public. The Inventors Council has a difficult and somewhat thankless task, but is doing it very well indeed. The wheat they sift from the chaff is passed on to the Army and Navy for development as needs arise.

Thus there exists in the organization of the Office of Scientific Research and Development the basis for an effort commensurate with the importance of science in modern war, which is a very high order of importance indeed. Of the work itself I can not of course tell at this time, but it will be a striking story when it is finally revealed. With 60 active sections in the NDRC and 50 committees in the CMR, the range of work is obviously large. I can, however, mention one thing that has already been made public. When the Battle of Britain took place in August, September and October, 1940, invasion failed for two reasons: First, the British fighting forces in the air were courageous, skillful and well equipped, better equipped than were the invaders in many ways; secondly, radio detection, developed by a group of devoted British scientists working from 1935 on, at times without much encouragement, offset the element of surprise. This one development may have saved the isle of Britain. It is one field of obvious importance; others undoubtedly occur to you.

Most of the matters that OSRD handles are quite naturally clothed with the mantle of secrecy, for every precaution must be taken in dealing with military matters of great potential importance. The various sections are working in specific fields, and the affairs of the organization have been compartmentalized in order better to follow the general policy of permitting a man to learn confidential things only to the extent that is necessary in order that he may function effectively. Another rule is that, in working with people outside the organization, OSRD members listen and do not talk. It is not the most agreeable way of working; it is not natural for a scientist, but it is necessary under present circumstances. Appointments to posts in the organization are made only when the Army and Navy, after careful investigation, have indicated that they have no reason to suspect that there is not complete loyalty.

I said that there were two points to be considered. One is the organization, but organization is very little. The spirit in which the work is conducted is much more important. There is no unanimity in this country as to how or when or where or to what extent the power of this nation should be exerted to defend our way of life. But there is unanimity on the thesis that the power of this country must be increased at once and to the maximum possible extent.

The scientists of this country have done more than speak on this subject. They have taken off their coats and gone to work, and much academic research has been postponed in the process. The matter of credit has been utterly forgotten. They have shown a willingness to work under necessarily rigid restrictions, as well as with a reasonable tolerance of the petty inconveniences and annoyances that are inevitable in the confusion of adapting themselves to military ways. They have shown that they are willing to go into a strange ball park and learn the local ground rules. In only a year they have done things. Ordinarily, it is at least three years from an idea in the laboratory to its use, and yet I say to you that results are being obtained, and they are taking form in copper and iron. Those of you who are privileged to participate in this work, as I am, will find therein a deep satisfaction, even though it substitutes for a thing we held more highly: the privilege of contributing to the growing knowledge of the race. Those of you who are not participating directly, but are holding the fort in order that your colleagues may participate, or who are carrying on in a field where the thread of growing knowledge might otherwise be broken in the present distress of the world, will also look back some day to this period, not only as a time of stress, but as a time when we were all privileged to participate in one thing on which we could become united: the defense of the country to which we owe our allegiance. The scientists of this country are united, and they are obtaining results.

ATMOSPHERIC-ELECTRIC DISTURBANCES ACCOMPANYING THE BRIGHT AURORAS OF MARCH 25, 1940, AND SEPTEMBER 18, 1941

By Dr. HARLAN T. STETSON

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

IN an article on "The Present State of Solar Activity and Associated Phenomena" printed in SCIENCE two years ago,[1] the results of an investigation of the brighter aurorae observed at the Blue Hill Observatory during the last 35 years indicated a lag of about one year between the occurrence of a sunspot maximum and the period of the greatest auroral activity.

[1] Harlan T. Stetson, SCIENCE, 90: 2343, 482–484, November 24, 1939.

As was therein indicated, the sunspot maximum passed with the passing of the years 1937–1938.

Two unusual auroral displays worth special mention have occurred during the last two years—the Easter disturbance of March 24–25, 1940, and the great aurora of September 18–19, 1941. Both of these auroral dates were preceded by a week of marked sunspot activity. The dates of the most conspicuous display of the polar lights in the two instances followed about one day after the passage of the respective sunspot groups across the sun's meridian. This again confirmed not only the association of such displays with particular sunspot areas, but reaffirmed the reality of the lag between the central position of the sunspot group on the sun and the occurrence of the aurora with its accompanying disturbances to the earth's magnetic field and to radio communication.

