exceeding an elastic or plastic stress limit.

The author gives details of efforts being made in France to introduce probability calculation in the evaluation of the safety of civil engineering structures, as being relevant and of interest.

As most of the loads imposed upon the aeroplane are not steady but vary rapidly with time, the question arises whether the static method of allowable stress calculation inherited from civil engineering practice is satisfactory for aeronautical purposes. The question can be answered only by including the inertia terms in the analysis of data on aeroplane loads, collected by V-g recorders measuring accelerations and flying speed under service conditions, and so determining whether they can be disregarded.

Finally, Mr. Hoff suggests that in future, aircraft will be classified, from the standpoint of safety, as (a) not expendable; (b) semi-expendable and (c) expendable. All aeroplanes flying at present belong in Class A, whilst a guided missile is obviously an expendable article and belongs in Class C.

The phenomenon of creep, which becomes increasingly noticeable as the structure is heated, necessitates the introduction of Class B for piloted aeroplanes. It will not be possible to design aeroplanes to fly efficiently for an indefinitely long period of time at Mach numbers of 3 or 4.

Inelastic deformations are bound to take place and a thorough understanding of the phenomena will be needed in determining just how long a particular aeroplane will remain safe. When a consistent theory corroborated by experiment is available, the crew and the passengers will trust the supersonic semi-expendable aeroplane just as much as the non-expendable subsonic aeroplane.

Some Problems of Turbine Transport Operations in Europe

By K. G. WILKINSON, B.Sc., D.I.C., A.F.R.Ae.S.

ALTHOUGH it is still too early to evaluate the effects of introducing turbine-engined transports on regular service, the pressure of events is already having an effect on the thinking of air lines faced with the problems of operating these revolutionary aircraft. When new operating practices were established they would in turn effect the design of the next generation of aircraft and ultimately determine the answer to the perennial question "Pure jet or turbo-prop?" The answer to this important question could not be given until a precise answer was forthcoming on the achievable limits of operational practice.

During 1950 B.E.A. operated the prototype Viscount V 630 for three weeks on the London-Paris and London-Edinburgh services and during that time the aircraft flew 138 hours. On these commercial services six defects of a minor nature gave rise to unscheduled maintenance work. Had, however, piston engines of a similar performance been fitted, the chances of achieving a result as good as this were about one in twenty.

During the time that the Viscount was being used the British traffic control was based on Zones and Flight information regions. There were no specific controlled airways.

Arrangements were made with the Ministry of Civil Aviation for the aircraft to climb away on course from its departure airport to reach the exit beacon at 10,000 ft. instead of the lower altitude specified for piston aircraft. With inbound flights, descents from 10,000 ft. were made from over the entry beacon to the destination airport.

This revised procedure saved about 100 lb. of fuel on each flight and had a similar arrangement been made in Paris a fuel weight equivalent to one passenger would have been saved on each flight or more than 3 per cent. of the capacity pay-load.

No preferential treatment was given to the Viscount and its high rates of descent enable it to clear an area quickly without serious inconvenience to other traffic. However, the trials ran for only a short time and with one aircraft but the methods used could not have been used on a large scale with the system of A.T.C. then in force without a dislocation of the control scheme. New control methods using airways introduced since the Viscount trials meant that the problem of turbine aircraft has had to be reconsidered.

Traffic flying on an airway was spaced to ensure adequate vertical or longitudinal separation and when traffic was light it may be possible for a turbine aircraft to climb through the control heights when it could be seen by radar surveillance that adequate separation could be maintained. Such a procedure might mean a delayed take-off to await for an unoccupied space, but if traffic was heavy this method might break down altogether.

An alternative method which offered the most promising arrangement was the routeing of aircraft at the greatest possible height and by the shortest route out of the Control Zone of the departure airport into the nearest Flight Information Region where the aircraft could climb to operating height and then rejoin the airway.

Slightly greater flying distances would be involved but this system would prevent the aircraft being held at a low altitude for long. Stacking would be accomplished at a point along the airway removed from the destination airport whilst the aircraft was at cruising altitude or at some point outside the airway but near to the arrival airport.

