economical use of power. The working section from the old tunnel has been renovated and adapted, and slots are cut in the walls at the downstream end to establish the static pressure as atmospheric. A 4-in. mesh safety screen of streamlined wires is fixed here to catch any part of a model which may accidentally break loose.

From the working section the air passes along an expansion to the first corner, which is fitted with thin turning-vanes made of rolled aluminium sheet, the same turning-vane section and pitching being used at all the four corners. The general layout of the tunnel led to the fan being most conveniently situated between the first and second corners. It is two-bladed, 6 ft. maximum diameter with a 2 ft. diameter boss and nacelle, the blades being made of laminated mahogany, covered with a plastic skin impervious to moisture. The fan is directly coupled, by a long shaft which passes through the tail of the nacelle and through a fairing at the second corner, to a 36 h.p. 1,400 r.p.m. direct-current motor situated outside the tunnel, the electrical equipment being of the Ward-Leonard type, which provides accurate and economical speed control from crawl to full speed. The nacelle is supported immediately downstream of the fan by five symmetrical aerofoil straightener vanes which remove any rotation in the airstream, and the fan section is designed with approximately constant net area. The air then passes round the second corner and along the return duct, where the section changes gradually to rectangular 9 ft. wide by 7 ft. high. (with corner chamfers). Throughout the circuit the equivalent cone angles of the expansions are no more than 4.8° , the maximum expansion in any plane not exceeding 7.1° (except for a short length across the chamfers at the third corner).

At the third and fourth corners the largest cross-section has been reached, and the air then passes through a honeycomb 9 in. long with 2-in. square cells, made of brass sheet with soldered joints, which breaks up eddies and smooths out irregularities in the airstream. The honeycomb can be replaced by a phosphor-bronze screen of 14-mesh 24 S.W.G. wire, to give increased quality of airflow at the expense of some reduction in maximum tunnel speed. The honeycomb is followed by a settling length 4 ft. long, and a 4:1 contraction 10 ft. long, the profile of which is designed to give uniform velocity distribution at the start of the working section.

The aerodynamic design of the tunnel was undertaken by British Railways, after consultation with the National Physical Laboratory and the College of

Aeronautics, Cranfield. The fan design and general construction of the tunnel were carried out by the Aircscrew Company and Jicwood, Ltd., Weybridge; the tunnel was built in sections at their works and assembled on site at Derby.

Standard wind-tunnel instruments are employed for the determination of air forces and speeds. Two general-purpose single-component balances are available, and wire suspensions are employed to connect the models to the balances. This arrangement, though having a high suspension drag, enables simple balances to be used, and has given good results. Pressure plotting can be carried out by the use of a multitube manometer. Equipment is provided for flow visualization by the use of smoke generated by dropping paraffin or lubricating oil on an electrically heated hot-plate. Models of locomotives and rolling stock are tested over a thin flat plate representing the ground, and for the sake of simplicity a fixed ground-plate has been employed.

A full-sized railway signal can be put into the working section for testing oil-burning signal lamps, and a test duct is installed for railway coach and roof ventilators. In the return section provision has been made for the temporary fitting of a plywood contracting cone which enables a 60 m.p.h. jet of air of about 4 ft. diameter to be produced for the testing of shunters' hand lamps, where both the effects of wind and manipulation require to be obtained simultaneously, or for other tests where the investigator requires to be in the airstream. Before the third corner, there is room for an alternative lower-speed working-section in which can be placed a larger site model in the study of such problems as dispersal of smoke from tall chimneys, and it is hoped that the airflow here can be made reasonably uniform by the temporary fixing of one or more screens, with a maximum airspeed of about 22 m.p.h.

The tunnel has so far been given a preliminary calibration, which has shown that the velocity distribution and steadiness in the working-section are good, and that the speed attained with a clear tunnel is 112 m.p.h. with honeycomb, and 98 m.p.h. with screen, both being taken with an output from the fan motor of 36 h.p. The corresponding power factors, defined as ratio of horse-power to fan to kinetic energy at working-section, are 0.24 and 0.36, values which compare well with similar wind tunnels.