The importance of radio technique as a tool in investigating the atmospheric-electric disturbances accompanying auroral phenomena was stated in the article mentioned, but is specifically well illustrated in the behavior of radio field strengths as measured at this laboratory for the week preceding and following each of these remarkable displays of the polar lights.

In Fig. 1 is depicted the field strengths in microvolts

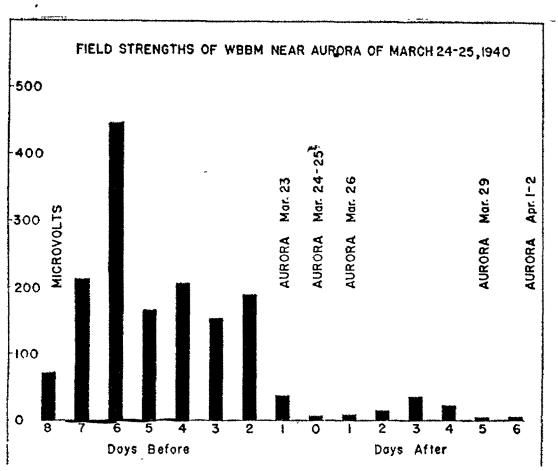

FIG. 1

per meter of the carrier wave of the broadcast station WBBM Chicago as received in the vicinity of Boston from March 17 to April 2, 1940. Since the 800-mile distance between Chicago and Boston is far beyond the radius of the ground wave, the variations in field intensity measurements are introduced through changes in the electrical characteristics of the ionosphere. Furthermore, the moderately long radio waves of WBBM's frequency (770, 780 kc.) presupposes reflection from the lower or E region of the ionosphere. The observations are based solely on night field strengths, since on account of the highly ionized state of this region in sunlight, the day field is rendered unmeasurable at the distance cited. The normal field strength based on many thousand hours of observations over a period of ten years is of the order of 100 microvolts per meter at the observing end. Reference to the diagram will show that the week preceding the auroral date of March 24–25 was a week of abnormally high reception and that the week following the auroral occurrence was marked by abnormally low fields.

A statistical study of the behavior of field strength measurements around auroral dates based on ten years' observations has been published elsewhere[2] and is graphically summarized here in a block diagram (Fig. 2). The top part of the diagram represents the mea-

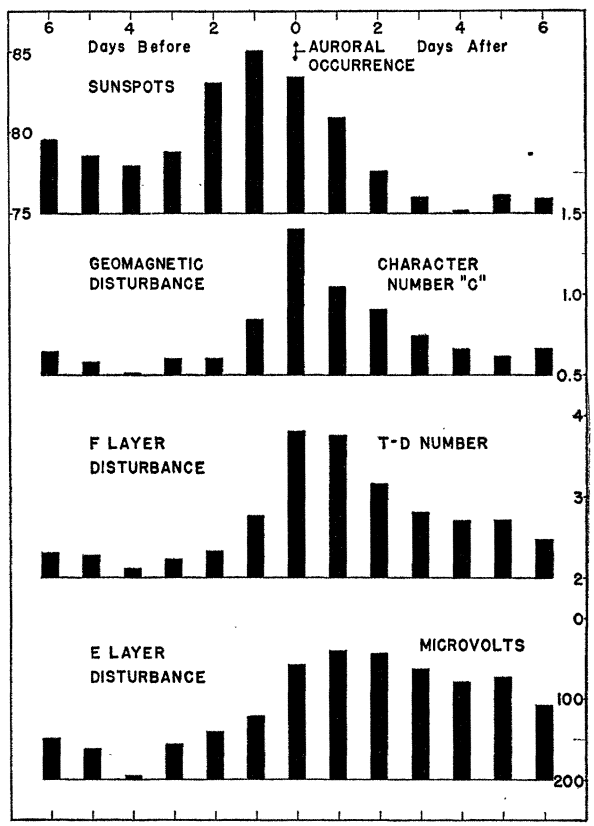

FIG. 2

sure of solar activity in terms of the conventional Zurich sunspot numbers. It will be observed that on the average the peak of solar activity precedes the date of auroral occurrences by one day.

