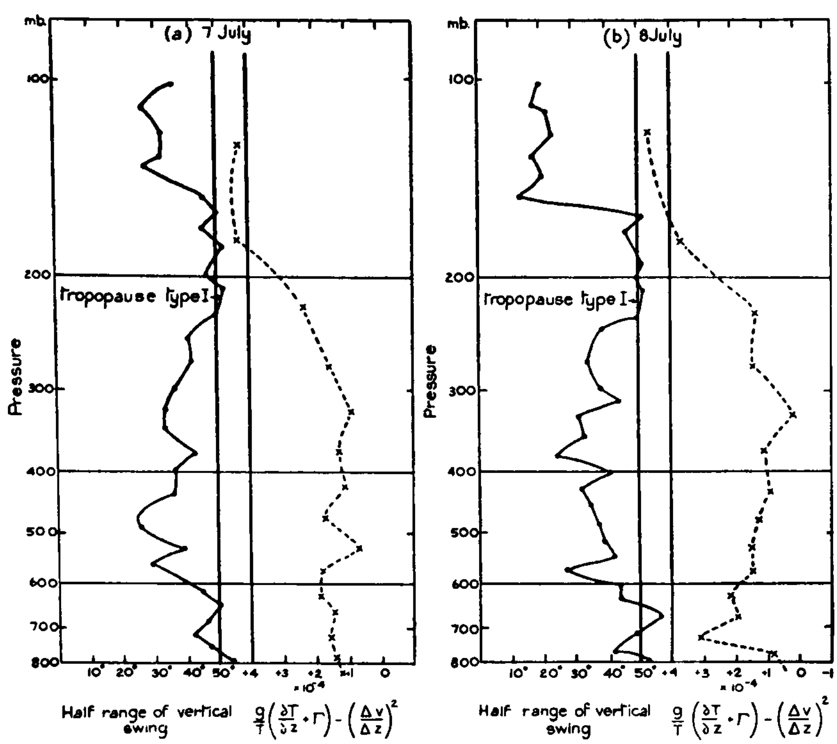



FIGURE 1 ($a$, $b$)—RELATIONSHIP BETWEEN THE SWING OF THE CAN OF A RADIO WIND-FINDING BALLOON AND RICHARDSON'S CRITERION, LARKHILL, 1942

7 *July* 1942.—Relative humidity: maximum 91 per cent at 830 mb., less than 90 per cent above 800-mb. level. Cloud: 0900 G.M.T.—cumulus at 4,500 ft. with cirrocumulus; 1300 G.M.T.—cumulus at 4,000 ft. with cirrocumulus.

8 *July* 1942.—Relative humidity: less than 80 per cent throughout. Cloud: 0900 G.M.T.—cumulus at 3,000 ft. with altocumulus; 1300 G.M.T.—cumulus and cumulonimbus at 3,500 ft. with altocumulus.

These results seemed to justify further observations being made, and a loop aerial was borrowed from the National Physical Laboratory and erected at Larkhill. Various delays occurred and the first observation of the new series was made on 7 July 1942. Since then eight other observations have been obtained giving nine in all, though of these the first two gave less reliable results than the later ones as observational technique was improved after 8 July. The observations were organized by Dr. D. N. Harrison who was at that time in charge at Larkhill. It was the intention to get the observations made in typical and varied synoptic situations and to some extent this was achieved.

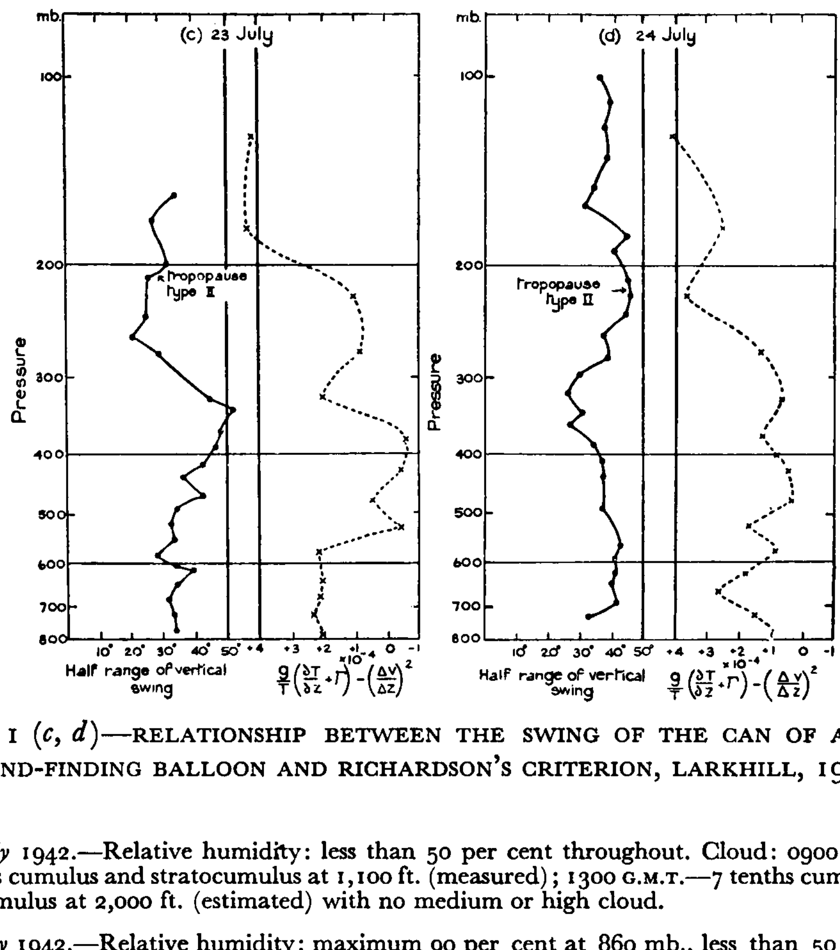



FIGURE I $(c, d)$—RELATIONSHIP BETWEEN THE SWING OF THE CAN OF A RADIO WIND-FINDING BALLOON AND RICHARDSON'S CRITERION, LARKHILL, 1942

23 *July* 1942.—Relative humidity: less than 50 per cent throughout. Cloud: 0900 G.M.T.—10 tenths cumulus and stratocumulus at 1,100 ft. (measured); 1300 G.M.T.—7 tenths cumulus and stratocumulus at 2,000 ft. (estimated) with no medium or high cloud.

