lems associated with the decomposition of organic matter in soils and stressed that all the different organisms concerned should be considered.

Dr. Katznelson, in an evening lecture, surveyed the work of the Bacteriology Division of the Canadian Department of Agriculture on rhizosphere problems. The ecological events in the rhizosphere and the general health of the plant were discussed in the light of the results of these studies.

Demonstrations, which were available for inspection throughout the period of the symposium, included an exhibition of the use of tracer techniques with special reference to studies of fungal growth in soil (Dr. E. Grossbard, Grassland Research Station, Hurley), the screened immersion plate technique (Dr. Thornton), and examples of soil sections prepared by a resin impregnation method (Dr. S. Hepple and Prof. Burges). The other exhibits were concerned with mycorrhizal studies. Slides and figures illustrating internal and external mycelial phases of vesicular-arbuscular endophytes associated with grass roots were presented by Dr. T. H. Nicolson (University of Nottingham), and Dr. B. Mosse (East Malling Research Station) demonstrated a method of obtaining pure inocula of an *Endogone* sp. capable of causing vesicular-arbuscular mycorrhizal infections: typical infections produced in apple, strawberry and onion roots were shown. Dr. D. G. Downie (University of Aberdeen) demonstrated strains of *Rhizoctonia solani*, pathogenic to potato, wheat and cauliflower, which stimulated embryo development of *Orchis purpurella*, and Dr. I. Levisohn (Bedford College, London) showed the growth of mycorrhizal mycelia on sterilized litter.

It is a pleasure to record the generous hospitality of the University of Liverpool and the excellent organization of this most informative and enjoyable meeting. The organizers are preparing the full proceedings of the symposium for publication by the University of Liverpool Press.

G. J. F. PUGH
G. W. F. SEWELL

PHYSICS OF ICE MOVEMENT

A SYMPOSIUM on the "Physics of Ice Movement" was held at Chamonix during September 16–24. It was organized by the International Association of Scientific Hydrology for its daughter Commission for Snow and Ice, and was attended by some eighty-five glaciologists from fifteen countries. The work of the symposium was greatly facilitated by the feat of the secretary of the Association, Prof. L. J. Tison, in publishing the forty-one papers submitted for the symposium in time for the opening session*. The president of the Commission, Prof. R. Finsterwalder (Munich), presided over the symposium, and Prof. A. Bauer, one of the vice-presidents, organized the details; despite poor weather, he managed to arrange two whole-day excursions of great glaciological interest as well as twelve working sessions. It is, of course, impossible to summarize all the papers here, and I will only try to give some impression of the material presented in the wide range of relevant subjects discussed, which ranged from the deformation of single crystals of ice to the behaviour of the Antarctic ice sheet.

Prof. U. Nakaya (Sapporo, Japan) reported the results of some very beautiful tests performed on single crystals of ice of great perfection derived from an Alaskan glacier. Rectangular bars cut from these crystals in various orientations had been deformed by bending, and the resulting deformation studied by shadow photography, which reveals the glide planes, and by polarized light, to determine changes in crystal orientation. All the phenomena of gliding and low-angle boundaries observed in hexagonal metals are to be seen, and the geometry of the deformation, deduced by Nakaya, was shown by Dr. J. F. Nye (Bristol) in the symposium to have a close relation to the theory of deformation by continuous distributions of dislocations. The flow law for ice single crystals was discussed by Dr. T. R. Butkovich and Dr. J. K. Landauer (Snow, Ice and Permafrost Research Establishment, United States), who found that for single crystals, like polycrystalline aggregates, the relation between minimum strain-rate and stress can be well represented by a power law for stresses around 1 bar. They used shear tests, and found that if the crystal is oriented for easy glide on the basal plane, the flow is considerably faster than for polycrystals, whereas if the specimen is oriented so that no glide on the basal plane is possible under the applied stress, then the minimum strain-rate is of the same magnitude as that of polycrystals. Butkovich and Landauer also reported results of tests on polycrystalline ice, and further tests of this kind were reported by Prof. S. S. Vyalov (U.S.S.R.) and by Dr. S. Steinemann (Neuchâtel, Switzerland). They all confirmed that a power law represents the data well over a range of strain-rates from 10^{-9} to 10^{-5} sec.$^{-1}$, but at the limits of this range there are signs that the law ceases to hold, in the sense that the power decreases for the low strain-rates and increases for the high ones. Steinemann also found that he could plot a similar power law for the final strain-rate to which the specimen settles down (as opposed to the minimum rate). In this state the ice is recrystallizing during the creep, and it is of particular interest that he has results for both compression and shear tests so that the relations usually assumed to hold between the results of these two types of stressing system can be tested. He finds that the relations are not obeyed, and that the disagreement is particularly bad in the case of the final rate—a result which is perhaps not so surprising when it is realized that the recrystallization is producing quite different textures in the two cases. Since, however, it is this final rate which is probably most relevant to the rate of flow observed in glaciers, this may well mean that glacier theories made with the usual assumptions are subject to some error. Dr. J. W. Glen (Birmingham) in his paper discussed what possibilities there might be for a flow law without making the assumptions in question.