Developments in the next few years of the greatest importance would probably lie in the field of operational technique. Its possibilities would be far clearer in about 12 months. In the meantime, flight planning and control appeared to offer at least equal scope for improvement.

Initial study had shown, for example, that the quality of operational practice, particularly for fuel reserves, can make or mar the economic success of a jet aircraft, yet little critical thought had been directed to the problem.

At the present moment the practice underlying the methods used to determine the amount of fuel to be loaded, the methods for monitoring the flight's progress and the complementary practices on the commercial side by which seats were sold varied greatly, depending on the length and nature of the route. But, broadly speaking, the current "sector fuel" method used in determining booking payloads on short-ranged routes was: (1) to calculate the fuel required at cruising power in 70 per cent. wind conditions; (2) an allowance of about one hour for holding at a destination was made, and (3) an allowance for a diversion to the farthest alternate laid down for the route was made.

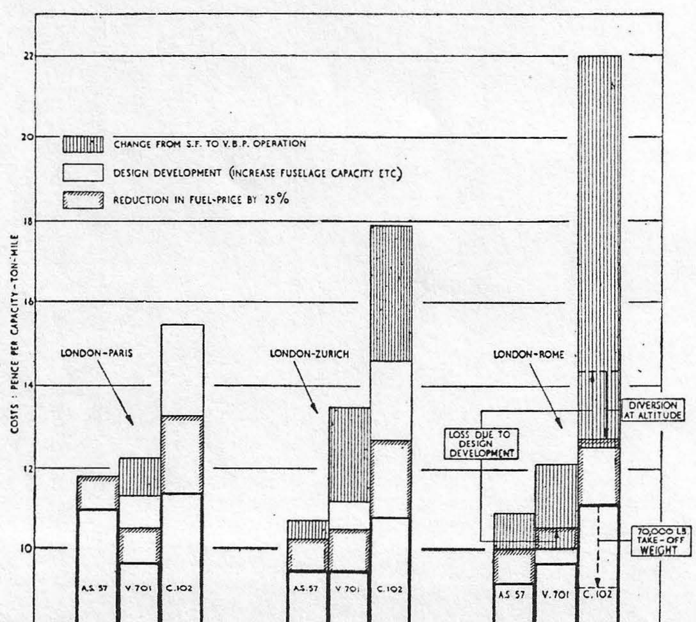
Payload was then booked on this fixed fuel figure. Depending on current trends more than 100 per cent. of this figure may be offered for sale if it were considered that the likelihood of cancellations would prevent overselling.

Turbine aircraft at present on order had all been designed for operations based on "sector fuel" practices, and it had been obvious for some time that even on routes of the length operated by B.E.A. that this was a wasteful procedure. The Corporation had been seeking ways of improving current practices and had come to the conclusion that important changes could be made. The new approach to this could be called the "Variable Booking Payload" method.

Stated simply, this was the accurate determination of the fuel required to complete a particular flight making due allowance for all contingencies. This calculation needed to be made twice, once at some time as far ahead of take-off as possible in order to release as many seats for sale as possible, and the second time immediately before take-off when the flight plan was being made out.

The first calculation would be exceedingly liable to error as the time ahead of take-off was increased; on the other hand, the seats were more likely to be sold the farther ahead of take-off they were offered—particularly on the longer routes.

In the sequence of making out a flight-plan the pilot would have available to him information on the payload booked and a meteorological forecast from which the component headwind and desirability to deviate from track could be estimated. He could then read from charts how much fuel would



Aircraft costs per capacity short ton statute mile for these aircraft types.

be necessary to complete the flight if all forecasts and assumptions were realized and average aircraft performance and terminal delays were encountered. In addition, there would be certain unforecastable factors which would have to be allowed for, which include terminal delays, liability to diversion, variations in aircraft performance, errors in meteorological forecasting and errors in loading fuel and dipping tanks.