24 *July* 1942.—Relative humidity: maximum 90 per cent at 860 mb., less than 50 per cent above 800-mb. level. Cloud: 0900 G.M.T.—10 tenths stratocumulus at 2,000 ft.; 1300 G.M.T.—stratocumulus, cumulus and fractocumulus at 3,000 ft. with no medium or high cloud.

It was suggested that if the swing of the can was due to the amount of eddying in the atmosphere and the amount of eddying was related to Richardson's criterion,

$$\left(\frac{\partial u}{\partial z}\right)^2 + \left(\frac{\partial v}{\partial z}\right)^2 - \frac{g}{T}\left(\frac{\partial T}{\partial z} + \Gamma\right) + \text{ve or } - \text{ve}, \qquad \ldots (1)$$

then a plot of the magnitude of the swing alongside this expression would serve as a verification of the reality of the swing as a representation of the amount of eddying and of the truth that Richardson's criterion gave, in fact, a measure of the stability of the atmosphere. Accordingly in each of the nine cases a

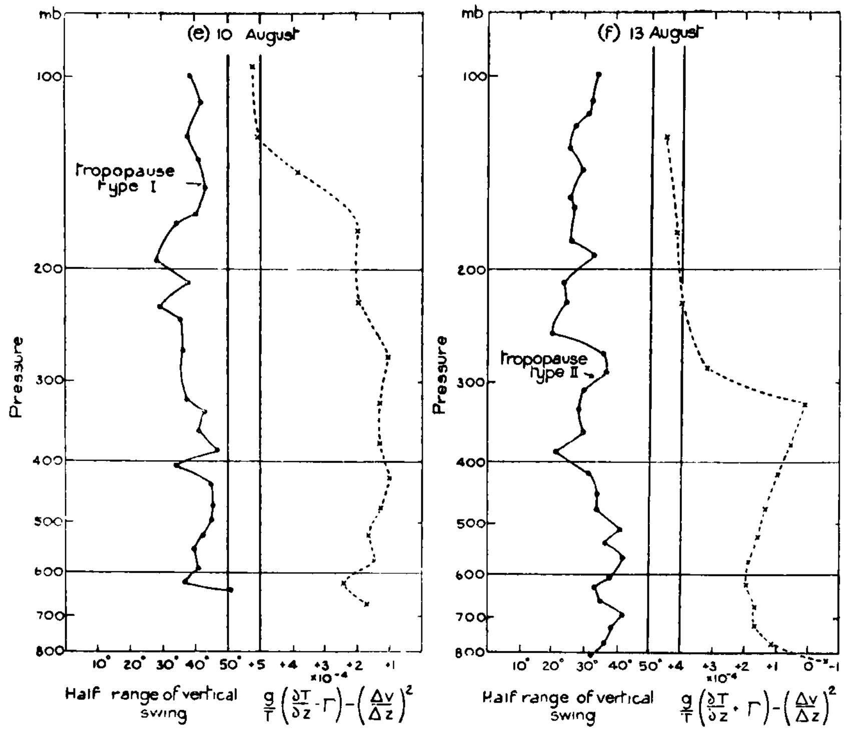



FIGURE I $(e, f)$—RELATIONSHIP BETWEEN THE SWING OF THE CAN OF A RADIO WIND-FINDING BALLOON AND RICHARDSON'S CRITERION, LARKHILL, 1942

10 *August* 1942.—Relative humidity: maximum 94 per cent at 825 mb., less than 50 per cent above 650-mb. level. Cloud: 0900 G.M.T.—9 tenths stratocumulus, cumulus and fractocumulus at 2,000 ft.; 1300 G.M.T.—10 tenths stratocumulus and nimbostratus at 250 ft.

13 *August* 1942.—Relative humidity: less that 80 per cent throughout. Cloud: 0900 G.M.T.—cumulus at 2,500 ft. with altocumulus; 1300 G.M.T.—10 tenths cumulus and stratocumulus at 2,000 ft.

diagram has been drawn showing the curve of swing and the curve of expression (1). These diagrams are given as Figures 1 (*a*)–(*i*). Brief notes as to the synoptic situation and the characters of the curves are given below:

7 *July* 1942. Maritime polar air circulating around a stale low pressure centre north-west of Scotland; fronts in the neighbourhood of British Isles.

There was a pronounced increase in the swinging observed at and above the tropopause, where stability as shown by the Richardson criterion was great. Above this the swinging decreased abruptly and decidedly.

8 *July* 1942. Maritime polar air circulating around a stale low pressure centre north-west of Scotland; a cold front moving south-east was about 300 miles north-west of Larkhill.

There was again a pronounced increase in the swinging observed at and above the tropopause. Above 160 millibars there was a sudden decrease in swing.

23 *July* 1942. Maritime polar air near surface and probably extending to 10,000 to 12,000 feet (600 to 700 millibars) warm air probably lying above that height; a cold front cut the surface about 200 miles south-east of Larkhill.

The swing increased fairly steadily between 600 millibars and 350 millibars and then decreased. There was a sudden change in the stability curve between 575 and 525 millibars and another about 350 millibars.

24 *July* 1942. In an active warm sector to a depression moving over north-west Scotland. The swing increased near the tropopause.

10 *August* 1942. Just in front of an active warm front to an occluded depression moving north-east to the west of Scotland. Ascent was in the warm air.

The swing was not measured below 650 millibars. The amount of swing was rather high. There was a decrease in swing below the tropopause and an increase at and above it.

13 *August* 1942. Just in front of an active warm front to an occluded depression moving north-east to the south-west of Iceland. Ascent was in the warm air except in perhaps the first 2,000 feet.

The swing increased from 800 millibars to 550 millibars where stability was fairly great. The swing increased just above the tropopause but decreased suddenly at about 250 millibars. The curve of stability and of swing are almost exactly opposed from 800 millibars up to the tropopause.

28 *August* 1942. A depression centred over Bay of Biscay. Easterly winds at the surface over British Isles, fronts not affecting air over Larkhill.

The swing was great above the tropopause. Between 500 and 160 millibars the two curves are almost exactly opposed.

31 *August* 1942. A complex low pressure system over the British Isles, with a number of ill-defined fronts.

The swing was comparatively small at all heights, perhaps it increased above the tropopause.

1 *September* 1942. A cold occlusion associated with a depression near Iceland was about 100 miles west of Larkhill.

The swing increased to a marked degree just above the tropopause. The swing was high between 550 and 450 millibars.

