Palm

GAS-TURBINE DEVELOPMENT

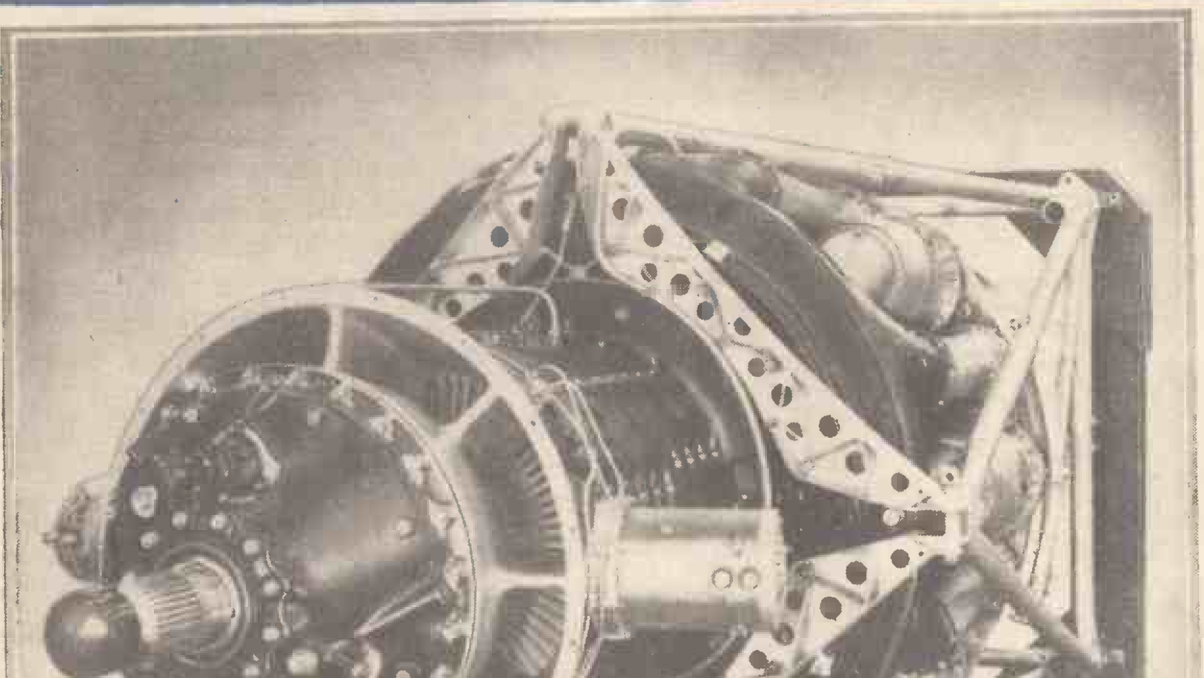
NEWNES

PRACTICAL MECHANICS

9d.

EDITOR: F. J. CAMM

JANUARY 1947



FRONT VIEW OF THE BRISTOL THESEUS GAS-TURBINE (See page 116)

Rocket Propulsion

Problems of High-speed Flight : Research Aircraft

By K. W. GATLAND

(*Continued from page 89, December, 1946 issue.*)

IN the six previous articles, emphasis has been on the rocket-fighter and the possibilities of the simple ram-jet athodyd. There is still much to be related of the strictly military aspect, but in order to obtain a more complete idea of the problems which, in view of the close proximity of the sonic "barrier" to aircraft speeds, now face designers of fighters, it will be desirable to investigate the methods by which data is obtained to base the design of new types.

Prior to the advent of jet-propulsion, designers were little worried by compressibility. It is true that shock waves were occurring at local points on the aircraft, for instance, behind underslung radiators and at wing joints, but by careful streamlining most of the troubles were satisfactorily overcome.

