Haley, of the American Rocket Society. The headquarters are to be in Switzerland, and the Swiss group (there is as yet no legally constituted society) will handle all international matters, such as the collection, classification and storage of an astronautical library and archives. It is envisaged that the Federation's main tasks will be in the exchange of information between member societies and the organization of technical congresses. The next congress will be held in Germany in 1952.

The latter part of the London Congress was devoted to a symposium of papers on the general theme of orbital vehicles, their construction and uses. There was general agreement among the speakers that such vehicles are possible from an engineering point of view; the first instrument-carrying vehicles could be built within ten to fifteen years; but man-carrying artificial satellites appear to be much further in the future. In all, seventeen papers were read dealing with the engineering problems of raising and constructing such vehicles, return to earth by high-speed glider, travel between artificial satellite orbits, radar tracking of vehicles from the earth, danger from meteors and other relevant topics.

Mr. T. Nonweiler dealt with the problem of descent from a satellite orbit by glider. The most difficult matter is the temperature reached during the descent. In general, the rate of heat transfer to a body moving at very high speeds cannot be accurately calculated. However, Mr. Nonweiler presented an approximate general solution which he has developed and which is applicable at Mach numbers of 10 or more if the Reynolds number is between about 10^5 and 10^8 A return glider would, in fact, be operating within these limits during the greater part of its flight time. The effects of the air slip at the wing surface have also been examined; this has led to an estimate of the maximum rate of heat transfer to the surface. A limit to the skin temperature is also imposed by the conduction of heat along the surface: this has also been calculated. It was shown that the wing surface temperature will be a minimum if a thin, double-wedge wing-section is used, with a position of maximum thickness well aft and with both its inner and outer surfaces acting as good radiators of heat; the temperature will be highest near the leading-edge of the wing under-surface, and its value will vary approximately as the fourth root of the wing loading. If a maximum skin temperature of 1,300° C. be allowable, then it should be possible, for example, to construct an all-wing delta planform aircraft with an all-up weight of 20-tonnes capable of accommodating a payload of 5 tonnes.

In a paper entitled "Meteor Hazards to Space Stations", M. W. Ovenden extended both his own earlier work[1] and that of Grimminger[2]. Grimminger considered a space station of about 100 sq. m. exposed area and calculated the probable times between collisions with sporadic meteors of various magnitudes. The astronomical factors affecting the validity of Grimminger's analysis were examined. The existence of iron meteors was shown to require a reduction in the collision times by a factor of about 2. Radar observations provide direct evidence for the relationship between the assumed number of meteors to their magnitude down to magnitude 7, but extrapolation beyond this limit is uncertain because processes exist which might disturb the distribution. One such process is the sun's radiation pressure, which would repel all meteors smaller than magnitude 30 out of the solar system. Another process affecting much larger meteors is the Poynting–Robertson effect. This may increase Grimminger's times by a factor of about 3, although a much greater possible increase cannot be ruled out. The danger from meteor showers is comparable with that from sporadic meteors. The greatest uncertainty in the estimates of collision times is due to the imperfect knowledge of the mass of a meteor of given magnitude. Error here may require, at worst, a decrease in collision times by a factor of 50. The use of a very thin 'meteor bumper' around a space station, which would explode any incident meteors, was suggested for space stations intended for use for a period of more than about a year.

The greatest problem of interplanetary flight is that of propulsion, and in his paper "Interplanetary Travel between Satellite Orbits", Prof. Lyman Spitzer discussed a method of applying nuclear energy. It was suggested that an electrically accelerated ion beam could be used for achieving a gas ejection velocity of 100 km./sec. without the use of very high temperatures in the propellant gases. Such a unit could not be built with a large enough thrust/weight ratio to allow it to take off from the surface of a planet. It would be capable of travelling from a close-orbital station about the earth to a similar orbit about any other planet. The mass flow of the working fluid in an ion rocket would be low, and hence interplanetary vessels of a very low mass ratio could be built.

In "Biological Problems of the Earth Satellite Vehicle", Médecin-General P. Bergeret discussed the conditions under which the human body would have to function in an artificial satellite. One of the major unknowns is the effect of zero g or 'free fall' conditions. This condition can be obtained for periods up to 10 sec. in high-speed jet aircraft. Artificial gravity may be necessary and this can be obtained by rotating the vehicle.

J. HUMPHRIES

[1] Ovenden, M. W., *J. Brit. Interplanet. Soc.*, **6**, No. 6, 157 (1947).
[2] Grimminger, G., *J. App. Phys.*, **19**, 947 (1948).

STRESS ANALYSIS

THE fifth annual conference of the Stress Analysis Group of the Institute of Physics was held during April 4–6 in the Mechanical Engineering Laboratory of the University of Liverpool. Papers were read on relaxation methods, fatigue, applications of electric resistance strain-gauge methods, brittle lacquer methods, a pneumatic strain-gauge, applications and problems of the 'frozen stress' method of photoelasticity, and hydraulic methods of applying test loads.

The opening lecture of the conference was given by Prof. D. G. Christopherson on "Numerical Methods in Stress Analysis with Special Reference to the Relaxation Method". He outlined the development of the application of numerical methods to stress analysis problems, emphasizing the different approach of the mathematician and the engineer. The mathematician faced with an insoluble differential equation or an unreasonably large number of simultaneous linear equations seeks for more rapid means of obtaining an approximate solution. The engineer, on the other hand, concerned in the first place with problems of complicated structural frameworks, rejects the traditional apparatus of analysis and seeks for help in processes in which experience, intuition and imagination about the probable behaviour of the structure can play as large a part as mathematical ability. Prof. Christopherson referred to the moment-distribution method of Hardy Cross as one such method. Sir Richard Southwell's relaxation method was also first applied to problems of frameworks, and although the greatest successes of the relaxation method have been won in fields remote from structural engineering, the nomenclature of the method still shows its original applications.