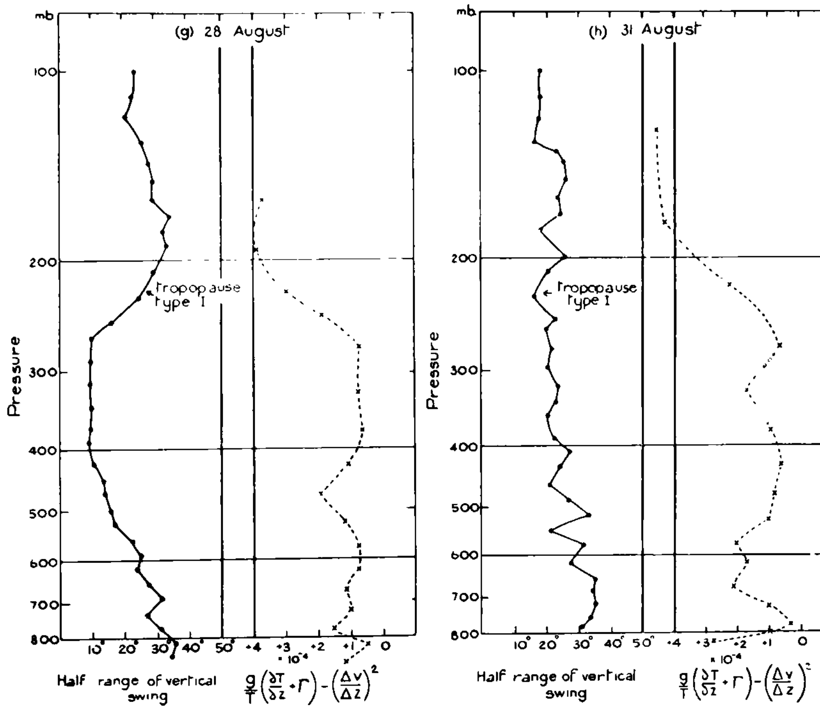
It is remarkable that on several occasions the curves of variation of swing with height are almost exactly the mirror of the curves of the expression

$$\left(\frac{\partial u}{\partial z}\right)^2 + \left(\frac{\partial v}{\partial z}\right)^2 - \frac{g}{T}\left(\frac{\partial T}{\partial z} + \Gamma\right).$$

In this latter expression it is assumed that the coefficients of transfer of heat and momentum are equal at all heights. It is not known whether this is in fact true. It may even be that the ratio of these two coefficients varies with height. Any such variation would, of course, have a great effect on the apparent stability as deduced from the vertical gradients of temperature and wind speed.

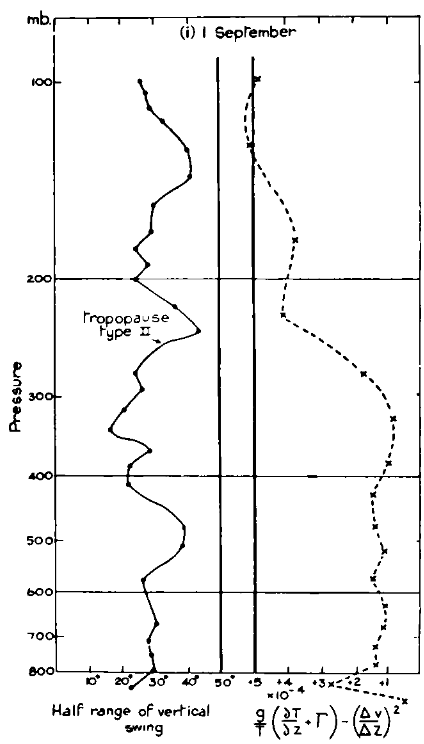
The outstanding feature of the curves of amplitude of swing is the decided tendency for swing to increase in the neighbourhood and for some distance above the tropopause. On a number of occasions there is a sharp decrease in amplitude some distance above the tropopause. In the one case in which Richardson's criterion was fulfilled, 23 July, the swing was greater than during any of the other ascents (the swing plotted for 7 and 8 July was measured in a somewhat different way and is not comparable) and the maximum swing is just above the region where stability appears to have broken down.

It has to be remembered that in the criterion quoted it is assumed that the coefficients of transfer of momentum and heat are the same. This is not neces-




28 *August* 1942.—Relative humidity: less than 60 per cent throughout. Cloud: 0900 G.M.T.—trace of cirrostratus only; 1300 G.M.T.—trace of altocumulus only.

31 *August* 1942.—Relative humidity: less than 85 per cent throughout. Cloud: 0900 G.M.T.—cumulus at 2,500 ft. with trace of altocumulus and altostratus; 1300 G.M.T.—cumulus and stratocumulus at 3,000 ft. with trace of altocumulus and altostratus.




1 *September* 1942.—Relative humidity: less than 85 per cent throughout. Cloud: 0900 G.M.T.—cumulus at 1,500 ft. with altocumulus, altostratus and cirrus.

FIGURE 1 ($g$, $h$, $i$)—RELATIONSHIP BETWEEN THE SWING OF THE CAN OF A RADIO WIND-FINDING BALLOON AND RICHARDSON'S CRITERION, LARKHILL, 1942

*Crown copyright*

A SCIENTIFIC OFFICER CLASS WORKING ON CHART ANALYSIS AT THE TRAINING SCHOOL

*Crown copyright*

THE INSTRUMENT CLASS INSTRUCTOR DEMONSTRATES EQUIPMENT TO TRAINEES AT THE SCHOOL

(see p. 257)

sarily true and may considerably modify the criterion. Also, in the curves showing the values of Richardson's expression, $\Gamma$ is assumed to be the dry adiabatic. If the balloon is passing through cloud $\Gamma$ should be the appropriate wet adiabatic. As an indication of when the balloon was likely to have been in cloud some notes in regard to the relative humidity and the amount and height of cloud have been added to the diagrams.

Acknowledgement is made of the help which Dr. D. N. Harrison has freely given in obtaining the observations of swing for this note.

### Comments by W. Swinbank

In connexion with this note by Mr. C. S. Durst, it may be worthwhile to mention the following points:

(i) It is stated that "it is remarkable that on several occasions the curves of variation of swing with height are almost exactly the mirror of the curves of the expression

$$\left(\frac{\partial u}{\partial z}\right)^2 + \left(\frac{\partial v}{\partial z}\right)^2 - \frac{g}{T}\left(\frac{\partial T}{\partial z} + \Gamma\right)."$$

It should be remembered, however, that this expression of Richardson's is a measure not of the *degree* of turbulence, but of the tendency to *change* of turbulence. Now if the degree of turbulence is very great, the most probable change from this state will be one of decrease; and if the turbulent motion is very small, increase can be the only change. Therefore it is to be expected that when the instrument has a wide range of swing, that is, the degree of turbulence is great, the turbulent tendency shown by Richardson's criterion, if this is correct, should be for decrease. And when the degree of turbulence is small, the only possible change is one of increase.

