A NUMERICAL CALCULATION OF THE GENERAL CIRCULATION OF THE ATMOSPHERE

MUCH work has been done in recent years in the calculation of changes in the wind and temperature of the atmosphere from hydrodynamic and thermodynamic theory. The equations are non-linear partial differential ones and, moreover, the atmosphere is a turbulent fluid of variable viscosity, subject to heating and cooling by radiation and changes of state of water and retarded at the ground by surface friction. It is now well realized that only by applying dynamical theory to the atmosphere can serious progress be made, and the method is the classical scientific one of studying simplified model atmospheres and comparing the results with observations.

Hitherto, the models used have not allowed for friction or for heating and cooling by radiation. In such models, temperature changes adiabatically only in association with pressure. Now, however, in a paper in the April number of the *Quarterly Journal of the Royal Meteorological Society*, which has since been awarded the first Napier Shaw Memorial Prize, N. A. Phillips, of the Institute of Advanced Study, Princeton, describes an experiment in the numerical calculation of atmospheric changes allowing for friction and non-adiabatic heating. Phillips starts with an atmosphere at rest relative to the Earth and at a uniform temperature, and calculates developments. The calculation is based on approximate equations of motion and thermodynamic energy-change. The upper atmosphere is represented by the 250-mb. level and the lower by the 750-mb. one. The surface of the Earth and its associated friction and zero vertical velocity is everywhere at 1,000 mb. The divergence at the 750-mb. level is necessarily equal and opposite in sign to that at 250 mb. Important assumptions are: hydrostatic equilibrium in the vertical; geostrophic wind except in one term of the equations; constancy of the Coriolis parameter and its derivative with respect to latitude; and constancy with height of the stability parameter $(\theta_1 - \theta_3)/\theta_2$, where θ_1 , θ_2 , θ_3 are potential temperatures at 250, 500 and 750 mb.

The atmosphere is supposed to be heated by radiation from the equator to latitude 45° and cooled

from there to the pole at a rate independent of height but proportional to distance from latitude 45° . Friction at the ground and lateral and vertical diffusion are allowed for with reasonable assumptions. Empirical mean values are used for the various constants. The equations of motion and energy are reduced to finite difference form and solved on an electronic computer for values at a grid of points at intervals of 625 km. latitudinally and 375 km. longitudinally.

Calculations were made over a rectangular area of width 6,000 km. from west to east and depth 10,000 km. from south to north. The boundary conditions were: (a) identity of values of all elements at a given latitude on the east and west boundaries; (b) zero normal geostrophic wind and zero disturbed geostrophic vorticity on the south and north boundaries.

Starting from the state of rest and uniform temperature and with the restraint that the flow was independent of longitude, the flow and temperature patterns were first computed step by step for a period of 130 days, by the end of which time there were a nearly uniform fall of temperature from equator to pole, broad westerly winds with the reasonable maximum of 36.3 m./sec. in middle latitudes at 250 mb., a weak easterly wind (order 1 m./sec.) at the surface and a minute southerly wind at 250 mb. On this circulation there was then superimposed a small random flow initially independent of height but varying horizontally in a random manner, and the development again computed. This culminated in the formation of a large central depression moving eastward at about 1,800 km./day and having features, such as isobars like those at fronts, corresponding to real depressions and with a marked westerly jet-stream and a mean poleward flux of energy.

Considering the assumptions made, the result must be regarded as a remarkably close approximation to reality, and the paper is one to be read by all meteorologists and mathematicians interested in that most difficult problem of hydrodynamics, the circulation of the atmosphere.

INDUSTRIAL APPLICATIONS OF THE ELECTRON MICROSCOPE

A CONFERENCE on "Industrial Applications of the Electron Microscope", organized by l'Association des Ingénieurs sortis de l'École de Liège, was held in Liège during May 2-5. Representatives of fourteen countries were present. The main part of the conference was devoted to the study of metals and one session to chemical problems. Throughout the conference it was noteworthy that, although applications of the electron microscope were described in all papers, in few was the microscope given undue prominence. It appears that the electron microscope is now being used as just one more piece of apparatus in the laboratory. The results obtained are valuable and, in many cases, not obtainable in any other way; but the time

has passed when problems are being sought specifically to find a use for the electron microscope.