Experiments on glaciers which have bearing on the mechanical properties of ice were reported by several authors. Dr. B. L. Hansen and Dr. Landauer (Snow,

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* Union Géodésique et Géophysique Internationale, Association Internationale d'Hydrologie Scientifique, Symposium de Chamonix 16–24 Sept., 1958. (Gentbrugge: Association Internationale d'Hydrologie Scientifique (61 rue des Ronces), 1958.) Pp. 394. 300 frs. belges.

Ice and Permafrost Research Establishment) used measurements of the rate of closure of a hole drilled 1,346 ft. into the Greenland ice sheet to deduce the flow law of the ice, and found results in good agreement with the laboratory work, and Dr. C. C. Langway of the same laboratory reported measurements on the pressure of bubbles in the cores removed from this drill hole which showed that the bubble pressures largely reflected the weight of the overlying ice. However, if the specimens were kept for one year before testing, the bubble pressure never exceeded a certain value, showing that bubbles of greater pressure than that, although they had survived intact the process of being brought to the surface in a core, had relaxed their pressure during the year, and microscopic examination showed small cracks spreading from these bubbles. A further series of mechanical tests on ice were reported by Prof. Nakaya, who has measured the resonant frequency and the damping of bars of ice from various sources as a function of temperature. Recent results which he reported in the symposium, but which are not in his submitted paper, show that the peaks in a plot of damping versus temperature depend critically on the ice used, peaks being present in glacier ice which are not present in single crystals, and laboratory ice being different again. Nakaya's interpretation of this in terms of such things as the mechanical properties of grain boundaries was challenged by Steinemann in the symposium, who suggested that perhaps proton movements associated with the boundaries might be responsible—thus emphasizing that ice, though in many ways similar to a metal, has its differences.

Steinemann also discussed the recrystallization structures of ice, as did Prof. P. A. Shumskiy (Moscow) and Dr. G. P. Rigsby (San Diego). Steinemann used the results of his laboratory tests to discuss the recrystallization and intragranular movements that occur in glaciers, Shumskiy distinguished six mechanisms of straining and their corresponding structures according to the magnitude and type of stressing, and Rigsby presented the results of observations of the preferred orientations found in glaciers and after laboratory tests. In a second paper, Steinemann discussed the applicability of laboratory tests made on ice at temperatures below the melting point to the discussion of the behaviour of temperate glaciers, which are at their melting point and therefore contain some liquid water. He has analysed the stability of the liquid phase theoretically, and concludes that water droplets will only be stable at the intersection between four grains. Thus, until a certain quite high percentage of the ice has melted, the temperate glacier will consist of essentially 'dry' ice with water droplets at four-grain intersections. These droplets will raise the effective stress on the rest of the ice somewhat, but not by a factor out of proportion to the fraction melted. As a result, Steinemann concludes that results of tests on cold ice can be applied to temperate glaciers without serious error.