If the foregoing reasoning is correct, the observed fact that the two curves are images of one another is rather to be expected than remarkable.

(ii) The fact that the balloon shows greater swing in one region than in another does not necessarily mean that the degree of turbulence, or the total turbulent energy, is greater in the first region. It does mean that in this region there is greater energy associated with eddies whose size is comparable with that of the balloon system. Only when the eddies in the region are of the same order of magnitude as the system itself will the balloon be disturbed. If the eddies are very small they will not perturb the balloon; and similarly if they are very great the disturbance will be very gradual and should not produce oscillations. It may be that in regions where the balloon is comparatively undisturbed there is considerable eddying energy, but not in that part of the spectrum of eddy size energy corresponding to the balloon size.

## LETTER TO THE EDITOR

### Low humidities in upland South Wales, January and February 1959

The contributions of R. C. Smith[1] and F. H. W. Green[2] indicate that low relative humidities may not be so rare an occurrence in upland locations. Whilst high humidities are likely to prevail for long periods in upland sites, especially of the western parts of the British Isles, and dominate the evapotranspiration, short spells of low humidities associated with the subsidence of upper air can radically transform conditions for some hours.

Two Stevenson screens, equipped with Casella thermohygrographs, have been established at heights of 2,000 feet and 1,225 feet O.D. in the Craig Cerrig Gleisiad Nature Reserve (Breconshire) since October 1958. The sites are 1½ miles apart. The lower station is in a deep valley while the upper one is on the plateau surface. Since the start of the record only two relative humidities under 50 per cent (both in October) had been registered at the upper station up to 27 January. Since that date three low values have occurred.

On 27 January 1959 at the upper site there were rapid oscillations of humidity between 40 and 60 per cent between 1300 and 1700 G.M.T. After 1700 G.M.T. for the next six hours the reading was below 40 per cent (most of the time below 35 per cent) with a minimum value of 25 per cent occurring at 1730 G.M.T. The lower station reading dropped to 22 per cent. The lowest value recorded at a sea-coast site at the University College of Swansea (30 ft. O.D.) during the same period was 70 per cent.

The second low relative humidity was between 1030 G.M.T. on 8 February and 0530 G.M.T., 9 February 1959. For 16 hours at the upper site the humidity was below 50 per cent. During a two-hour spell below 30 per cent, the minimum of 27 per cent occurred at 2330 G.M.T. The lower station was enshrouded in mist and did not drop below 92 per cent. At Swansea the minimum was 90 per cent.

The most impressive readings were those of 17–19 February. At the upper station a rapid, steady drop from 70 per cent at 1915 G.M.T. 17 February to 21 per cent took place in the next 3½ hours. For 23½ hours the humidity was below 30 per cent with a six-hour spell below 20 per cent. Low values persisted throughout the night but the minimum reading of 15 per cent was at 1100 G.M.T., 18 February. The dry-bulb temperature dropped 10°F. just before the sharp fall in humidity on the 17 February and remained at 37° until a rapid rise on the morning of 18 February to a maximum of 55° at 1400 G.M.T. The lower station recorded eight hours below 20 per cent and a minimum of 14 per cent. The lowest Swansea value during the whole period was 73 per cent.

The thermohygrographs had been checked against wet- and dry-bulb readings at weekly intervals and at the middle and upper ranges at least found to be reliable and sensitive.

For the two periods with the lowest relative humidities, the *Daily Aerological Record* reveals the existence over the British Isles of well-marked low-level inversions associated with warm anticyclones situated to the south-east of the country. Surface winds were mainly light south-east or south. The aircraft flight from Worcester at 0850 G.M.T., 28 January, showed such an inversion between 992 and 900 millibars (surface 1028·5 millibars) whilst the flight of 0915 G.M.T., 18 February, indicated an even more strongly defined inversion between 1015 and 985 millibars (surface 1039·5 millibars). The radio-soundings for Camborne, Crawley and Aughton confirm the existence of these inversion conditions associated with low relative humidities at heights which could have affected the stations being discussed. At the times of the minimum humidities the subsidence inversion must have extended its effect down to influence both of the observing sites. In the afternoon of 27 January the inversion level must have been oscillating about the height of the upper station, but the longer duration of low humidities, 17–18 February, indicates a greater persistence of the low-level inversion.

Previous data have shown that low relative humidities occur in spring, particularly in April and May. Low values in January and February have not been recorded in recent discussions but under the anticyclonic circumstances outlined above there is no reason why they should not.

J. OLIVER

*Department of Geography, University College of Swansea,* 30 *March* 1959

## NOTES AND NEWS

### Mr. J. M. Craddock – Special Merit Promotion to Senior Principal Scientific Officer

The news of the promotion of Mr. J. M. Craddock to the grade of Senior Principal Scientific Officer will have been heard with great pleasure by his colleagues in the Office and by the many meteorologists who know him through his scientific work. The promotion has been made in recognition of "Special Merit" by the Interdepartmental Scientific Panel. As one who has been closely associated with Mr. Craddock for more than 10 years, I am particularly pleased to be able to express, on behalf of the Director-General and the staff of the Meteorological Office, our very hearty congratulations to Mr. Craddock on this well-deserved award.

Mr. Craddock has contributed much to meteorological research and our understanding of the atmosphere. This is not the place to detail Mr. Craddock's numerous published papers, but it is appropriate to mention his early interest in the growth of cumulonimbus cloud in the tropics and his important studies on the factors which lead to the large-scale temperature changes in the free atmosphere, in particular the heating of cold air masses by convection over warm sea.

Studies of radiation fog led Mr. Craddock to devise a practical method of fog forecasting which is in regular use at the Central Forecast Office. In this work his ability in the handling of statistical problems of meteorology was demonstrated and his remarkable mechanical ingenuity led to the construction of an efficient "dew-balance".

More recently Mr. Craddock has been concerned with the statistical problems related to long-range forecasting and to the use of mechanical and electronic methods in the analysis of the vast store of meteorological observations which is available. Long-range forecasting presents problems which are particularly difficult and in the past many false claims have been made. The Office is therefore particularly fortunate to have an officer of Mr. Craddock's statistical ability actively interested in long-range forecasting. Now that an electronic computer has become available within the Office for large-scale computational work, the work on long-range forecasting will make heavy demands upon the scientific ability and statistical aptitude of the Office staff. It is therefore very fortunate that the scheme of Special Merit promotions exists, whereby the ability and achievement of officers such as Mr. Craddock can be recognized by promotion to a higher grade without the need for them to assume additional administrative duties or to give up the scientific work upon which they are engaged. J.S.S.