Dr. L. Habraken (Centre National de Recherches Métallurgiques, Liège) welcomed the visitors on behalf of the Association and of the C.N.R.M. and introduced the first speaker, Dr. J. B. Le Poole (Technisch Hoogeschool, Delft), who traced the history and probable future of electron microscopes. Early electron microscopes were merely optical analogues of light microscopes; the resolution obtainable to-day had only been achieved when methods of lens correction specifically applicable to electrons and not to light had been applied. New methods in the optics of charged particles, in particular, devices using velocity

selection, made it possible to go further and use the electron microscope as a direct means of chemical analysis of the specimen. Prof. C. Fert (University of Toulouse) described the present state of his researches on the direct examination of metallic surfaces by the reflexion electron microscope. Resolution of 300 Å. is now obtained and the distortion of the image resulting from the small angle of viewing has been eliminated, partly by viewing at larger angles, partly by the use of cylindrical lenses to equalize the magnification in directions parallel to and perpendicular to the beam. A paper from Prof. G. Mollenstedt (University of Tübingen) and read by Dr. H. Mahl described a new form of microscope which depends on focusing electrons released from metallic specimens by ionic bombardment. Using it, bulk metallic specimens can be examined with a resolution of 500 Å. The theoretical limit of resolution is 100 Å., and specimens can be examined at any temperature, for example, during the course of phase transformations.

One session was devoted to new techniques in metallography. There were no papers describing yet more replica techniques. Instead, all contributors dealt with methods of making use of the full resolving power of the electron microscope instead of the many times inferior resolving power of replicas. The highest resolving power (10 Å.) was claimed by Prof. R. Castaing (University of Toulouse) for his thin-specimen techniques. Metal foils are first etched, then bombarded cathodically until they are thin enough to transmit electrons. Using specimens prepared thus, it has been possible to study the early stages of precipitation in aluminium-4 per cent copper alloys, including observations of the formation of Guinier-Preston zones. Thin films had also been studied by Dr. K. Ito (Electron Optical Laboratory, Tokyo), who had prepared his metal films by evaporation. The Japanese workers had constructed small furnaces and cryostats in which these films could be heated and cooled while actually under observation in the electron microscope. The stages in the precipitation of the various intermetallic phases from a 50-50 aluminium-copper alloy had been followed at high temperatures, and the crystallization of mercury had been observed at -180°C . Mme. Stoyanova (Electron Microscopy Laboratory of the Electronics Industry, Moscow) described how electron microscopy under dark-field conditions made possible the chemical identification of sub-microscopic and even sub-electron microscopic particles. In conjunction with the thin-film methods of Castaing and Ito, these dark-field techniques give most powerful methods of investigating the earliest stages of segregation of foreign atoms in metallic solid solution. Two papers from the Technical High School, Aachen, were devoted to the location and identification of fine precipitates in steels. In a new process described by Dr. H. Goossens, the specimen is etched until the precipitates stand out from the surface. A plastic film is then cast on the surface in order to hold the precipitates in position and finally the rest of the metal is etched away. By this means the actual precipitates can be examined free from the matrix but in their correct relative positions and at the highest resolution available in the electron microscope. Their chemical nature can likewise be determined by X-ray or electron diffraction. An application of this method to the study of grain-boundary inclusions was reported by Dr. H. K. Gorlich of the same laboratory, while a third paper describing the use of a similar technique was delivered by Dr. A. Schrader (Max Planck Institute, Düssel-

dorf), who had examined extremely fine precipitates in chromium-nickel-molybdenum steels, and followed the changes produced in them during creep.