An allowance would have to be made to cover these contingencies. In the early stages of a new route the amount could be determined by arbitrary allowances for holding-time plus diversion mileage as was commonly done, but once experience was accumulated a more detailed analysis was possible.

Once this analysis was made the component of the fuel required due to forecast errors could be calculated. Then, if the variation in forecast error with time ahead of take-off could be established, the safe booking payload at any time prior to the flight could also be calculated, with any required probability that it would not be available at the time of take-off.

There were three distinct classes of event: (1) the flight might arrive at the scheduled destination; (2) it might divert en route to an alternative airport; or (3) it might arrive at the destination and then divert to an alternative airport.

Classes (1) and (3) were associated with characteristic route mileages which vary very little. Class (2) would include cases of diversion from various points en route with highly variable total flight mileages. The first step, therefore, was to determine from operational records for particular airports and seasons the liability to diversion for flights planned to terminate there, and for particular routes, the characteristic route mileages and variance in mileage for the three classes of event.

To implement such a scheme called for a regular and accurate scanning of operational results.

A good deal more work was involved in doing the job of calculating accurately the payload and fuel requirements than was necessary in the "sector fuel" calculations.

The cost per capacity short-ton-mile has been calculated for the piston-engined Ambassador (A.S.57), the propeller-turbine Viscount (V.701) and the pure jet Jetliner (C.102) on three routes, and the results are shown below. There were four main assumptions: (1) that the landing weight was increased to give optimum results and fuselage capacity changed to give optimum results for equal annual capacity ton-miles on each route; (2) that European fuel prices were reduced by 25 per cent., to bring the American and European prices more into line; (3) that the C.102 diverted from cruising altitude on the London-Rome route; and (4) that the C.102 took-off at a higher T.O. weight on the London-Rome sector (this change does not affect other sectors).

From the results so calculated (see chart on preceding page), certain simple conclusions can be stated:—

(a) Airline A can gain a worthwhile benefit of some £400,000 per annum by refining operating techniques on the "Variable Booking Payload" basis. The old sector fuel method, however, enables profitable operation.

(b) For airline B, old methods still permit a profitable operation, but the new proposals are now worth £1½ million per annum. A redesign of the aircraft to take full benefit of "Variable Booking Payload" enables a further £800,000 revenue to be gained. (Note that the change in traffic increases costs by £300,000.) Optimum operation with the developed aircraft is appreciably more profitable than for airline A.

(c) For airline C, old methods will not suffice and lead to considerable loss. Optimum procedures and "Variable Booking Payload" enable them to break even: development of the aircraft to suit the route system more closely enables the same profitability to be attained as for airline B. Note that redesign without optimum operation still results in a loss.

These three conclusions in their generalized form contain the lesson of this paper.

Performance Characteristics of Jet Nozzles

By GEORGE SCHAIRER, A.F.I.Ae.S.

ONLY RECENTLY have aeroplanes been propelled solely by jet propulsion. The specific problems of the jet nozzle as applied to aircraft have received little research or consideration. A number of experimental investigations of jet nozzles has been made which indicate some of the problems, the known facts, and the unexplained regions of the jet nozzle problem.

The author uses one dimensional nozzle theory as a basis for studying experimental test data. Such data on the internal flow characteristics of a number of different nozzles are examined and compared with theory, after which various related problems confronting the aircraft designer are considered.

A number of experiments are described by the author to answer the question how closely actual convergent nozzles approach the one-dimensional theory.

Tests were run with various diameter square-edged orifices; the mass flow data shows a change in effective nozzle area with pressure ratio, since the mass flow is not constant above a pressure ratio of 1.89. This is to be expected for a square-edged orifice. The velocity coefficients are relatively independent of diameter ratio.

A group of smoothly convergent nozzles with various cross sections was also tested. The nozzles were smoothly convergent but were not tangential to the axial direction. These nozzles had a cross-sectional area of approximately 0.786 sq. ins.

Weight flow data are nearly constant above a pressure ratio of P_1/P_a (free stream pressure/ambient static pressure) = 2.0. Scatter between the different nozzles has not been explained by dimensional inaccuracies, although some are known to have existed. Velocity coefficients are essentially identical for all nozzles and show a fall-off at the higher pressure ratios, as would be predicted by theory.