## A centenary of observations at Ross-on-Wye

In 1859, Mr. Henry Southall, J.P., a draper and member of a well known Quaker family, began making daily records of the weather at Ross-on-Wye. Initially his instrumental observations were of rainfall only at his house in Henry Street but, on moving to his new home at "The Graig" a few years later, his enthusiasm led him to purchase thermometers and also a barometer; a Stevenson screen was brought into use in 1875. These daily measurements were carried out by Mr. Southall until his death at the age of 90 in 1916. Anxious that the meteorological record for Ross-on-Wye should be continued, Mr. Southall persuaded Mr. F. J. Parsons, the organist at the parish church and a keen weather observer, and Mrs. H. E. Purchas of Chasedale, where Mr. Parsons lived, to help carry on the observations. The Chasedale site was brought into use in July 1914 and whilst Mr. Parsons was on service, during World War I, with the Meteorological Section (commanded by Mr. E. Gold) of the Royal Engineers, Mrs. Purchas although in her seventies made most of the observations herself. In her will, Mrs. Purchas left a site at Crossfields for the purpose of carrying on the weather observations. This site was brought into use in 1921 and has been maintained ever since. Mr. Parsons, who resolved to carry on the work himself, now has over 40 years' weather observing to his credit. During these years the equipment of the station has been increased and, in addition to the usual screen, thermometers, raingauge, barometer and barograph, there are a wind speed and direction indicator, sunshine recorder and earth thermometers. At present Mr. Parsons provides full reports and renders climatological returns for 0600, 0900, 1200, 1500, 1800 and 2100 G.M.T. daily.

On 17th July 1959 at Ross-on-Wye there was a ceremony presided over by Councillor S. G. Little, J.P., Chairman of the Urban District Council, in honour of a century of weather records. After an introductory talk, in which Councillor Little expressed the town's appreciation of the work of the observing station, the Lord Lieutenant of Herefordshire, Viscount Cilcennin, made a congratulatory speech supported by Mr. E. Gold (on behalf of the Royal Meteorological Society). The Meteorological Office was represented by the Deputy Director for Central Services, and several members of the Southall family and Purchas family were present together with representatives of various local authorities, schools and press, and former and present assistant observers.

The observations made at Ross-on-Wye were first published in Symons's monthly *Meteorological Magazine* in 1869. In 1881 the observations were published by the Royal Meteorological Society in their "Meteorological Record". Following an agreement in 1912 whereby the Meteorological Office took over the administration of co-operating stations, the Ross-on-Wye observations first appeared in the *Monthly Weather Report* in July 1914. In 1917 the observations appeared, as for a health resort, in the *Daily Weather Report*. The meteorological station at Ross-on-Wye became an official synoptic reporting station in 1920 and was then listed as such in the *Daily Weather Report*. Since that time the programme of observations has been maintained without a break until the present day. Inspection reports on the Ross-on-Wye station have invariably been "excellent" or "very good".

Mr. Parsons has always shown a very keen interest in his observations and has written many interesting letters about them to the Meteorological Office.

In fact, the Ross-on-Wye meteorological station has always had a high reputation and, because of its long-period record, it has been classed as a "key" climatological station, that is, one which the Meteorological Office would particularly wish to see maintained.

The Meteorological Office is happy to place on record its appreciation of the efforts of all those who have helped to maintain the Ross-on-Wye meteorological station and, in particular, of the valuable co-operation of Mr. Parsons who, it is hoped, will still carry on the good work for many years to come.

R.G.V.

## METEOROLOGICAL OFFICE NEWS

**Retirements.**—The Director-General records his appreciation of the services of:

*Mr. W. A. L. Marshall, M.B.E.*, Chief Experimental Officer, who retired on 31 August 1959. After service in the 54th Infantry Brigade from 1914 to 1919, he joined the Office in June 1920 as a Technical Assistant in the Forecasting Division. In 1928 he was transferred to Cardington, but he returned in 1931 to the Forecasting Division where he remained for three years. After short spells in the General Services Division and on a forecasting course he was back again in 1936 in the Forecasting Division. In 1941 he took charge of the Forecasting Section in London where he stayed for some twelve years. In 1953 he was transferred to Dunstable as head of the branch dealing with observations and communications and continued in that capacity until his retirement. He was appointed a Member of the Most Excellent Order of the British Empire in the New Year Honours of 1952.

*Mr. A. H. Lupton, B.E.M.*, Senior Experimental Officer, who retired on 1 September 1959. He joined the Office in December 1915 as a Boy Clerk. During his first two years he served at Kew Observatory and then during the First World War was away on duty with the Meteorological Section, Royal Engineers. He returned to the Office in July 1919 and nearly all his subsequent career was associated with services for the Army and the Ministry of Supply. From 1954 to 1958 he served in the Military Services Division at Headquarters. At the time of his retirement he was serving at Shoeburyness. He was awarded the British Empire Medal in the Birthday Honours of 1941.

*Miss H. G. Chivers*, Experimental Officer, who retired on 31 August, 1959. She joined the Office in September 1916 as a Probationer in the General Services Division where she remained for seventeen years. In 1934 she was transferred to the Climatology Division, but in 1936 she returned to the General Services Division. After service in the Instruments Division from 1937 to 1942 she once again returned to the Administrative Division where she served continuously until her retirement.

*Mr. H. Forster*, Senior Assistant (Scientific), who retired on 14 August, 1959. He joined the Office in 1927 as a locally entered clerk at Heliopolis and he stayed in the Middle East until 1938. He was then transferred to the United Kingdom and he served at several aviation outstations. Between 1947 and 1952 he again served tours of duty overseas in the Middle East and Far East with a spell in the Instruments Division between the two tours. On his return he was posted to Dunstable, and in 1955 he was transferred to the British Climatology Division where he remained until his retirement.

*Mr. G. E. Court, B.E.M.*, Principal Foreman of Stores, who retired on 18 August 1959. He was transferred to the Office in July 1920 from the Air Ministry Publications Department, and he served continuously in the Instrument Division as a packer, Foreman of Stores and Principal Foreman of Stores. He was awarded the British Empire Medal in the New Year Honours of 1944. He served in the First World War in the Royal Berkshire Regiment and the Royal Engineers and was awarded the Military Medal.