The position to-day is far more perplexing. In the past it has always been the power plant that has lagged behind, and, very largely, it was the structural designer to whom credit was due in improving performance of aircraft. Now, the case is completely reversed. No longer has the airframe designer to wait patiently for the engine manufacturer to coax a few more horsepower out of his already highly tuned product.

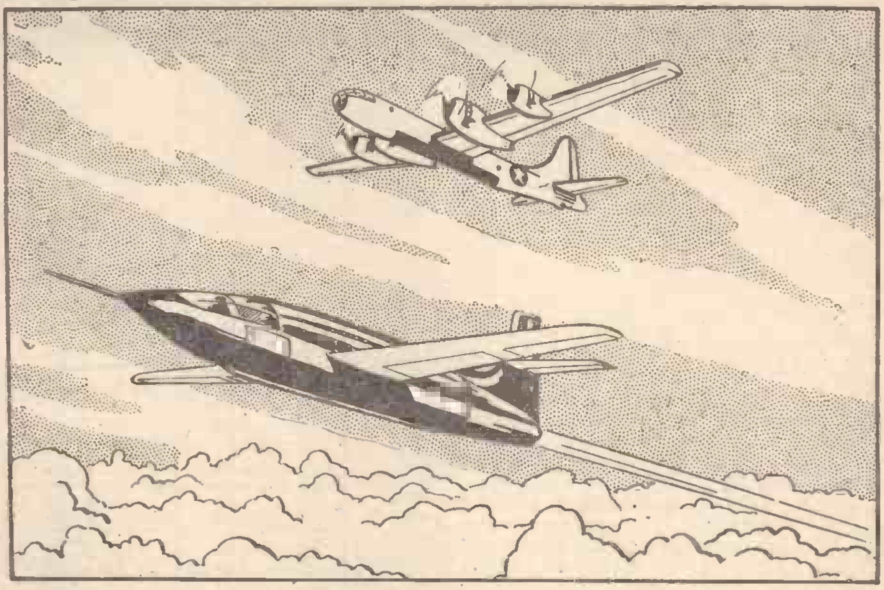


Fig. 87.—An impression of the Bell XS—1 after its release from a specially modified B.29. In forthcoming tests it is hoped to attain speeds in excess of sound and to fly at over 15 miles' altitude.

It is a fact that many jet and rocket engines now in production have quite considerable *reserves of power* which literally dare not be used because structures and controls are not yet ready to withstand such great stresses as would be imposed at anything approaching full throttle. So rapid is the rate of engine progress that aeroplanes in project a year or two ago and now approaching production stages will, in the light of new design technique, soon be ready for the scrap heap. Witness the cancellation by the Air Ministry of the Miles M.52 contract.

Dangers of Compressibility Shock

The dangers of flight near the sonic region were made only too clear in the tragedy which overtook Geoffrey de Havilland while testing the D.H.108 tailless research aeroplane. An explosion in the 3,500 h.p. "Goblin" engine was the popular theory for the mishap, but this was soon discounted by de Havilland technicians. The more likely explanation is that the machine was flying at a speed approaching sound values and compressibility caused its break-up, possibly upon encountering an air-pocket. The vibrations set up in the airframe under such conditions would have been considerable.

What then, one may ask, is the best shape for such high-speed aircraft? The answer to this question is open to argument, but high in consideration is the true "flying wing," for in this form the weight could be spread more uniformly over the span. The cantilever wing and tailplane are the most vulnerable in orthodox aircraft because the air-flow is always tending to lever them from the fuselage, and therefore a self-contained structure containing engines, fuel tanks and all other miscellaneous equipment evenly distributed across a single expanse of wing would be far less likely to receive a mortal blow as the result of compressibility. The D.M.2, reviewed in last month's article, is an excellent example of this type.