At the bottom of Fig. 2 there is plotted the disturbances to the E layer based on field intensities. The height of each column plotted represents the inverted field intensities so that the weakest intensities correspond to the days of greatest disturbance to the E layer reflections. It will be seen that for the week

[2] *Idem, Jour. of Terrestrial Magnetism and Atmospheric Electricity*, 45: 1, 80, March, 1940.

preceding the auroral occurrence, disturbances were remarkably low, the very lowest value occurring four days preceding when remarkably high field intensities of 200 microvolts were recorded. Following the auroral dates was a week of unusual disturbance with corresponding low values of field intensities, ranging from but 50 to a little over 100 microvolts per meter. This suggests that the damage suffered by the E layer requires nearly a full week for recovery. The lag between the maximum disturbances in this broadcast band and the date of the auroral occurrence of about one and one-half days appears definitely real.

Field strength measurements at the higher frequencies involving the F region during this period were not immediately available, but through the courtesy of the Bell Telephone Laboratories, transmission disturbance figures served as a convenient index for comparison. These transmission disturbance numbers for the wave-lengths used involve the F layer, and again show close correspondence with the values derived from field intensity measurements in the broadcast band except that the time of maximum disturbance is definitely nearer the date of the auroral occurrence. For comparative purposes the disturbances in geomagnetism based on the magnetic character number *C* are plotted for the same interval. The almost identical performance of the geomagnetic disturbance with that of the disturbances involving the F layer shows that the ionic changes affecting the earth's magnetism appear to be definitely associated with the higher ionized regions of the atmosphere in which the aurora itself occurs.

During the last year, in addition to the continuation of the field strength determinations at the broadcast frequency from WBBM, apparatus has been provided at this laboratory for measuring field strengths of the short waves continuously broadcast from the Bureau of Standards station (WWV) on 5 megacycles. The simultaneous records, therefore, obtained on both the moderately long and the short radio waves for days immediately preceding and following the great auroral display of September 18–19 are of immediate interest. In Fig. 3 are the records of these two series. In the upper part of the diagram are plotted the field intensities in microvolts of WWV. It will be observed that abnormally high reception anticipated the auroral date by several days, and that for the four days immediately following the auroral occurrence, field strengths were abnormally low, but strong recovery was shown by the end of the week. In the case of the field strengths of WBBM (780 kc.) involving E layer reflections, an abnormally strong field six days before the aurora showed marked weakening thereafter, with practically a zero record on the night of the aurora. Small recovery but with abnormally low field strengths persisted throughout the entire week following. These measurements suggest that recovery from the E region is much more slowly accomplished than the recovery where the F layer is chiefly involved. If one were to smooth these curves by moving averages, the tendency for a lag between the period of maximum disturbance in the E and the F layer would be distinctly evident, confirming the deductions of the ten-year study shown in Fig. 2.

The sunspot group of September 18–19 represented a much greater disturbed area than the corresponding group preceding the aurora of March 24–25. Radio communication difficulties were experienced in both

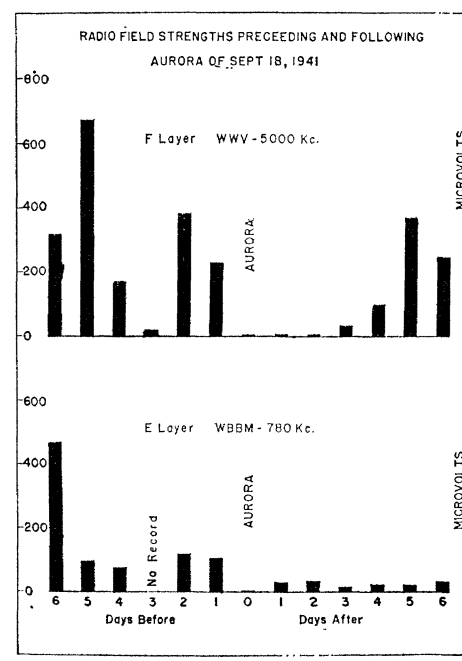

FIG. 3

instances. The communication complications of Easter Week, 1940, however, were of greater duration, but from Fig. 1 it will be seen that the major auroral display was followed by at least two other auroral occurrences in the days immediately following the major display. As has been previously pointed out in the article cited,[2] the lag of about one day between auroral occurrences and solar activity near the central meridian is consistent with the hypothesis of relatively slow moving particles passing from the disturbed regions of the sun to the earth's atmosphere. If such particles carry charges of one predominant sign, it is hardly to be expected that the trajectories of the flight of such particles will remain radial with respect to the sun. It seems possible that the trajectories of these ionizing particles will be warped not only by the earth's field in entering the atmosphere, as has been demonstrated by Störmer, but that the initial

direction taken in the immediate vicinity of the sun will be determined by the magnetic field of the sun together with that of the sunspots in the disturbed area from which the particles emanated. It is suggested that this may be at least one reason why in many instances large sunspots may cross the central meridian without accompanying auroral displays, and on the other hand, the biggest auroral disturbances may occur long after the passage of even a conspicuous sunspot as was the case in the instance of the aurora on January 25, 1938.