Prof. Christopherson dealt with several types of problems of importance in stress analysis, demonstrating how they can be tackled, how the accuracy of a solution can be improved or at least reliably estimated, and how previous experience or intuitive knowledge of the type of stress distribution to be expected can all be made to give a more rapid convergence and therefore a quicker solution.

The two papers dealing with electric resistance strain-gauge work were by P. H. Wolfenden, on the use of these gauges for the measurement of transient forces in power looms, and by R. G. Boiten, on the determination of residual stresses, respectively. The latter dealt with the problems encountered when it is not possible to take the structure under investigation through a loading cycle while the gauges are in place. This arises mainly when determining stresses due to the self-weight of a structure such as a bridge, and when investigating locked-up stresses such as those due to welding. The method described by Mr. Boiten consists essentially of the measurement of the change of stress around a circular area 6 mm. in diameter. Three gauges are placed radially as close as possible to the area, which is then removed by drilling a hole of that diameter. From the change of stress observed the original locked-up stresses can be computed on the generally sound assumption that the stresses are reasonably uniform over the small circular area. Considerable care under what must often be field rather than laboratory conditions is required in the placing of the gauges and the hole.

Dr. D. G. Sopwith, in a lecture on "Fatigue", dealt with the subject of the failure of components or structures under repeated loads from the point of view of the designer or stress analyst rather than that of the metallurgist. He discussed the correlation of the safe stresses under fatigue conditions with other physical properties of the material and also the influence of factors such as temperature and corrosion on the behaviour of a specimen subject to repeated loading.

Dr. A. W. Hendry and J. K. Tattersall, and G. Robertson described work they have done using the 'frozen stress' method of photoelasticity, which makes use of a phenomenon observed in certain photoelastic model materials—namely, that a model subjected to load and taken through a heating and cooling cycle retains the relevant fringe pattern after the load has been removed and can even be sliced without the resulting slices losing their 'frozen' pattern. Dr. Hendry and Mr. Tattersall have used the method to analyse the stresses in a buttress dam of a hydroelectric power scheme in Scotland. They dealt separately with the stresses induced by the water pressure and those due to the weight of the dam. The former were tackled by ordinary 'frozen stress' methods using 'Catalin' as their model material. The latter posed a more serious problem since none of the usual photoelastic model materials capable of being sliced is sufficiently stress-optically sensitive to show fringes under its own weight. To simulate a gravitational field using a centrifuge necessitated the use of the longest convenient rotor arm so that the body force on the model should be reasonably uniform throughout the depth of the model. This made it impossible to spin the model in the oven as is usual; it would have involved the use of an impossibly large oven. To overcome this difficulty the model was heated in an oven and then transferred very rapidly in a heat-insulated box to the centrifuge, where it cooled slowly while being spun.

Mr. Robertson's work dealt with the stresses in pipe flanges. He used the comparatively new American material 'Fosterite', with which he could find no fault apart from its very high cost. He overcame one difficulty which is inherent in the analysis of three-dimensional problems by the 'frozen stress' method, this difficulty being that the slices cut from the three-dimensional models should be as thin as possible, as they are treated afterwards by the methods of two-dimensional photoelasticity. Very thin models, however, display very few fringes, since the fringe order at a point is proportional to the thickness of the model as well as the principal stress difference. Thin slices, therefore, require accurate measurements of fringe order by compensator methods. Having had to deal with a solid of revolution, Mr. Robertson was in a position to cut a large number of radial slices which by symmetry were identical. He made these slices thin enough to meet the requirement that the stresses should be reasonably constant through the thickness of the slice, but obtained satisfactory fringe photographs by using a pile of half a dozen or more slices superimposed on each other. The fringe photographs obtained in this way were strikingly well defined.

H. de Leiris discussed the development of brittle lacquer methods and of a pneumatic strain-gauge of very short gauge-length. He compared the fusion technique of applying strain-sensitive lacquers with the dissolving technique exemplified by such commercially available lacquers as 'Stresscoat' and 'Strainlac'. He discussed the relative merits of using different criteria such as the appearance of the first crack, the crack density or the lengths of the cracks when interpreting crack patterns. He dismissed the first two criteria as unsatisfactory, being dependent on variations in the thickness of the lacquer and other fortuitous circumstances. He was in favour of the method by which a family of curves, one for each increment of load, is obtained by drawing a line through the extremities of all the cracks. This method has the merit of dealing with a large number of cracks each time, thereby eliminating the effect of some of the random variations. M. de Leiris emphasized the important part played by the contraction stresses in the lacquer which are present before any load has been applied to the specimen. The load is, in fact, only the proverbial last straw which makes the lacquer crack. He therefore found it difficult to envisage any mechanism of failure which did not in some way require a tensile stress to open the crack. No simple law of cracking has as yet been suggested. There is, all the same, no doubt that the brittle lacquer method used as an auxiliary to more accurate methods of analysis fulfils an important function. In the second part of his paper M. de Leiris described a pneumatic gauge operating on the 'Solex' principle. This instrument has a gauge-length of 2 mm. with a magnification of 200,000; a stress of 1 kgm./sq. mm. in steel is indicated by a change of level of 20 mm. on a manometer.

E. K. FRANKL