Several invited papers reviewed the current position in the study of the relationship of microstructure to mechanical properties: Dr. J. Nutting (Metallurgical Laboratory, University of Cambridge), dealing with ferrous materials, showed that it was now possible to predict the creep properties of steels quickly by means of the electron microscope and without the necessity for lengthy creep tests at high temperatures. Creep resistance has been found to require the presence of highly refractory, very small (about 20 Å.) particles highly dispersed in the matrix. Dr. A. Saulnier (Société Pechiney, Chambéry) explained how the strength of non-ferrous alloys were derived from the clustering of solute atoms into metastable aggregates with dimensions often less than $1/10\ \mu$. In the aluminium alloys containing copper or magnesium, and also in various titanium alloys, these aggregates had been detected and identified by the electron microscope. Similar work in relation to the complex gas-turbine alloys containing nickel, copper, aluminium and titanium was reported by Dr. Y. Baillie (Office National d'Études et de Recherches Aéronautiques, Paris). Plastic deformation of pure metals was reviewed by Dr. A. F. Brown (University of Edinburgh). Present evidence obtained from electron microscope observations of the surface of pure metals conflicted with the results of other experiments, such as electrical resistance measurements, which aimed at studying the properties of the bulk of the material. Thus, experiments required to be devised by which the effects of plastic deformation could be detected under the surface of the metal. One such method based on the use of radioactive tracers was further developed in a paper by Prof. N. Feather, Dr. D. J. Shapland and Dr. A. F. Brown (University of Edinburgh), which described an electron optical method of improving the resolution of autoradiography.

A study of fracture surfaces had been systematically carried out by J. Plateau, G. Henry and Prof. C. Crussard (Institut de Recherches de la Sidérurgie, St. Germain-en-Laye), who presented micrographs showing the fine structure of brittle, ductile, intergranular and fatigue fracture surfaces. In ductile fracture it has sometimes been possible to trace the origin of the fracture to submicroscopic inclusions. Etching techniques of great delicacy had been employed by Dr. Wan Wijk (Metaal Instituut, Delft) to reveal the distribution of dislocations in pure iron and mild steel. It appears that the Cottrell atmospheres which surround the dislocation lines are either more or less susceptible to chemical attack than the surrounding matrix, depending on the nature of the impurities and the etchants. The surface of the metal is thus seen to be covered with a system of about 10^{10} tiny pits or mounds per cm^2 , giving the well-known 'orange peel' appearance usually observed after electrolytic polishing.

A complete session was devoted to the uses of the electron microscope in the chemical industry. The chief speaker was Dr. H. Mahl (Zeiss, Oberkochen), who reviewed the methods available and the results achieved in industrial quality control. Dr. J. J. Fripiat (University of Louvain) described how the electron microscope was assisting conventional techniques of soil analysis. Other notable contributions to the conference included a brief description by Prof. G. M. Kushnir (Electron Microscopy Laboratory of

the Electronics Industry, Moscow) of the various electron microscopes and electron diffractographs manufactured in the U.S.S.R. All types are available, including electrostatic instruments and reflexion instruments, the best resolution commercially available being about 20 Å. There are about 350 electron microscopes in use. From the United States, Dr. W. L. Grube (General Motors Corporation, Detroit) summarized the work of the committee of the American Society for Testing Materials, which is investigating the electron microstructure of steel. It is intended to collect complete metallographic evidence of the structure of steels as seen in the electron microscope at highest resolving power, and thus to encourage the use of the results in steel works laboratories for ordinary quality control.

The final session included a visit to the laboratories of the Centre National de Recherches Metallurgiques. These richly equipped laboratories have been built since 1945 on the site and using the external architecture of an old abbey. They have already made notable contributions to metallurgy, particularly to the knowledge of steels.

A. F. BROWN

HYPOTENSIVE DRUGS AND THE CONTROL OF VASCULAR TONE IN HYPERTENSION

UNDER the auspices of the Co-ordinating Committee for Symposia on Drug Action, a symposium on hypotensive drugs and the control of vascular tone in hypertension was held at the Wellcome Building, London, N.W.1, during April 5 and 6. The meeting was organized by a committee representing the British Pharmacological Society, the Physiological Society, the Section of Experimental Medicine and Therapeutics of the Royal Society of Medicine, the Fine Chemicals Group of the Society of Chemical Industry, the Biochemical Society, the Pharmaceutical Society, the Association of Anaesthetists and the Society for Endocrinology.