The immediate programme proposed for the new tunnel includes work on air resistance of wagons, heat dissipation from axle-boxes, smoke dispersal from engine sheds, and the design of roof ventilators.

¹ Peacock, D. W., *Inst. Locomotive Eng. J.*, 41, 606 (1951).

METEOROLOGICAL CONFERENCE AT TORONTO

METEOROLOGISTS are notably and necessarily internationally minded, and the American Meteorological Society, the Royal Meteorological Society and the Canadian Branch of the latter have recently realized a new expression of this spirit by holding a successful—first—joint meeting. It took place in the University buildings at Toronto during September 9–15, the Canadian Branch of the Royal Meteorological Society acting as the very generous hosts. Prof. H. R. Byers (Chicago), president of the American society, sowed the seeds of the meeting, and its realization was made possible by a generous grant

from the Munitap Foundation of America. More than 250 meteorologists attended, of whom about twenty formed the British delegation from overseas. A necessarily selective account of the nine symposia which were held is given below.

The first session was on ozone and the high atmosphere, under the chairmanship of Sir Charles Normand, president of the Royal Meteorological Society. It was largely descriptive in content, for knowledge of the stratosphere and higher layers is not yet sufficiently precise and comprehensive to evoke a well-conceived dynamical theory which, it is

now at least evident, is required to give meaning to the observed structure; radiation thermodynamics is certainly not enough, although there is much work for it to do. An admirable survey of ozone behaviour by the chairman suggested, however, that dynamical meteorology might well soon profit by much of the evidence now accumulated on the spatial and temporal distribution of ozone. Recent additional studies of its vertical distribution were presented by F. S. Johnson (U.S.), from rocket solar spectra, and by R. M. Goody (Great Britain), from ultra-violet and infra-red solar spectra observed at the ground. Temperatures and winds at high levels as currently measured by means of sounding balloons, from the propagation of sound, by observations on noctilucent clouds and by means of ionospheric radio reflexions were described; but a coherent picture of the motions, and of the thermal gradients in the meridional and vertical directions, did not emerge.

The second symposium, on radiation problems, under the chairmanship of Dr. G. D. Robinson (Great Britain), was appropriately divided into three sections, one on the methods of computation of the flux of atmospheric radiation, a second on laboratory investigations of infra-red spectra, and a third on the application of radiation studies in physical climatology. The material of some of the speakers was too detailed for immediate apprehension by all but a very few specialists, and will wait on more suitable occasions for appraisal. It is, however, evident that the complexity of infra-red absorption and emission in the atmosphere is slowly being mastered, to the end of computing reliable values of flux and, more particularly, of flux divergence (position and strength of radiation heat sinks) in model atmospheres. The validity of simple, approximate treatments for day-to-day application might then be tested. An interesting 'savoury' to the discussion was provided by A. W. Brewer's report of the first actual measurements of atmospheric radiation above the tropopause by Houghton at Oxford.

Canada now has an extensive network of Arctic *radio-sonde* stations, and it was appropriate, therefore, that a session should have been devoted to Arctic meteorology, with Andrew Thomson, controller of the Canadian Meteorological Service, in the chair. H. U. Sverdrup (Norway) showed how certain problems in atmospheric radiation and heat transfer are peculiarly amenable to investigation in high latitudes owing to the absence of solar radiation and the presence of snow surfaces with extreme thermal properties. Results obtained on the recent Norwegian-British-Swedish Antarctic Expedition were also presented. F. W. Rae (Canada) spoke on the setting up and maintenance of an Arctic *radio-sonde* station, and H. P. Wilson (Canada) described an investigation of cyclone behaviour within the Arctic Circle.