It is of interest that for the days near the date of the aurora of September 18, no significant changes in the potential gradient of the atmosphere at the earth's surface level were noted in the examination of the records obtained from our potential gradient recorder. The point discharger in operation at this laboratory which records significant passages of atmospheric-electric currents between the sky and the earth recorded no discharges surpassing those of the usual fair-weather intensity. These observational records of the lower atmosphere, therefore, give no indication of atmospheric-electric phenomena below the region of the ionosphere accompanying the auroral displays of September 18.

It has sometimes been stated[3] that the Northern Lights are seldom seen south of the Canadian border. It may be of interest in the amplification of this statement to note that in the list of aurorae observed at the Blue Hill Observatory, over 400 have been recorded since 1887. Returns from observatories of the Easter aurora of March 24–25, 1940, demonstrated that the aurora was seen in that instance as far south as Texas and Arizona and that the line of visibility in the South Atlantic states was cut by cloudiness. The aurora of September 18–19, 1941, was conspicuous over practically the entire area of the United States.[4] An authenticated observation of one of my associates gives assurance for an auroral display having been visible in Mexico City several years ago. Other instances are of course on record.

Dr. C. F. Brooks, director of the Blue Hill Observatory, has kindly sent to me in manuscript form a somewhat detailed discussion of his observations of the aurora of September 18, which is reproduced herewith with his permission.

[3] *Science News Letter*, 40: 12, 187–188, September 20, 1941.

[4] Since this was written a communication from Chief Reichelderfer of the U. S. Weather Bureau reveals that this aurora was reported by 106 of its subsidiary stations covering 47 of the 48 states; Arizona alone not officially reporting the display. In several instances the aurora was reported as visible on September 17, 18, 19, 20 and at Sault Saint Marie extending even to September 21.

OCCASIONAL OBSERVATIONS OF THE GREAT DISPLAY OF AURORA BOREALIS OF SEPT. 18, 1941, AT MILTON, MASSACHUSETTS

EST

7: 20 p. General illumination over prac. entire sky, down to about 15° above S. hor. Corona moderately developed.

7: 38 p. Bright arch with beams about 30° S. of zenith. Corona.

7: 50 p. (approx.) Crimson spot in W. Fairly bright arch up abt. 25° in S.

7: 54 p. to 8: 00 p. Gorgeous red and green corona in rapid motion, with waving red and green curtain over much of southern sky. First (?) flickers (rapidly upward) from bright spots in NW and S.

8: 14 p. Generally colorless, not much light, though extensive; no flickering.

8: 16 p. Corona and flickering.

8: 29 p. General curtain in south, reaching to zenith. General corona; lights in all directions. 1 color.

9: 30 p. General illumination; pulsating; no color. Arch with streamers in NW about 25° up. (Arch prob. more extensive; view of NE sky mostly cut off.)

10: 05 p. Corona narrowly developed in band from overhead to about 20° south of zenith. Little if any lights in northern sky. Not pulsating, but movements rapid (of the lateral or unvolding type).

10: 35 p. Brightening up. "Searchlight" in NW. Corona. Broad arches at about 20° up in north; 70° up in N to 80° up in S.; and 20° up in S. No pulsating.

10: 55 to 11: 00 p. A maximum phase nearly as great as that just before 8 p. Rapidly moving colored corona, taking on nearly circular form about 15° in radius.

11: 15 p. and later, the aurora continued, with much general illumination, punctuated by beams. CFB did not observe after about 11: 30 p., but Miss Margaret Sutermeister, nearby, saw it about every hour during the night, though she did not notice any illumination at 4 A.M., up to which time radio reports said the display was still visible.