These convergent nozzle data indicate very high values of velocity coefficients approaching within several per cent. of theoretical values. The velocity coefficient appears to be quite insensitive to nozzle shape or method of contraction. The effective area of the nozzles varied materially with nozzle shape and the flow continued to increase with pressure ratio somewhat more than would be expected from one-dimensional theory.

If an expanding nozzle is used, the nozzle velocity can be accelerated above sonic velocity and high velocity coefficients can be obtained at high-pressure ratios. By proper choices of expansion area ratio, a nozzle can be given a velocity coefficient of 1.0 for any pressure ratio. Any given expansion ratio will give best results at only one pressure ratio. Expanding nozzles can have very poor thrust at low-pressure ratios where they are over-expanded.

A conical 10 degrees half-angle expanding nozzle was tested with various cut-offs to give different area ratios. Measured thrusts under over-expanded conditions were much better than estimated.

An over-expanded nozzle which separates would appear to be better than one which does not. At high-pressure ratios, the nozzles with small expansion give better thrust than the convergent nozzle, but the differences are small over the range of test pressure ratios. A convergent nozzle will be optimum for most uses where the pressure ratio does not exceed 4.0.

Expanding nozzle data leaves much to be desired. No usable theory exists for over-expanded flow. A variable area expanding nozzle is important and should be investigated. The flow through expanding nozzles is much greater than for convergent nozzles at the lower pressure ratios. This characteristic might be quite valuable for special applications. Experimental data show the predicted improvement in velocity coefficient at high-pressure ratios for properly expanded nozzles.

In propelling an aeroplane a jet nozzle will nearly always be arranged with a convergent external air flow immediately surrounding the nozzle. The problem is then to have not only an efficient nozzle, but an external shape with low drag. Inter-actions between the external and the internal flow at the rear of a fuselage or nacelle are to be expected. A number of experiments have been conducted at low subsonic speeds on this problem. A nozzle was arranged in a wind tunnel in such a way that the internal and external forces on the nozzle could be measured and separated. Measurements were made with no external flow, with no internal flow, and for a large number of intermediate cases.

The net drag or thrust deficiency of the overall system shows a marked reduction as the internal flow is initiated. By the time the internal flow velocity has reached one-half of the external velocity, a more normal variation of net drag with internal flow is encountered. The net drag curves with and without external flow should be parallel in regions where mutual interference effects are constant. There appear to be no important mutual interference variations, except at very low internal flows. A small amount of internal flow appears to have cleaned up the external flow. The external flow appears to have changed the quantity of the internal flow without changing the efficiency of the internal flow.

A static pressure distribution on the surface of this nozzle and along the axis of the nozzle is illustrated by the author. It is obvious that a marked change in external pressure distribution occurred between the no-flow condition and the two conditions of internal flow which are presented. The pressures on the external surfaces of the nozzle became more positive when an internal flow was present, and the pressures along the axis of the nozzle indicate a material change in flow conditions when an internal flow is initiated. These experiments were conducted at Mach numbers below 0.2.

Since mutual interference effects appeared to be reasonably constant after a small amount of internal flow had been initiated, a series of experiments were conducted in which internal flow was provided by unrestricted flow through a rammed inlet ducted nacelle model. With no internal resistance, the theoretical thrust should equal the theoretical inlet drag and the velocity ratio should be of the order of 1.0. A number of different exit shapes were tested on a model which had a relatively high critical Mach number for the forward portion. External drag was found to vary by large amounts between three different configurations tested.

Pressure distributions were measured over a number of shapes, and the author presents data at a forward speed Mach number of M = 0.90 for five different shapes. Appropriately shaped nozzles can have quite high critical Mach numbers, but poor critical Mach numbers can be expected from many of the more commonly used shapes.