**Sports activities.**—*Athletics.* We offer our congratulations to Mr. C. W. Fairbrother, Assistant (Scientific) at Renfrew, on his recent High Jump successes in athletics meetings, namely:

| | | |
|---|---|---|
| June 1959: | Won Scottish Championship, | 6ft 5in |
| July 1959: | Won British Championship, | 6ft 7in |
| | Won for United Kingdom versus Holland, | 6ft 7in |
| August 1959: | Second for United Kingdom versus West Germany, (the best jump to date by a British athlete) | 6ft 8in |
| | Won for United Kingdom versus Poland, | 6ft 7in |
| September 1959: | Third for United Kingdom versus Russia, (the best jump ever by a British athlete) | 6ft 8¼in |
| | Second for United Kingdom versus Finland, | 6ft 7in. |

*Shooting.* Mr. P. S. Griffiths, Experimental Officer at Stansted, was a member of the Civil Service team to shoot against the Royal Air Force in the annual representative Services Rifle Match at Bisley on 2 July 1959.

*Motoring.* On 28 June 1959 a team from the main meteorological office at Wahn succeeded in winning the arduous Sauerland Rally organized by Royal Air Force Butzweilerhof Motor Club. The success was all the more creditable since the opposition consisted of experienced Royal Air Force teams from all over Germany. This was the first time that a team entry had been submitted by the meteorological office, Wahn. The winning team consisted of R. R. McNair/A. J. Clifton (Morris Minor) 5th, T. Denholm/T. G. Thomley (Volkswagen) 8th, D. W. Turner/E. J. English (Hillman Minx) 10th.

*Cycling.* On 10 May 1959 Mr. G. A. I. Lewis, Assistant (Scientific) at Uxbridge, made an attempt on the Lands End to London tricycle record and established a new record time of 16 hours 32 minutes. The new time has been recognized by the National Road Records Association.

**Royal Air Force Volunteer Reserve (Meteorological Section).**—*Awards.* It was announced in Air Ministry Orders dated 3 June 1959 that Flight Lieutenant R. T. Gethin had been granted the Air Efficiency Award.

## REVIEWS

***Atmospheric explorations.*** Edited by H. G. Houghton. 9 in. × 6 in., pp. x + 125, *illus.*, Chapman and Hall Ltd., 37–39 Essex Street, London, W.C.2. 1958. Price: 52*s.*

The five lectures in this book formed the material of a symposium organized by the American Academy of Arts and Sciences on 11 January 1956 to celebrate the two hundred and fiftieth anniversary of the birth of Benjamin Franklin.

Since Franklin's greatest researches were concerned with the nature of lightning, it is natural enough that the first two-thirds of this volume should be devoted to this subject. The first lecture, "The electrification of cloud and raindrops", was given by Ross Gunn, and set out his well known theory that cloud droplets and raindrops acquire charges by the diffusion of ions. The hypothesis has an elegant simplicity, and it is obvious that the process must occur: but one may perhaps raise an eyebrow at the suggestion, in the final paragraph, that this is the principal source of thunderstorm electricity. Joachim P. Kuettner, at all events, is of a different opinion, for in the second paper "The formation of electric charges in thunderstorms" he ascribes the formation of thunderstorm electricity to rime forming on falling ice-particles, and shows that this mechanism explains most of the known features of thunderstorms.

The third paper, "The positive streamer spark in air in relation to the lightning stroke" by Leonard E. Loeb, is a laboratory study of sparks, and a comparison of their structure with that of lightning flashes as revealed by the well known researches of Schonland. Most of the material of this paper is new, and it was particularly appropriate that it should be presented on this occasion, since the investigation is an exact modern equivalent of Franklin's most famous experiment.

The remaining two papers are not quite so closely related to Franklin's work. In "A meteorologist looks at the upper atmosphere", Harry Wexler concludes (with an almost audible sigh of relief) that events in the upper atmosphere do not greatly influence "real" weather, though they are themselves affected by occurrences in the troposphere. The last paper, "Phenomena of radio scattering in the ionosphere" by Henry G. Booker, is the least interesting since it merely presents a set of facts which are almost entirely unexplained.

Save possibly for this last, all the papers deal with subjects which have a wide appeal; the presentation, in all cases, is simple, and readily followed by the non-specialist; and the style is invariably easy and elegant. These are the qualities that such an occasion calls for, and the organizers are to be congratulated on their felicitous choice of speakers. The book makes pleasant and stimulating reading and will probably hold its interest for many years. Since it is, essentially, a commemorative volume, one must regret that it is disfigured by the three enormous folded maps facing page 90: but apart from this, it is attractive and excellently produced.

B. C. V. ODDIE

*On the ring current hypothesis.* By Nelson Wax. Acta Polytechnica 187 (1956). Electrical Engineering Series, Vol. 6, No. 13 (also Chalmers Tekniska Högskolas Handlingar No. 171), pp. 32, *illus.*, Royal Swedish Academy of Engineering Sciences, Stockholm, 1956.

Many attempts to explain the changes that occur in the earth's magnetic field during geomagnetic storms and the occurrence and distribution of aurora are based on what is known as the "corpuscular theory"; that is, that these phenomena are caused by particles emitted from the sun. There is a variety of theories which differ according to the type, speed and distribution of the particles. The main ones are linked with the names of Störmer, Alfven, Chapman, Ferraro and Martyn. A common feature, however, in all these diverse ideas has been that they have led to the postulation of the development of a permanent or long-lasting ring current of charged particles flowing around the earth outside the effective limit of the earth's atmosphere and approximately in the plane of the geomagnetic equator. The current flowing in the ring, its radius and its size have varied with the requirements of each theory. In this paper the author sets out to review the observed facts and to examine the theories critically to see whether the existence of this ring current has been proved beyond reasonable doubt.

He first of all reviews the important facts. He includes an account of the observed relationship between solar activity and geomagnetic storms (which is not so close as is sometimes believed) and a general description of the auroral forms and their distribution in space. The evidence for the corpuscular origin of aurora is also described. The author then discusses the different corpuscular theories with special reference to the ring current hypothesis. The limitations and assumptions of each theory are critically outlined; this is not so drastic as it may sound for the authors of these theories make no claims that their work does more than point the way to a final solution.

The final summing up of this paper, is, however, that at present the existence of the ring current has not been proved either experimentally or by convincing theory and it is difficult to disagree with this statement. This paper is an account of preliminary work by the author on this difficult subject and it is to be hoped that it will be followed by further papers in due course.