Higher flying speeds thus introduce a problem of great magnitude—the risk of "flutter." Whereas at moderate foward speeds the air always has a damping effect and causes any vibration (started perhaps by a gust or a sudden movement of the controls) to die out rapidly, the opposite is often the case when travelling at speeds upwards of 500 m.p.h. The damping qualities of the air may disappear or, worse still, actually contribute to *building up* the vibrations with increasing amplitude, when the beats can then become so violent that fracture of the structure follows within a very short time. It is, therefore, obvious that the aircraft which go out to pierce the sonic "barrier" (about 760 m.p.h. at sea level) will have involved some knotty problems for the design and stress technicians who conceived them.

The structural problem, however, is by no means the designer's only headache. His efforts are required to perfect new control systems, both to maintain stability and permit manœuvres at high speeds, and yet enable safe flying in the low speed register.

At present there seems no alternative other than to produce "compromise aircraft," which means that form (exterior) efficiency must always be impaired by the need for a reasonably moderate landing approach. In any event, there does not appear to be a great future for aircraft which fall out of the sky at 170 m.p.h., as the Miles M.52 supersonic research aeroplane was intended to do.

Flying Wings and Supporting Jets?

To satisfy both structural and aerodynamical problems at high speeds, the flying wing layout then emerges as the logical development. Small wing area, knife-edge sections, acute sweep-back—these are the more obvious requirements for trans-sonic and supersonic flight, making the aeroplane efficient in reducing drag at high speeds but, alas, poor in qualities of lift at the time of landing. An ultimate solution may be found in the use of turbo-jets balanced by three-axis gyros to provide an upward or supporting thrust, permitting the aircraft to hover and descend slowly in the same manner as a helicopter; but this is mere speculation as yet. However, there does not appear to be an alternative answer, unless one considers folding or partly retracting wings; but few to-day would suggest that either of these schemes was practicable.

There is little doubt that as flight loads rise and wing areas diminish—as it seems logical to expect in the attainment of increasing speed—landing will present one of the pilot's greatest hazards.

Fig. 88.—Small athodyd ram-jets have been fitted experimentally to the Bell X—83, development of the "Airacomet."

Friction

The difficulties that manifest themselves when flight in or above the speed-of-sound range is considered are truly enormous. Not only has the structure to be of herculean strength and the control system such as to permit safe flying at all speeds but *friction* also gives rise to concern.

The heat generated by air buffeting may be as much as 400 degrees at 1,500 m.p.h., and so it is reasonably safe to say that pilots and crews will need refrigeration. A solution to some degree, however, is found in flight at great heights. At 80,000 feet, for instance, the outside temperature will be 67 degrees below zero and thus, in order to eliminate as much bulky refrigeration machinery as possible, forthcoming test flights are being planned to take place between 60,000 and 80,000 feet up. Eventually, it is reasonable to expect that all flights by long-distance jet-driven aircraft will be in the stratosphere, for not only does the heating problem find partial solution but drag reduces with altitude. At 60,000 feet the drag for a given speed would be approximately one-fourteenth as much as it would be at sea-level, or, in other terms, only one-fourteenth of the power would be required for propulsion. A climb to 80,000 feet and the resistance becomes one-twentieth that at sea-level, one-half that at 60,000 feet.

This would be an encouraging prospect but for the fact that the efficiency curve for the jet-engine begins to fall off around the 60,000 feet mark. The turbo-jet and the athodyd require vast volumes of air to operate, and again the compromise path is the only one left open. Whether the rocket engine, which—at this stage it is surely unnecessary to stress—operates independent of atmosphere, will eventually rectify this state of affairs is yet to be seen, but its voracious appetite in fuel would seem to limit its application in all normal conceptions of commercial aircraft. A ceiling of 55,000 feet, at least, should give a reasonable operating efficiency for high-speed turbo-jet and athodyd-driven airliners, and this is some consolation.