The next three sessions, on the general circulation of the atmosphere (chairman, Prof. P. A. Sheppard, Great Britain), on modern cyclone theory (chairman, Prof. S. Petterssen, U.S.) and on high-level forecasting (chairman, General W. O. Senter, U.S.) may conveniently be treated together as atmospheric dynamics and thermodynamics. The mean wind systems of the globe up to a height of about 20 km. are now becoming tolerably well established, and the problem is to account for their maintenance against dissipative processes and in the presence of large-scale turbulence provided by the migratory long waves, cyclones and anticyclones, and of other,

smaller-scale motions, the whole to conform with the distribution of energy sources and sinks. Papers were presented describing the momentum transfer by turbulence from low to high latitudes and in the vertical, and there was some speculation on the role of quasi-steady large-scale overturning of the atmosphere in meridional planes (mean meridional circulations) in the general circulation. These necessarily small mean meridional motions are difficult to establish where zonal motions many times larger are present, as is mostly the case. But they can be most important in the creation of relative (air to earth) zonal or angular momentum, because of the earth's rotation.

Cyclones not only play a fundamental part in the transfer processes of the general circulation but are also, of course, of intrinsic interest and great practical importance. While it has been shown that, for example, a westerly current which increases with height may be dynamically unstable and so give rise to disturbances of the scale, form and growth-rate and perhaps with the transfer properties which we observe, other forms of shearing instability are regarded as possible, and J. Bjerknes (U.S.) spoke on these. The nature of the instability in individual cases is, however, scarcely identifiable, and a new technique of investigation is now being exploited. This is to carry out numerical integrations of the hydrodynamical equations of motion, using electronic digital computers, and working from initial observed states of the atmosphere. The equations are first simplified to such a form as is thought valid for developments of the scale concerned. J. G. Charney (U.S.) described a particularly strong case of cyclonic development computed in this way, and gratifying success over 24-hr. intervals was achieved. The particular simplifications of the equations correspond, of course, to assumed model behaviours of the atmosphere, and already a sequence of models of increasing complexity has been investigated in a search for that model which is sufficiently realistic and also amenable to machine computation. The application of the technique to day-to-day forecasting is not the least of its potential rewards.

The jet stream of the upper troposphere remains obstinately outside current dynamical theory, but much work of a descriptive kind on the behaviour of the jet and on smaller-scale motions associated with it, some made visible by aircraft condensation trails, is in progress and was reported upon.

Sessions on climatic change (chairman, Prof. G. Manley, Great Britain) and on micrometeorology (chairman, Dr. C. W. Thornthwaite, U.S.), that is, on the extreme ends of the atmospheric turbulence spectrum, produced a crop of papers indicative of the current activity in these fields. It was particularly appropriate to hear speakers discussing the phase differences of climatic change on the two sides of the Atlantic, and as intriguing as ever to note the diverse forms of evidence which are brought to bear, with more or less certainty, on this problem. Fact-finding is still the need, though the facts for times before the instrumental records begin must necessarily be transformed by imagination controlled by critical power. Theorizing is not at present of great power; for here, as much perhaps as elsewhere in meteorology, cause and effect seem to be almost inextricably mingled.

The micrometeorologists ranged from the very practical problems of the micro-climate of the potato crop and of atmospheric pollution to the sophisticated

investigation of isotropic and anisotropic turbulence near the earth's surface. The difficulty in separating turbulence from mean motion in the latter work was again made manifest. Dr. H. Lettau (U.S.) concluded this symposium with a colour film of a large joint project undertaken a month before on the great plain of Nebraska, where a dozen or so teams compared their methods of measurement of mean profiles and the vertical transfer of momentum and heat.

The final symposium, on cloud physics and induced precipitation, under Prof. H. G. Houghton (U.S.), began in the laboratory and ended in large-scale weather systems. It is now well known that the laws of supercooling of water droplets are intimately concerned in the colloidal stability of clouds, and Dr. C. L. Hosler (U.S.) showed how supercooling increases with decrease in drop size and increases or decreases according to the nature and amount of the hygroscopic material forming the nucleus of the drop. Radar studies of precipitating cumulonimbus clouds by the Chicago school have shown how the initial radar echo, that is, the region containing precipitation particles as opposed to cloud droplets, appears wholly below the 0° C. level and later grows both upwards and downwards. This was interpreted as evidence that the ice-phase is not essential in inland areas such as Illinois for the initiation of shower precipitation, but no mechanism of initiation was suggested. If the interpretation is sound, the stimulation of a cloud to produce precipitation using