R. H. COLLINGBOURNE

## WEATHER OF MAY 1959

### Northern Hemisphere

The greatest departure of the mean pressure distribution from normal was in the region of the British Isles. A small high cell, central pressure 1022 millibars, centred over northern Scotland gave anomalies of +8 millibars there. Associated positive anomalies occurred over the eastern Atlantic and Europe north of 45°N, and there were slight positive anomalies over much of Russia. Over the Mediterranean and north-west Africa negative anomalies of up to −4 millibars occurred. The Azores high, although of normal intensity, had a greater westward extension than usual which was associated with persistent anticyclones in the eastern states of the United States of America where mean pressures were 4 millibars above average. Apart from a small area in central Canada there were small positive anomalies everywhere in North America. In the Arctic and the Pacific sector anomalies were negligibly small.

Over most of Europe where conditions were more anticyclonic than usual mean temperatures for the month were a little above average (anomalies generally +1° or +2°C). The largest temperature anomalies were reported from North America. Parts of the Canadian Arctic were 5°C colder than usual and a large area in which temperatures were below average extended from the southern end of the Rockies, across western and central Canada and much of the Arctic, into northern Siberia. In the east of the United States of America persistent southerly flow was responsible for an unusually warm month. An anomaly of +5°C occurred at one station just south of the Great Lakes, and +3°C was reported at many other places. Small and variable anomalies were reported from all other parts of the hemisphere.

It was a dry month over the British Isles and western Europe, the rainfall amounts being only 20 per cent of normal at a number of places. At some stations in southern Spain, however, totals reached four times the normal. In Quebec, Newfoundland, and north-eastern districts of the United States of America rainfall was less than normal, but further west over North America, apart from a narrow belt on the eastern slopes of the Rockies, totals were near or above normal. The first tropical storm of the season developed over the Gulf of Mexico on the 28th and moved across the Louisiana coast on the 30th giving locally excessive rainfall.

## WEATHER OF JUNE 1959

### Northern Hemisphere

The pressure distribution over the whole hemisphere was very similar to the normal one. An exception to the generally weak circulation was an area from mid-Atlantic to western Britain and the Norwegian Sea where the south-westerly air stream was twice the normal strength. A stronger ridge than usual extended north-east from the Azores high, giving small positive temperature anomalies throughout Europe. Similar small positive anomalies occurred over much of Russia and the United States of America, whereas slight negative anomalies of temperature were reported from the whole of Canada.

Much of northern Europe had less rainfall than usual but heavy falls occurred in a belt from northern Spain across Switzerland and Austria to south-east Europe, severe floods occurring in Austria. Likewise in south-east Asia heavy flooding caused many deaths and much damage, particularly in south China and Hong Kong.

## WEATHER OF JUNE 1959

### Great Britain and Northern Ireland

The moderately westerly winds with which the month began fell light on the 3rd but were renewed three days later and persisted until an anticyclone spread north-east from the Azores and became the dominant system over the British Isles from the 10th to 15th. A brief spell of fresh north-westerly winds followed as the anticyclone receded westward but high pressure was re-established over the country on the 19th. This second anticyclone, however, soon moved to Scandinavia and light southerly winds were maintained over the British Isles from the 21st to 26th. During the last few days of the month winds were mostly between north and west.

June 1st was rather cool, and there was occasional slight rain as a cold front moved eastwards across the country, but the 2nd and 3rd were sunny and warm although slight rain occurred here and there; on both days more than 14 hours of sunshine was recorded at many places and afternoon temperatures exceeded 70°F. Thunderstorms broke out on the 4th and 5th, being most severe in the north of England where at some places more than one inch of rain fell in 24 hours. With freshening westerly winds the next few days were cooler but outbreaks of thundery rain or showers continued. Falls generally were not large although a cold front gave some very heavy orographic rain in western districts on the 6th.

Pressure began to rise on the 10th as an anticyclone spread north-eastwards from the Azores, and this was the beginning of a long dry spell which lasted in most parts of the country for about 12 days. Many places had 15 days or more without measurable rain about this time. The anticyclone intensified, becoming centred over the country on the 12th, and by midnight the following night pressure over almost the whole country was higher than had been recorded in a previous June anywhere in the British Isles. Pressures exceeding 1042 millibars were reported from a number of stations, which compares with the previous highest pressures during June of 1037 millibars at Rhayder in 1957 and 1036·5 millibars at Valentia in 1890. The 14th was sunny and warm, especially in eastern Scotland and north-east England, where some places recorded nearly 16 hours of sunshine with temperature in excess of 80°F. The following day the anticyclone moved westwards and cooler air spread southwards to most districts; slight ground frost was experienced locally in the Midlands during the night of the 15th to 16th. Nevertheless, from the 16th to 21st, the days were mainly sunny and rather warm with little measurable rain in England and Wales, although in north-west Scotland it was rather wet.

From the evening of the 21st until the 26th, with light southerly winds over the country, weather was generally warm with good sunny periods, although there were frequent, and often heavy, outbreaks of thundery rain and thunderstorms. Temperature rose to 84°F at Cardington on the 24th and there were severe thunderstorms in the Midlands and in Wales on the 24th and 25th; at Bristol about three inches of rain fell in an hour and a half, while at Llanidloes, central Wales, 2¼ inches was recorded in two hours, both on the evening of the 25th. It was somewhat cooler from the 29th but unsettled thundery conditions persisted for the remainder of the month with heavy rainfall occurring in the Pennines and North Riding of Yorkshire on the 27th to 28th.

Temperature was above average in nearly all areas both by day and by night and sunshine was markedly above average nearly everywhere. It was the driest June over England and Wales for eight years with rainfall only 80 per cent of the average. In Northern Ireland rainfall was about 10 per cent below the average, and in Scotland about 10 per cent above. Less than half the average occurred in west Cornwall, parts of Somerset, on the Sussex coast and in the Birmingham–Oxford area. More than 150 per cent of the average was recorded in parts of Wales, the English Lake District and in western Scotland.

Outbreaks of rain during the last week of the month did little to alleviate the effects of the hot dry spell. Where irrigation was possible it was used extensively. The weather was ideal for haymaking and most farmers brought in good crops of high quality; there was, however, little after-growth of grass. Milk yields dropped steeply as pastures suffered from the dry weather which also encouraged pests, particularly green and black aphides on sugar beet, broad beans, hops and fruit. Fungus diseases, on the other hand, were relatively absent.

## WEATHER OF JULY 1959

### Great Britain and Northern Ireland

For the greater part of the month a ridge of high pressure extended north-eastward from an anticyclone near the Azores towards northern Europe. Often this ridge covered much of England and Wales and weak fronts moved eastward across Scotland and Northern Ireland, but occasionally it moved further south and fronts from the Atlantic affected the whole country. The ridge system broke down on the 26th and thereafter weather was generally unsettled and rather cool.