Definitions

In this vast study that is opening up in flight at ballistic velocities, it is inevitable that new terms will creep in to augment the already extensive aeronautical vocabulary. Already, aerodynamisists have presented us with several additions, and it will be as well to explain some of them. *Mach number*, for instance, is the relation of flight speed to the speed of sound, M = 1, and hence, *Machometer*, an instrument recording the relation of flight speed to the speed of sound. More familiar are the speed zone terms: *subsonic*, less-than-sound; *trans-sonic*, range of speed lying between M = 0.8 and M = 1.2; *supersonic*, faster-than-sound; and then, *compressibility*, phenomenon occurring as flying speed approaches sound values, causing sudden change in density and pressure with accompanying increase in drag and decrease in lift. *Shock waves* are a wave formation—the outward (and under certain conditions visible) sign of compressibility.

Having summarised briefly some of the problems related to flight at trans-sonic and supersonic speeds, it is now possible to investigate matters a trifle more fully in the light of work that is proceeding with high-speed research aircraft, both manned and unmanned.

Undoubtedly the most significant of these special types is the Bell XS-1, a machine said to be capable of 1,500 m.p.h. at 80,000 feet altitude. Some confusion had arisen in early descriptions of this project, for it was originally said to be athodyd-driven and to incorporate a rocket booster, but a recent Press release by the manufacturers has now clarified matters and an impression of the machine is given in Fig. 87.

The XS-1 has a strong outward resemblance to the Miles M.52 supersonic research aircraft (work on which was abandoned last February), but its power derives from four bi-fuel rocket engines and not from turbo-jets or athodyd ram-jets. A possible explanation is that confusion arose from the fitment of athodyd units at the wing tips of a Bell XP-83, development of the "Airacomet" (see Fig. 88), which, incidentally, crashed during a recent test flight.

The fuselage is packed tight with fuel tanks, and the pilot, clad in a pressure suit, fits snugly into the bullet-shaped nose, which had actually been designed to suit the dimensions of Jack Woolams, the firm's test pilot. Short-span thin-section wings and tail-assembly are also the vogue.

The machine had already completed satisfactory glide tests, having been taken up to about 30,000 feet beneath a specially equipped B-29 and released. Woolams was loud in his praises of its flying qualities, and so successful in fact were considered the preliminary tests that preparations were in hand for the first flight under power.

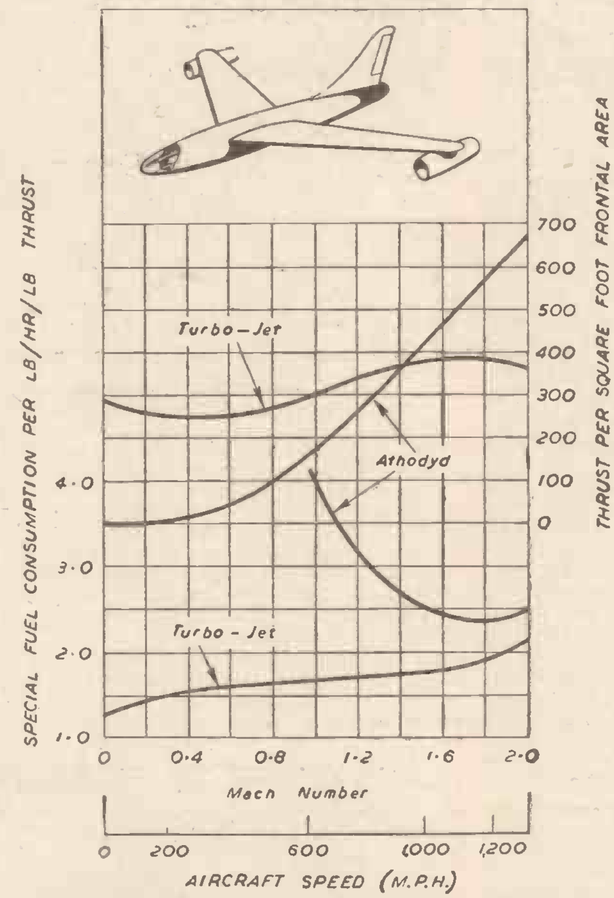


Fig. 89.—A graph prepared from figures given by Dr. S. G. Hooker, of Rolls-Royce, Ltd., comparing a high-output turbo-jet with an athodyd ram-jet at 40,000ft. altitude. In the inset, the author illustrates a logical development, a tailless fighter with athodyd units at the wing-tips, and a booster rocket in the tail fuselage.