ice-forming agents can scarcely be adequate. K. G. Pettit (Canada) described cloud characteristics as inferred from aircraft-icing investigations, and the Massachusetts Institute of Technology school presented the results of a very detailed investigation of five depressions by aircraft, ground radar, etc. They relate precipitation patterns to cloud development, cloud-particle form and concentration, frontal structure and upper-level flow fields—an investigation, it appears, from which much may ultimately be inferred on the physics, including the dynamics, of the production of cloud and precipitation in the depressions which constitute so much of temperate-latitude weather.

The Conference was stimulated by a number of social functions: a conversation by the Canadian Branch of the Royal Meteorological Society on the first evening, a reception by the Lieutenant Governor of Ontario, an excursion to Niagara Falls, and a cocktail party (by the Friez Instrument Co.) and dinner on the last evening. The dinner was notable for speeches from the Minister of Transport for Canada and from Mrs. C. Beech, of the Munitalp Foundation, and for the announcement of the election by the American Meteorological Society of the first six honorary members on its roll: of these, five were British—Sir David Brunt, Sir Nelson Johnson, Sir Charles Normand, Mr. J. Patterson (Canada) and Sir George Simpson; the sixth was the distinguished Norwegian geophysicist, Prof. H. U. Sverdrup.

P. A. SHEPPARD

COSMIC-RAY PRODUCTION OF HELIUM IN METEORITES AND THEIR AGES

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IT has recently been proved that a major part of the helium found in iron meteorites is due to the influence of cosmic rays¹. This interaction should produce helium-3, helium-4 and tritium (see, for example, ref. 2), and the tritium will have decayed in geological time to helium-3. Helium-3 has been measured by mass-spectrometry in the helium from meteorites. If the ratio of helium-3 to helium-4 for helium produced by cosmic rays could be assessed accurately, then ages of meteorites could easily be calculated by the classical radioactivity method; but the ratio is dependent on the excitation energy of the iron nuclei which produce the helium and tritium by evaporation processes, and is therefore not constant at different points within meteorites. However, approximate limits to this ratio can be set in a number of ways.

Le Couteur³ has predicted a ratio of the order of 0.3, and in helium from the meteorites so far examined the highest observed ratio is 0.315. A study of the variation of the ratio with depth in a large meteorite, "Carbo"⁴, showed a change in the ratio from 0.288 at a depth of 3 cm. to 0.277 for 29 cm. depth of iron. The helium content decreased also, and the values obtained theoretically by Martin⁴ for the dependence on depth of the amount of helium produced by cosmic rays were in excellent agreement with the experimental values.

An estimate has been made by one of us⁵ of the probable limits of the ratio helium-3 to helium-4 in the meteorites examined. The relative amounts of helium produced separately by primary and secondary radiation were calculated for points along a radius of an iron sphere, of size equal to the probable pre-atmospheric size of "Carbo". Since it is to be expected that the helium-3 to helium-4 ratio will decrease with depth as the mean excitation energy of the iron nuclei decreases², the measured values of the ratio $^3\text{He}/(^3\text{He} + ^4\text{He})$ inside "Carbo" were plotted for the appropriate depths, against the ratio of helium due to primaries to helium due to primaries plus secondaries. The relationship was found to be linear, and, by extrapolating to 100 per cent primary radiation (that is, the value to be expected in a very small meteorite), the ratio of helium-3 to helium-4 was found to be about 0.4; and by extrapolating to 0 per cent primaries (that is, the inside of a very large meteorite, where only secondary radiation is effective) a ratio of about 0.25 was obtained. In "Carbo", at a depth of 29 cm. below the present surface, the observed ratio of helium-3 to helium-4 was 0.277; at this point, the production of helium would already be about 90 per cent due to secondary particles.

It has been pointed out by Bauer⁶ that for meteorite samples which were once largely screened from