The problem of varying the area of a nozzle while still retaining good external and internal flow conditions, is of great importance for certain applications. Data

Fi rst Seven Papers

"Aeroplane" photograph

TECHNICAL SESSION.—Part of the audience during a lecture in the theatre at the Corn Exchange.

Structural Problems

Covering as it did a highly specialized field, Prof. Hoff's paper drew a considerable amount of interesting and serious discussion. Among the many speakers who took part were PROF. J. HADJI-ARGYRIS, A.F.R.Ae.S., of Imperial College, who said that the lecturer had drawn a fascinating, if terrifying, picture of the difficulties that have to be faced in the future. On the subject of joints he commented on the remarkable achievements attained with the use of the Redux bonding process. He felt that problems associated with temperature effects were not quite so bad as appeared at first sight and could be reduced by intelligent design.

DR. A. E. LOMBARD, JR., F.I.Ae.S., of the Directorate of Research and Development, U.S.A.F., remarked that it would appear that yet another class of technician—thermo-elasticians—was needed in addition to aero-elasticians. He spoke of the very important developments that had taken place since the War in the field of computing machines and referred to their usefulness as a means of solving some of the necessary problems.

DR. P. B. WALKER, F.R.Ae.S., of the R.A.E., said that Prof. Hoff had covered a very wide field with his usual clarity. He was particularly interested in the physical models in inelastic materials shown by the lecturer. He remarked that in this country factors of safety were decided on a statistical basis and it looked as if we made more use of V.G. recorders.

MR. A. H. FLAX, M.I.A.S., of the Cornell Aeronautical Laboratory, said that there would seem to be ample room for thermo-aero-elasticians! On the subject of temperature effects he conjured up a picture of the thin wing with a sharp leading edge getting hot and "curling up."

He said that there was a vast programme of material testing to be accomplished alongside theoretical development. Our knowledge of notch sensitivity was not overwhelming at ordinary temperatures, let alone high temperatures. He felt that we had opened Pandora's Box and got a lot of problems to solve.

MR. J. F. CUSS, A.F.R.Ae.S., of Glosters, said that everyone should be grateful to Prof. Hoff for the glimpse that had been given of the shape of things to come. He felt that the variation of stress in a member which has a variation of temperature across its section was not so alarming as shown because there may not necessarily be a direct metal connection between the outer skin and the stress-carrying member; there was, too, slip in riveted joints. He thought there might be something to be said, in some applications, for having a ceramic material round the outside of the skin with a sliding connection and insulation—in other words, a form of flying thermos flask in which the inside never gets hot.

MR. D. J. FARRAR, F.R.Ae.S., of Bristols, remarked that two or three years ago Pandora's Box had been labelled "fatigue"; it was nice to see that we now had a new label for it. Prophecy reasonably far ahead gave time to take thought and, judging by the discussion, Prof. Hoff had timed his prophecy about right. He thought that designers would want to test structures under simulated temperature conditions; he would like to know whether the lecturer could suggest how this might be done under the new difficult conditions that had been outlined.

In his reply, PROF. HOFF said that the stress distribution in a delta wing was an important and difficult problem for the structural engineer. On the subject of stresses due to temperature effects he said that there were many factors that would alleviate stress due to heat; slipping joints was one such factor. The remedy chosen would depend on the type and purpose of the aircraft concerned; for example, ceramics might well be used for guided missiles. There was no danger, he said, that we might not be able to solve these problems.

The Suction Wing

Mr. Keeble's lecture, with its wealth of practical detail, aroused many congratulatory comments during the discussion which followed. Among the speakers MR. A. H. FLAX, M.I.Ae.S., of Cornell Aeronautical Laboratory, said that they had done some work with high-lift boundary-layer control, but not much with low-drag control. He thought that the Australians had made a well-reasoned approach to the problems and wanted to know what would be the effects of high Reynolds Number.

The problems of duct design in an all-wing aircraft might be difficult, although it was possible that on very thick wings room was available. He thought that the possibility of using continuous suction in the slot area might be worth investigating.