Everything went according to plan—until the tragic news was received that Woolams, having entered a special P-63 in the Bentix Trophy Race, had crashed to his death.

Now, with a new pilot at the controls, a further series of glide tests will be necessary, and it may be months before thoughts can again be directed toward powered testing.

When, however, the XS-1 eventually drops away from its parent B-29 and for the first time shoots away under power, it will not be just a "do-or-die" attempt to out-fly sound. The beginning of another testing phase, doubtless even more extensive than the previous glide flights, will have begun, and only when the machine has performed satisfactorily at moderate subsonic speeds and the pilot has gained some experience of flight at really great altitudes will it be reasonable to expect the throttle to be pushed into "maximum boost."

The voracious consumption of its motors will limit the duration under power to within a few minutes, but, nevertheless, having been released at a height of about 35,000 feet, the pilot is expected to climb to between 70,000 and 80,000 feet before making his bid for maximum speed.

The XS-1 has been constructed by the Bell Aircraft Corporation with co-operation from the Material Command of the Army Air Forces at Wright Field and the National Advisory Committee for Aeronautics. The four bi-fuel rocket engines were built by the Reaction Motors, Incorporated, a firm inaugurated during the war and which was responsible for many of the power units of American guided missiles.

A recent disclosure suggests that the new unit develops 6,000lb. thrust at sea-level and that its development occupied the firm in research for four years. It is more powerful than any of the Walter bi-fuel engines and has a far greater operating efficiency.

The unit may be presumed to be a developed version of the 1500N4C, weighing 210lb., and consisting of four cylinders, each capable of delivering 1,500lb. thrust. Each cylinder contains an igniter, combustion chamber and expansion nozzle.

What fuel the machine carries has not yet been made known, but it is probably an alcohol compound with liquid oxygen.

Low Speed Research with Supersonic Aerofoils

An attempt to obtain reasonable lifting characteristics in supersonic section wings at low forward speeds is seen in the tests of a full-scale wing and tailplane of the projected M-52 on a Miles M.3B "Gillette" Falcon, basically a Falcon Six four-seat monoplane powered by a D.H. Gipsy Six Series II in-line engine.

The fuselage of the developed Falcon is the sole link with the commercial version, and even the fully trousered undercarriage, originally rooted in the wings, has been replaced by a strutted chassis fixed around the cabin under-fairing. This has elminated any possibility of turbulence in the air flowing over the "knife-edge" bi-convex wings, which, incidentally, were of all-wooden construction and high-gloss finished.

By the time all modifications had been completed the Falcon was a single-seater, with the cockpit fitted out with a formidable array of special recording instruments and two additional fuel tanks. Flight tests were commenced in August, 1944, and when the machine was satisfactorily trimmed an M.52-type tailplane with independent elevators was fitted. This arrangement, however, was eventually displaced by a special "all-moving" tailplane.

The comparative figures for the two versions are given below, with the Falcon "Gillette" data quoted in parentheses for easy reference: Dimensions: Length, 25ft. (25ft.); span, 35ft. (29ft.); height, 6ft. 6in. (7ft. 9in.);

wing area, 181 sq. ft. (160 sq. ft.); weights: empty, 1,550lb. (1,730lb.); loaded, 2,525lb. (2,500lb.); performance (speeds): maximum, 180 m.p.h. (164 m.p.h.); landing, 40 m.p.h. (61 m.p.h.).