Naturally, several of the papers were devoted to aspects of the theory of glacier flow. One of the main topics discussed here was the propagation of surges through glaciers. If a glacier develops a greater thickness in some part, as a result, for example, of a very snowy winter, a wave of increased thickness will travel down the glacier at a velocity greater than the velocity of flow itself. A paper on the theory of this phenomenon was published earlier this year in *Nature*[1], and at the symposium, Prof. L. Lliboutry (Grenoble) analysed the observations made on the Mer de Glace during 1891–95 by Joseph Vallot to test this theory. He showed that, although there was qualitative agreement in that a wave of increased thickness moved through the glacier several times faster than the flow velocity, the agreement was not quantitative, and he suggested various possibilities to account for this. His main suggestion was that the friction on the bed may not be completely accounted for on the current theories, but that at high speeds it may diminish considerably due to the inability of the ice to close up behind obstacles past which it has flowed. Dr. J. Weertman (Washington, D.C.) also presented a paper on the subject of surges in which he developed further the theory of their propagation, and in particular discussed the question of the change in shape of the surface of such a surge.

Another sort of wave on a glacier was discussed by Dr. Nye; the waves in question are the undulations which form beneath ice falls and which have a wave-length corresponding approximately to the flow in one year; they are often called wave ogives, and sometimes pressure arches, since pressure was assumed to be responsible for their formation. Dr. Nye has pointed out that in an ice fall where a high velocity is reached, accompanied by an extension of the ice, such waves are to be expected from the fact that glacier flow continues throughout the year, whereas the ablation (loss of ice from the glacier surface) occurs only in summer. Using a simple theory in which it is assumed that the velocity is constant throughout the year and that the ablation occurs suddenly once a year, he showed how such waves could be predicted from velocity and ablation data. He then applied this theory to the ice fall on Austerdalsbreen (a Norwegian glacier), for which measurements of these quantities are available, and found that the location of the crests and troughs agrees well with the predictions, and the order of their amplitude is right, though they are, in fact, less marked than the theory predicts—a result that is to be expected if the assumptions made in the theory are relaxed in a reasonable way.

Among others who discussed glacier theory, Prof. M. Matchinski (France) emphasized the importance of obtaining glacier theories which could be used to describe any glacier of complex shape, and proposed a theory to do this containing parameters to be determined from the glacier itself, and Prof. D. Tonini (Italy) suggested the use of the concept of the characteristic time of a glacier to describe the rate with which the outflow of material on a glacier responds to a change in its accumulation.

Measurements of ice movement on glaciers were naturally also discussed, and here one of the most interesting contributions came from Prof. R. G. Millecamps and M. M. Lafargue (Paris). They have sunk a large number of barium titanate ultrasonic transmitter/receiver units into the ice at the corners of a rectangular lattice, and have used measurements of the time taken for signals to travel between the different units for determining the strain suffered by the ice. At present, only preliminary results are available, and these seem to be curiously irregular; however, the technique is clearly one that holds out great promise, since it enables the full deformation of the ice through the depth of the glacier to be measured. A second technique of great importance was reported by Profs. R. P. Sharp and S. Epstein (California Institute of Technology). They have used the variations in the ratio of the isotopes oxygen-18 and oxygen-16 to determine the history of different parcels of ice. This ratio varies according to the season of the year, and also the altitude of the place in which the snow fell, and they quoted several examples where it had been of value in confirming whether ice samples found to be close to each other in the lower reaches of a glacier in fact came from the same region.