MR. A. FAGE, F.I.Ae.S., F.R.Ae.S., said that at the N.P.L. they had been doing research on the Griffiths aerofoil for some years and this had certainly indicated the aerodynamic possibilities of a thick Griffiths wing. Its practicability depended on the results of flight experience and he congratulated the Australians on the success achieved. He thought that the great advantages to be gained by the Griffiths suction wing would only be attained in fairly large aircraft and wondered whether application to aircraft the size of the Skymaster was worth while.

MR. PERKINS, M.I.Ae.S., A.F.R.Ae.S., of MacDonnel Aircraft Corporation, was most interested in the application of the suction wing to a tailless aircraft, but pointed out that a difficulty with the Northrop tailless aircraft had been a low maximum lift coefficient of the order of 1.3. He was not sure that the Australians might not have the same problem.

The failure of the Northrop aircraft, he said, was really due to bad handling qualities, the tailless layout led to bad dynamics and poor directional stability. Again, he was not sure that using the suction wing would solve such problems.

MR. F. M. OWNER, F.R.Ae.S., had something to say from the engine designer's point of view, and wondered whether Mr. Keeble would consider the ejector action of a jet as a suitable source for providing the pumping power required. MR. HANDEL DAVIES, F.R.Ae.S., of the R.A.E., gave some details of the experiments done with a suction wing on a Meteor airframe. The standard of surface waviness required was very much finer than that found in Australia, the reason being the higher Reynolds Number, which in the case of the Meteor was 15×10^6. On the transport aircraft suggested by Mr. Keeble the Reynolds Number was of the order of 32×10^6, and he thought that the difficulties would be increased. Leading-edge contamination was a serious problem and the system used to combat it must be 100 per cent. reliable.

In his reply, MR. KEEBLE said that in a 100-ft. span tailless aircraft there was a space available for the necessary ducting. He did not entirely agree that the Griffiths suction wing was best applied to large aircraft; so far as the 70,000 lb. aircraft was concerned it certainly showed good advantages over contemporary types.

Referring to the remarks made by Mr. Perkins, he said that they would probably get a higher maximum lift coefficient with the thick wing and less trouble with tip stalling than was found with the Northrop thin wing. Stability was an awkward problem, but there were others. He was convinced, however, that Australia was going to build the first successful all-wing aircraft. Leading-edge contamination was a serious problem, but was less serious with a thick wing than with a thin wing.

Turbine Transports

Among the many speakers who took part in the interesting discussion which followed Mr. Wilkinson's paper, MR. R. D. SPEAS, M.I.Ae.S., A.F.R.Ae.S., U.S. representative of Avro Canada, pointed out that the lecture had focused attention on an aspect of air line operation which had suffered through too little research in the past. It was the question of how the turbine-powered aircraft was to be made to work economically. The lecturer had not, however, given full recognition to the possibility of a load-factor variation in his estimations and had merely assumed an average load-factor of 60 per cent.

The variation in load factor was important because it seemed quite likely that the faster aircraft would attract a larger number of passengers. It seemed possible to re-assess the figure given by the lecturer to a new set of results based on a variable load-factor.

Assuming that the slower aircraft—in this case the AS57—attracted the lowest load factor, say 50 per cent., then the hypothetical Airlines A illustrated in the lecture would

Anglo-American Aeronautical Conference . . .

lose £500 a year and not make a profit of £1.25 million. Airline C with the pure jet attracting a 70 per cent. payload would show a surplus on the year of £5,350,000 and not about £2.25 million.

Mr. G. R. Edwards, F.R.Ae.S., of Vickers-Armstrongs, remarked humorously that the paper seemed to contain a suppressed veil of a hint that the aeroplane which would produce the real answer would be the Viscount 701 when it had been "redesigned again." If the operator wanted a bigger wing or a longer fuselage, Vickers would listen with rapt attention and customary old-world charm, but whether that would change anything would be another thing.

He would like to think that as much attention was being paid to reducing the time spent by the customer outside the aeroplane as had gone into the research directed towards speeding up flight times.