During the first three days of the month a cloudy moist south-westerly air-stream gave some rain in most districts, but on the 4th many places recorded between 14 and 15 hours of sunshine and temperature over much of England rose into the eighties. Although thunderstorms broke out in many parts of the country the following day temperature rose locally to 90°F and this temperature was again reached at some places on the 8th. The 9th was notable for some remarkably heavy rain during thunderstorms, especially in the London area; at Northolt 1¾ inches fell in 30 minutes. The thundery weather continued until the 11th but weather was warm and dry over most of England from the 13th to 25th with temperature above 80°F at many places. The month ended with five days of rather cool unsettled weather.

The mean monthly temperature and sunshine were above the average except in north-west Scotland. Rainfall was very irregularly distributed. Most of England and Wales had about half the average with isolated areas of much higher rainfall, a reflection of the thundery breaks in the predominantly fine weather.

The corn harvest started in England about three weeks earlier than usual and good yields of high quality were expected, especially of barley. Generally crops stood up well to the thunderstorms except perhaps on the 10th and 11th when the heavy rain caused some lodging of crops in southern areas. Fungus diseases were notably absent, although pests were troublesome.

## WEATHER OF AUGUST 1959

The general character of the weather is shown by the following provisional figures:—

| | AIR TEMPERATURE | | | RAINFALL | | SUNSHINE |
|---|---|---|---|---|---|---|
| | Highest | Lowest | Difference from average daily mean† | Percentage of average* | No. of days difference from average* | Percentage of average† |
| | °F. | °F. | °F. | % | | % |
| England and Wales ... | 88 | 27 | +2·7 | 46 | −7 | 122 |
| Scotland ... ... | 83 | 32 | +2·6 | 52 | −7 | 99 |
| Northern Ireland ... | 76 | 37 | +2·4 | 33 | −11 | 112 |

* 1916–1950 † 1921–1950

# RAINFALL OF AUGUST 1959

## Great Britain and Northern Ireland

| County | Station | In. | *Per cent of Av. | County | Station | In. | *Per cent of Av. |
|---|---|---|---|---|---|---|---|
| *London* | Camden Square ... | 1·89 | 82 | *Pemb.* | Maenclochog, Dolwen Br. | 1·43 | 28 |
| *Kent* | Dover ... ... ... | 1·22 | 55 | *Carm.* | Aberporth ... ... | ·68 | 20 |
| ,, | Edenbridge, Falconhurst | ·83 | 28 | *Radnor* | Llandrindod Wells ... | ·48 | 15 |
| *Sussex* | Compton, Compton Ho. | 4·00 | 130 | *Mont.* | Lake Vyrnwy ... ... | 1·81 | 36 |
| ,, | Worthing, Beach Ho. Pk. | 1·12 | 49 | *Mer.* | Blaenau Festiniog ... | 1·60 | 15 |
| *Hants.* | St. Catherine's L'thouse | 2·26 | 106 | ,, | Aberdovey ... ... | 1·28 | 30 |
| ,, | Southampton, East Pk. | 1·55 | 60 | *Carn.* | Llandudno ... ... | ·68 | 27 |
| ,, | South Farnborough ... | 1·58 | 70 | *Angl.* | Llanerchymedd ... | ·38 | 11 |
| *Herts.* | Harpenden, Rothamsted | 1·57 | 69 | *I. Man* | Douglas, Borough Cem. | ·29 | 7 |
| *Bucks.* | Slough, Upton ... ... | 1·38 | 63 | *Wigtown* | Newtown Stewart ... | ·68 | 17 |
| *Oxford* | Oxford, Radcliffe ... | 1·73 | 77 | *Dumf.* | Dumfries, Crichton R.I. | ·69 | 17 |
| *N'hants.* | Wellingboro' Swanspool | ·78 | 34 | ,, | Eskdalemuir Obsy. ... | ·97 | 18 |
| *Essex* | Southend W.W. ... | ·93 | 48 | *Roxb.* | Crailing ... ... | ·39 | 12 |
| *Suffolk* | Ipswich, Belstead Hall | ·84 | 41 | *Peebles* | Stobo Castle ... ... | ·96 | 27 |
| ,, | Lowestoft Sec. School ... | 1·69 | 79 | *Berwick* | Marchmont House ... | ·41 | 13 |
| ,, | Bury St. Ed., Westley H. | ·64 | 26 | *E. Loth.* | N. Berwick ... ... | ·47 | 15 |
| *Norfolk* | Sandringham Ho. Gdns. | 2·34 | 97 | *Midl'n.* | Edinburgh, Blackf'd H. | ·40 | 13 |
| *Dorset* | Creech Grange ... | 1·57 | 54 | *Lanark* | Hamilton W.W., T'nhill | ·69 | 19 |
| ,, | Beaminster, East St. ... | 1·33 | 42 | *Ayr* | Prestwick ... ... | ·35 | 11 |
| *Devon* | Teignmouth, Den Gdns. | 3·04 | 124 | ,, | Glen Afton, Ayr San. ... | 1·37 | 32 |
| ,, | Ilfracombe ... ... | 1·06 | 34 | *Renfrew* | Greenock, Prospect Hill | 1·74 | 38 |
| ,, | Princetown ... ... | 3·28 | 49 | *Bute* | Rothesay ... ... | 1·00 | 21 |
| *Cornwall* | Bude ... ... ... | 2·27 | 80 | *Argyll* | Morven, Drimnin ... | 2·71 | 54 |
| ,, | Penzance ... ... | 1·30 | 44 | ,, | Ardrishaig, Canal Office | 1·90 | 35 |
| ,, | St. Austell ... ... | 6·54 | 182 | ,, | Inveraray Castle ... | 3·00 | 43 |
| ,, | Scilly, St. Marys ... | ·98 | 39 | ,, | Islay, Eallabus ... ... | 2·37 | 56 |
| *Somerset* | Bath ... ... ... | 2·16 | 76 | ,, | Tiree ... ... ... | 1·40 | 39 |
| ,, | Taunton ... ... | 1·44 | 62 | *Kinross* | Loch Leven Sluice ... | ·73 | 20 |
| *Glos.* | Cirencester ... ... | 2·20 | 71 | *Fife* | Leuchars Airfield ... | ·77 | 29 |
| *Salop* | Church Stretton ... | ·76 | 24 | *Perth* | Loch Dhu ... ... | 2·76 | 45 |
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