Work on this enterprising little research aeroplane was abandoned when the contract for the M.52 was cancelled. The data obtained from its numerous flights, however, must have proved of immense value in designing the parent machine, and in view of the vast speeds expected of future aircraft it is obvious that more and more attention will need to be paid to research toward ensuring safety in flight at low speeds.

Control Problems

Then there is the problem of maintaining control at *high* speeds. In orthodox aircraft, the first effects of compressibility manifest themselves at about 500 m.p.h.; controls stiffen and become sluggish, and as speed increases still further, the pilot has great difficulty in manœuvring his aircraft.

Several possibilities have been suggested, and one of the most promising is illustrated in the fitment of "drag rudders" at the tips of the new XP-79B flying-wing fighter. These consist of small open ducts, the area of which can be moderated independently. To cause a change in direction to port, it is necessary only to restrict the flow through the port duct. The drag built up on that side then naturally results in the machine turning.

A similar scheme is the fitment of small rocket motors at the tips, but this would be rather wasteful in fuel.

In future high-speed aircraft, especially in fighter types, there is little doubt that athodyd ram-jets will occupy the space at the wing tip, with turbo-jets or rocket units mounted inboard, either in the fuselage or at the wing roots. It should then not prove too difficult a matter to incorporate the principle of the "drag rudder" in the athodyd motor. A device to vary the area of the intake would satisfy the problem admirably.

The light weight of the athodyd makes it ideal for installation at the wing tip (see Fig. 89), and, indeed, this is the logical step to expect from the successful carriage of "overload" fuel tanks and bombs in this manner, an arrangement first tried on the "Shooting Star" and which is now common practice in the U.S. Wind tunnel tests have shown it to be a most efficient location owing to the inevitable formation of vortex. A streamlined protuberance at the tips, therefore, involves no great increase in drag, and with athodyds the form efficiency may be expected actually to benefit.

(To be continued.)

Science Notes

By Prof. A. M. LOW

IT will be interesting when the cinema gives us a reasonable imitation of stereoscopy. Perfect colour, extreme speed, with probably a few smells thrown in. Some of the films that I see are a terrible waste of our celluloid that ought to be devoted to discovery. Not so long ago there was a great discussion as to how a fly landed on a ceiling. Did it fly upside-down, or did it do a somersault at the last moment? High-speed pictures have soon illustrated that these charming insects either make a half-loop or half-roll, as our pilots say, a few inches from the ceiling, thus making a perfectly good six-point landing. Yes, they have six legs. For many years Plato gave the number as four, which was considered to be so logical that no one ever troubled to look. That probably was an early instance of the bad method of learning by alleged logic instead of by the best of all systems—that of scientific observation. The fly, I should mention, has free feet, which can easily hold on to the small hills and dales of a whitewashed surface. Under a microscope, a ceiling looks like the mountains on the moon, a razor edge like a saw, and the most beautiful skin in the world like a rather ancient toad. As I explained before, everything is relative, and beauty is in the eye of the beholder. I want to make it clear that the fly knows that also.

Are You Wrong?

IT is extraordinary that popular errors should last so long. Lightning is not attracted by your penknife on the table. A few miles of air are much more important. But that is the interesting point. There is nearly always some slight truth in a fallacy. To suppose that a small piece of steel could make any difference to a lightning flash is ridiculous, but it is true that the lightning would prefer to pass through steel rather than air. The sun does not put out the fire, but makes it more difficult for you to see whether the little flame is there, and prevents your discovering so quickly that the wretched thing has gone out. Pokers leant against a grate do not increase the draught, but I suppose they would do so to an extent that could hardly be measured by the most sensitive instrument. I often think that some of the most laughed-at sayings of our grandmothers were very true. At one time it was common practice in the West of England to scrape the mould from a copper kettle which had been left in a dark cellar and to use this mould for curing septic wounds. Humiliatingly like penicillin, is it not? We all know that bee venom is an important medicament, but I am sure that doctors who had said so forty years ago would have been condemned as quacks. "The hair of the dog that bit you" is a very common phrase, yet to dissolve the hair of a cat and to inject the resultant liquid has proved very useful in the diagnosis of asthma. Many sufferers are greatly affected by the presence of a cat. I am no believer in witch doctors, but when they used to stick pins into a wax image it is not impossible that this was merely a mascot which helped them to concentrate thought, and that the result was mildly inimical to their enemy. No doubt a far more common case was the surreptitious dose of poison, but I would not like to state that the witches, on the other hand, were quite all nonsense. One should be very careful before stating a fact without adding: "Or so it seems to me."