Mr. J. A. Chamberlin, M.I.Ae.S., of A. V. Roe (Canada), asserted that the variable booking payload method seemed to put passengers more at the mercy of the weather than they were to-day and it seemed a step in the wrong direction. It appeared that the designer could do something about adequate fuel reserves by building sufficient tankage into the aircraft.

Mr. J. L. Watkins, A.F.R.Ae.S., of Trans-Australia Airlines, said that B.E.A. alone of all the air lines had been able to get practical experience with airscrew-turbine aircraft. In Australia studies along the lines made by B.E.A. supported the lecturer's contention that refinements in operating techniques were required. It seemed that the variable booking payload method was the answer and it need not be an embarrassment to the passenger. The variable payload factor could be made up of stand-by freight if necessary.

Mr. P. G. Masefield, F.R.Ae.S., of B.E.A., quizzically addressing Mr. Edwards, said that if he was highly concerned about getting people quickly from Balham to the Bal Tabarin, he should forget the Viscount and produce a big helicopter. B.E.A. would even like to use the Viscount's fuselage for such a project, but perhaps the constructor's old-world charm would not stretch that far.

B.E.A. believed that the prop-jet was the answer, but it was something that could not be rushed. There was a great deal of educational work to do, especially with aircrews.

Variable booking payload was a fundamental necessity to turbine aircraft and the way was being felt with Viking aircraft on the London-Rome route, using a modified system. It had been found that with this method it was possible to offer 1.70 seats extra—"the point seven is obviously a reduced fare"—and sell 1.10 of the extra space.

In its future aircraft orders B.E.A. had decided that it would require only turbine engines. No more piston-engined aircraft would be wanted. It seemed that prop-jets covered the Corporation's requirements for at least the next ten years, but if the variable payload method could be made to work and jet engine manufacturers could offer greater flexibility of operation with their engines, then the Corporation might be able to use pure jets.

In reply, Mr. Wilkinson said that it appeared that the aeroplane B.E.A. was looking for was, in fact, the next one on the line. It was difficult for the Corporation with only a few years' experience to come up yet with the right answers on what it wanted. He would like to see a more detailed evaluation of the air line's requirements for the next generation of aircraft to prevent modifications and redesigning.

The variable payload method was designed to give the most efficient method of operation of any aircraft. Its main purpose was to cut out large reserves of fuel and convert that weight into payload.

Plastic Structures

Opening the discussion on Mr. Gordon's paper, Prof. N. J. Hoff, A.F.I.A.S., F.R.Ae.S., of the Polytechnic Institute of Brooklyn, said that the lecture could be considered as a chapter in the book of unorthodox methods of construction. The use of plastics in aircraft construction had been discussed in the United States ten years ago and designers had promised that plastics would solve nearly all problems of aircraft construction.

The difficulty of introducing a revolutionary method of construction such as offered by plastics was that it cut across the enormous capital investments that aircraft manufacturers had made in their present plants. Looked at in a purely engineering light, however, it seemed obvious that the present system of construction, embodying, in the case of a big bomber, millions of rivets, was not the obvious method of building an aircraft.

With plastic construction there was a possibility of using the fibres in the material in a purposeful way as the material did not need to give a uniform strength in all directions. The fibres could be used in required directions to give the necessary strength called for in the design and weight could be saved. Engineers had become used to the idea that the ideal material must be isotropic.

Among the other speakers, Dr. J. Zand, F.I.Ae.S., F.R.Ae.S., of the Lord Manufacturing company, asked if in the programme for developing plastic wings other materials such as nylon now being developed in the U.S. were being considered. Mr. H. Templeton, A.F.R.Ae.S., of the R.A.E., pointed out that an extension in the use of plastics to all types of wings might bring with it a number of difficulties. There was, however, evidence that plastics had a greater inherent structural damping effect than other materials and this might help in overcoming flutter.

Mr. W. B. Bergen, M.I.Ae.S., of the Glenn L. Martin company, asserted that it might be a serious mistake to substitute plastics for the well-proven materials, but there were a number of cases where it could be shown that plastics were superior to conventional materials.