One of the most interesting developments in more orthodox methods of glacier study is the increasing use of photogrammetry, both terrestrial and aerial, to determine not only the map of a glacier, but also the velocity of flow and the variation in surface height of glaciers. For flow measurements, the photographs are usually taken with an interval of several days, and preferably from an identical position, but it was shown that even aerial photographs (which are necessarily not taken from exactly the same position on two different flights) could be used, if necessary, to determine glacier flow. There was some discussion of the best method of analysing such photographs, M. M. Baussart (Paris) favouring the plotting of two maps, one for each date, and deducing the velocity either from these or from the data from which they are constructed, whereas Dr. W. Hofmann (Munich) preferred to use two photographs taken at different times to give the velocity directly. However, it seems clear that both techniques give accurate results, and can even do so when no ground control at all is available. There were also many reports of measurements of glacier flow and variations of the more conventional kind, and perhaps the most interesting of these were some of the first results of International Geophysical Year expeditions to Antarctica given by Dr. L. D. Dolgushin (Moscow) and Dr. J. H. Zumberge (Ann Arbor, Michigan). The former described the features developed by flow in the large outflow glaciers of Queen Mary Land, while the latter reported on the deformation features on the Ross Ice Shelf.

J. W. Glen

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[1] Nye, J. F., *Nature*, **181**, 1450 (1958).

THE HUMAN OPERATOR AND HIGH-SPEED FLIGHT

THE first International Congress of Aeronautical Sciences was held in Madrid, during September 8–13, when representatives from twenty countries met to discuss forty-five papers delivered under the presidency of Dr. Theodore von Kármán.

The subjects included theoretical and applied science dealing with structures, aerodynamics, speed, height, range, propulsion, the handling of supersonic aircraft, navigation, aircraft taking-off and landing vertically, engine noise, and also the important subject of human engineering.

The human element is the limiting factor which faces the designer and operator of the new generation of high-speed aircraft. But considerable information has been accumulated over the past fifteen years about the physical and mental strains on a pilot subjected to violent manœuvres, and also about the psychological factors causing fatigue and thus an involuntary falling-off in efficiency. This experience has come from branches of science outside the general field of aeronautical engineering, namely, in the aero-medical field including physiology, neurophysiology and psychology.

From the early stages of design study for a new aeroplane the problem of the human operator is studied by scientists working with the design team to ensure that human limitations do not prevent the machine being flown to the best advantage.

Military and civil aircraft present some common problems, but naturally those of the combat aeroplane are particularly difficult; pioneering work on military aircraft is frequently useful for the later generations of civil machines, including the now familiar pressure suits worn by air-crews for the protection of the body against physical damage, and radar devices for navigation.

An invariable problem posed by the human operator and his working space in the cockpit lies in variations in size and shape of body, and arm- and leg-reach, all in some way affecting operating comfort and efficiency and involving, for example, the clearance between apparatus, controls, and the canopy. More intangible problems are those concerned with muscle, nerve and brain, underlying the senses and reactions, and much has yet to be discovered.

Laboratories exist in many countries for practical work as well as for theoretical analyses in the study of human engineering, which applies to any task in which physical and mental co-ordination is required of the operator. Too many tasks in the past have been carried out by the human operator adapting himself to the machine, whether it be aeroplane, machine tool, forging machine, or instrument observation.

The aircraft designer is thus increasingly required to range over a varied scientific field, and to consult other specialists on the human operator aspect. The following topics were discussed at the Congress:

(1) Simplification of the work of the air-crew, both physical and mental.

(2) The study of all aspects of visual observation both inside and outside the cockpit, including the design and arrangement of the instruments. Outside the cockpit the angle of view from a pressurized aircraft is limited, and with increase in performance a television display, reliable under all weather conditions, is desirable.

(3) Location, design and shape of controls, levers, and knobs, for instant recognition by sight or touch, day or night.

(4) Reliable information about what fuel remains at any given time, and what aerodromes are available within the remaining range.

(5) Warning lights that are insistent, but not too violent, for vital emergencies, and illuminated descriptive panels for secondary troubles.

(6) Air conditioning and temperature control.

(7) Methods of escape to safety in case of an emergency; the self-contained detachable cockpit dropping by a parachute, after clearing the air wreck, to a suitable altitude from which the crew can escape on their own parachutes.

(8) Disorientation in flight.

(9) Protection against cosmic radiation during space flight.

(10) The problem of weightlessness in space.