Don't Hurt the Snail

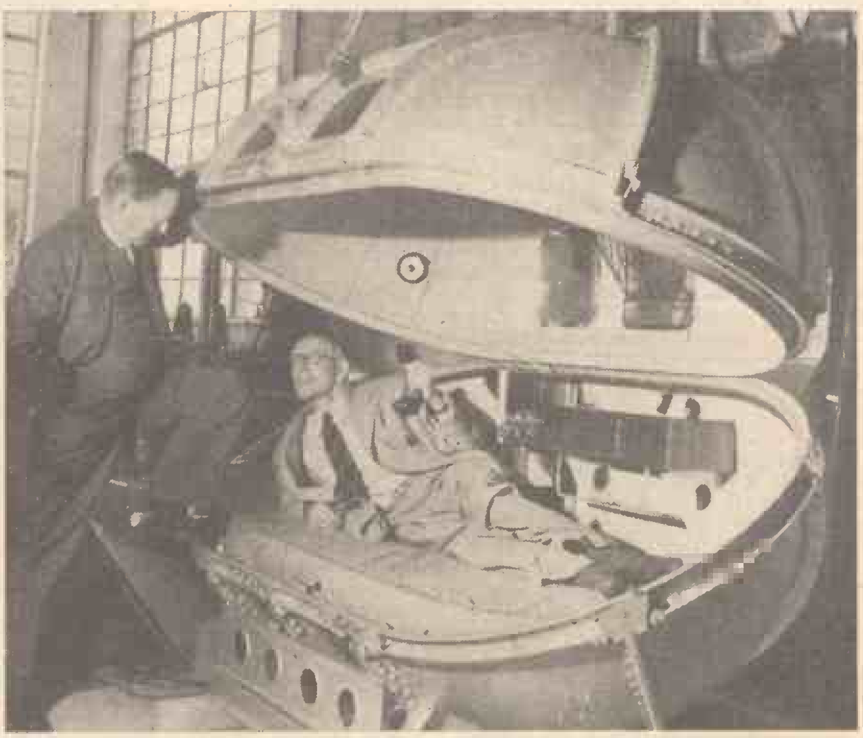
NATURE designed her products so much better than any human being could hope to emulate. Nature also knows all about speed. A jet of water travelling fast could knock a hole in you; travelling slowly it is fars ofter than butter.

Put a razor blade edge upwards and a snail in front of it. The snail will climb over that blade using its own lubrication so that tiny particles of mucous substances act as roller bearings. It moves so slowly that it will safely traverse a bridge which even a fakir might find very troublesome.

Child's Play

HERE is a simple problem to which any child should be able to give an answer; yet it is one which can puzzle all of us very easily.

When a fast bowler is practising spinning a ball can the ball progress faster after its first bounce than the speed at which it is originally thrown? I should say "yes," because he might throw it very slowly, but with so high a speed of rotation that upon contact with the ground its peripheral velocity would be far higher than the rate of its forward motion. So it will jump forward or sideways.



This Easter-egg-shaped pressure chamber was specially designed for Mr. Winston Churchill when his doctors had warned him of the danger of his flying at a greater height than 8,000 feet. The cabin is fitted with a comfortable couch, ash trays, cupboard, bookshelf and telephone.