Guided missiles offered a fertile field for the development of plastic structures, especially as these missiles had to be built as cheaply as possible. The Glenn Martin company, after considerable experience with plastics in the guided missile field, was now almost ready to take the development of this material a stage further by building a man-carrying structure.

One of the difficulties experienced with complicated plastic forms was the inspection of all parts of the structure to ensure that there were no flaws.

Dr. A. E. Lombard, Jr., F.I.Ae.S., Directorate of Research and Development, U.S.A.F., pointed out that a structure composed of bonded metal and plastic had a likeness in many respects to reinforced concrete. The application of plastics to reinforcing aluminium was an aspect of construction which should not be overlooked.

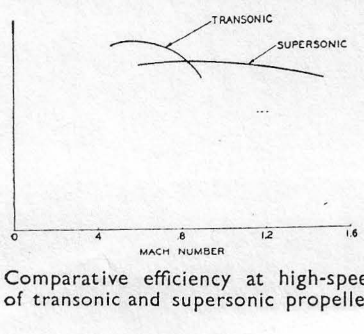
Mr. Gordon, commenting on the discussion, agreed that there was an essential slowness in the whole development of plastic forms, part of which came from a reluctance to swing over to new materials. The trouble with talking about the subject was that it was liable to lead to all sorts of fascinating "garden paths."

A plastic structure such as a wing, for example, would suffer considerably from a fixed arrangement of the fibre direction because a wing gave an awkward set of load requirements. As to the use of other materials such as nylon and teflon employed in the U.S. they were satisfactory for employment in the manufacture of small parts. There were, however, fundamental snags from a structural point of view which sprang chiefly from their low E value.

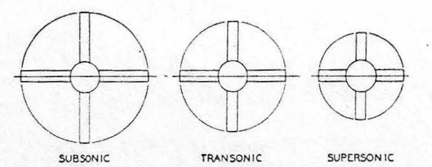
It did seem as if a combination of metal and plastic had a future but not necessarily aluminium. Steel might be better because of its cheapness.

High-speed Propellers

The concensus of opinion during the discussion on Mr. Brady's paper was that there appeared to be a strong case for the supersonic propeller. Each application, however, would have to be individually considered and the propeller should only be used where it showed a definite advantage. One contributor emphasized, however, that power plant plus fuel weight for a given task, was the deciding factor, and showed that, by the



Comparative efficiency at high-speed of transonic and supersonic propeller.



Relative size of various types of propellers for same power.

use of this yardstick, the supersonic propeller would only be worthwhile at relatively low altitudes and only then if high wing loadings were used.

Another contributor thought that a stronger case would have to be made for the propeller if it were to succeed in view of its inherent complexity and expense. The efficiency values given in the paper were questioned by one or two contributors, as was the lecturer's optimism that vibration and flutter problems would be overcome.

Questions were asked, such as, what type of blade sections were advocated; whether or not sweepback might not be reconsidered for still higher speeds; if flapping blades were a practical proposition to overcome difficulties of 1 × P stresses. Other speakers asked what governing system had proved the most promising and what would be the effect of the slipstream on the aircraft drag at the high flight speed envisaged.

In his reply, which, unfortunately, had to be curtailed due to shortage of time, Mr. Brady succeeded not only in summarizing the discussion, but also in dealing with his critics. He agreed that each case for the supersonic propeller should be considered on its merits, but that there was at this moment a need for a general decision on future policy.

He thought sweepback might have to be reconsidered, but that the most promising solution to the problem seemed, at the moment, to consist of a conventional-sectioned straight-bladed propeller made as thin as possible. He agreed that the application of reheat to the propeller-turbine might further enhance the case for the propeller.

The efficiency values given in the paper were, he thought, reasonable, but were, of course, free air efficiencies—the propulsive values being about 8 per cent. lower. He was of the opinion that the present method of using an r.p.m. sensitive governor held the most promise for the supersonic propeller. He thought much work on the effect of the slipstream on aircraft drag would be required, but agreed the use of a pusher propeller might be the answer to this problem.