(Note: On Tuesday morning Mr. H. H. Clayton's projection of sunspots showed a very considerable group beginning to cross the center of the sun's disk. This led me to write Mrs. Brooks to "Look out for an aurora tomorrow night." The display began, as predicted, Wed. evening, and on Thursday morning, Mr. Clayton reported by card: "Very brilliant aurora seen here (Canton, Mass.) 3 A.M. to 3: 45 A.M., continuing: brightness 3 on scale of 0 to 3; double arches, one about 20°, the other 40° to 50° high with streamers to zenith; shades of green and red seen in brightest portion." The aurora evidently continued throughout the day, and was very brilliant (as described above in detail) Thurs. night. Continuing through

Fri. it was seen again Fri. evening, the 19th, though very low in the north.)

CHARLES F. BROOKS

The occurrence of the Northern Lights is of course unquestionably the most spectacular evidence of the high degree of ionization of the upper atmosphere that may be produced from radiation disturbances apparently originating in the sun itself. The use of radio technique affords a new tool for accumulating data that may ultimately help in the solution of the mechanism involved in the ionization of the upper air due to such solar conditions as are conducive to the incandescent visible discharges producing displays of the Aurora Borealis.

The phenomenally high field intensities that appear to predominate the week previous to the occurrences of aurorae with their accompanying ionospheric disturbances suggests that field intensities may be used along with sunspot activity to predict periods of poor communication.

OBITUARY

WALTER MATHEW DUNAGAN

MAY 23, 1894–NOVEMBER 24, 1941

WALTER M. DUNAGAN, associate professor of theoretical and applied mechanics at Iowa State College, died on Monday, November 24, as a result of an emergency operation for a stomach ailment.

Professor Dunagan was born in Des Moines 47 years ago, was a graduate of East Des Moines High School, had an A.B. degree from Simpson College, 1919, a B.S. in civil engineering from Iowa State College, 1923, followed by degrees of civil engineer, 1928, and master of science, 1930. His freshman year was spent at Grinnell College. In both high school and college he participated in football and in distance running. He was captain of the track team at Simpson and helped in football coaching for a number of years at Iowa State. His interest in athletics and hunting continued and he was one of the well-known amateur golfers of the state. He was a former member of the athletic council of the college and assisted locally at most of the major athletic events, including the Drake Relays. At the outbreak of the First World War he enlisted in the 109th Engineer Regiment of the 34th Division and held the rank of first lieutenant in the infantry at the time of his discharge in 1919.

After preliminary field experience with the South Dakota and Iowa State Highway Departments, Mr. Dunagan joined the civil engineering staff of Iowa State College in 1924 and in 1933 became associate professor of theoretical and applied mechanics. He had long been interested in construction and engineering materials, his best known technical contributions being the result of his researches and writings in the field of concrete. In this field his name was internationally known and he was drawn in as a consultant on a great variety of concrete problems many of which were in connection with novel or large construction. He was also the friend and counselor of the small concrete practitioner and for years there have been few concrete jobs in central Iowa upon which he was not consulted formally or informally. He spent occasional periods as a member of the research and testing staff of the Portland Cement Association at Chicago.

Professor Dunagan was the inventor of equipment widely used in the analysis of fresh concrete; the author of two important bulletins of the Iowa Engineering Experiment Station, one on "The Field Control of Concrete" and the other on "The Use of Color in Concrete"; of a manual for use in the teaching of courses in plain concrete and of several technical papers and discussions published in the proceedings of the American Concrete Institute and the American Society for Testing Materials. About five years ago he developed a type of reinforced tile floor construction which already has gained wide acceptance and use. One of his most interesting and successful researches was his own residence of monolithic concrete, completed only a year ago, in which he embodied many unique features of both a utilitarian and artistic nature.

His membership in professional and technical organizations included: The American Society for Testing Materials, in which he had long been active, being chairman of Subcommittee VIII of C9, on Permeability Tests of Concrete; American Concrete Institute, some of his most recent labors having been in connection with the work of Committee 613, on the Design of Concrete Mixtures, besides being chairman of Committee 408 on Color in Concrete, and the Iowa Engineering Society, of which he was for a number of years chairman of the Committee on State Building Code. He was also a member of the Society for the Promotion of Engineering Education and was a registered engineer in the state of Iowa. He belonged to Epsilon Sigma and Sigma Xi, scholastic and scientific honorary societies, to the Knights of St. Patrick and to the Alpha Tau Omega social fraternity. He was a member of the American Legion and the Masonic Lodge and had served as superintendent of the Methodist Sunday School and as a member of its orchestra.

As a teacher he was inspiring and exerted a pro-