The conference was opened by Sir Charles Harington, chairman of the Co-ordinating Committee for Symposia on Drug Action, who briefly reviewed the function of the Committee in organizing symposia on subjects which are of interest to several different societies. He expressed appreciation of the generous hospitality of the Wellcome Foundation, Ltd., the contributions of which to knowledge of the subject extend over many years. He felt particular pleasure in opening the symposium because of the work of the late Dr. Harold King at the National Institute for Medical Research on the development of the methonium compounds and on the elucidation of the chemical structure of D-tubocurarine. After referring to the work of Dr. H. R. Ing, Dr. Zaimis and others, he invited Prof. F. Bergel to take the chair at the session on "Chemical and Biochemical Aspects".

The first speaker was Dr. H. R. Ing (Oxford), who discussed "Structure-action Relationships of Hypotensive Drugs". Of the veratrum alkaloids, the most potent are the ester-alkaloids, which retard the heart-rate and respiration by interference with the

afferent nerve endings in the lungs. The vasodilator amidines behave similarly and, of these, phenyldiguanide, its *o*-chloro derivative, and 2- α -naphthylethylisothiourea are especially potent. Compounds of similar type which have found clinical application are tolazoline, hydralazine (1-hydrazinophthalazine), and phentolamine, all of which produce rapid but transient competitive inhibition of the actions of adrenaline and noradrenaline.

Dibenamine (N-[2-chloroethyl]diphenylamine) exhibits a non-competitive inhibition. The onset of activity is slow and, though the blockade can be overcome in the early stages, its action becomes permanent. It is suggested that initial adsorption at an active centre, possibly involving intramolecular alkylation, is followed by reaction of the ethylene-immonium ion with groups such as —SH, —OH, or —NH₂.

The *Rauwolfia* alkaloids, for example, reserpine, deserpidine and reserpinine, also show a slow onset of action. Little is known of their structure-action relationships.

Ganglionic stimulating and blocking activity is shown by a considerable number of secondary, tertiary and quaternary bases. Several quaternary trimethylammonium bases exhibit stimulatory activity, while their triethyl analogues are inhibitors. The *bis*-quaternary ammonium bases, such as hexamethonium and pentolinium, have a purely blocking action. The end-groups vary in potency with differences

in chain-length. $\text{Me}_2\text{EtN}^+\text{CH}_2\text{CH}_2\text{OCH}_2\text{CH}_2\text{N}^+\text{Et}_3$ is more effective as a blocking agent than corresponding symmetrical compounds. The blocking agents are frequently of value in hypertension when administered parenterally. It is probable that the quaternary bases will eventually be supplanted by tertiary or *bis*-tertiary compounds, which are usually better absorbed from the alimentary canal. These are frequently stimulatory in small doses, but inhibitory in larger amounts.

Dr. H. Blaschko (Oxford) then presented a paper entitled "Biochemical Principles in relation to Hypotensive Drug Action". After explaining that the effectiveness of a given compound is governed by its concentration in the neighbourhood of the receptor centre, the biosynthetic route to adrenaline was traced. The metabolic pathway appears to be as follows:

Tyrosine $\rightarrow$ 3:4-dihydroxyphenylalanine (DOPA) $\rightarrow$ 'Dopamine' $\rightarrow$ noradrenaline $\rightarrow$ adrenaline.

It has been established that chromaffin tissue is rich in DOPA decarboxylase, which controls the second stage of this route, and also that in various systems about 6 per cent of 'Dopamine' can be converted into noradrenaline. Inhibitors of DOPA decarboxylase have been investigated, but it seems that studies of 'Dopamine' dehydrogenase might offer a more hopeful approach.

Reserpine has been shown to stimulate the release of 5-hydroxytryptamine (serotonin) from mitochondria. This substance then undergoes degradation to 5-hydroxyindoleacetic acid, which is excreted in the urine: