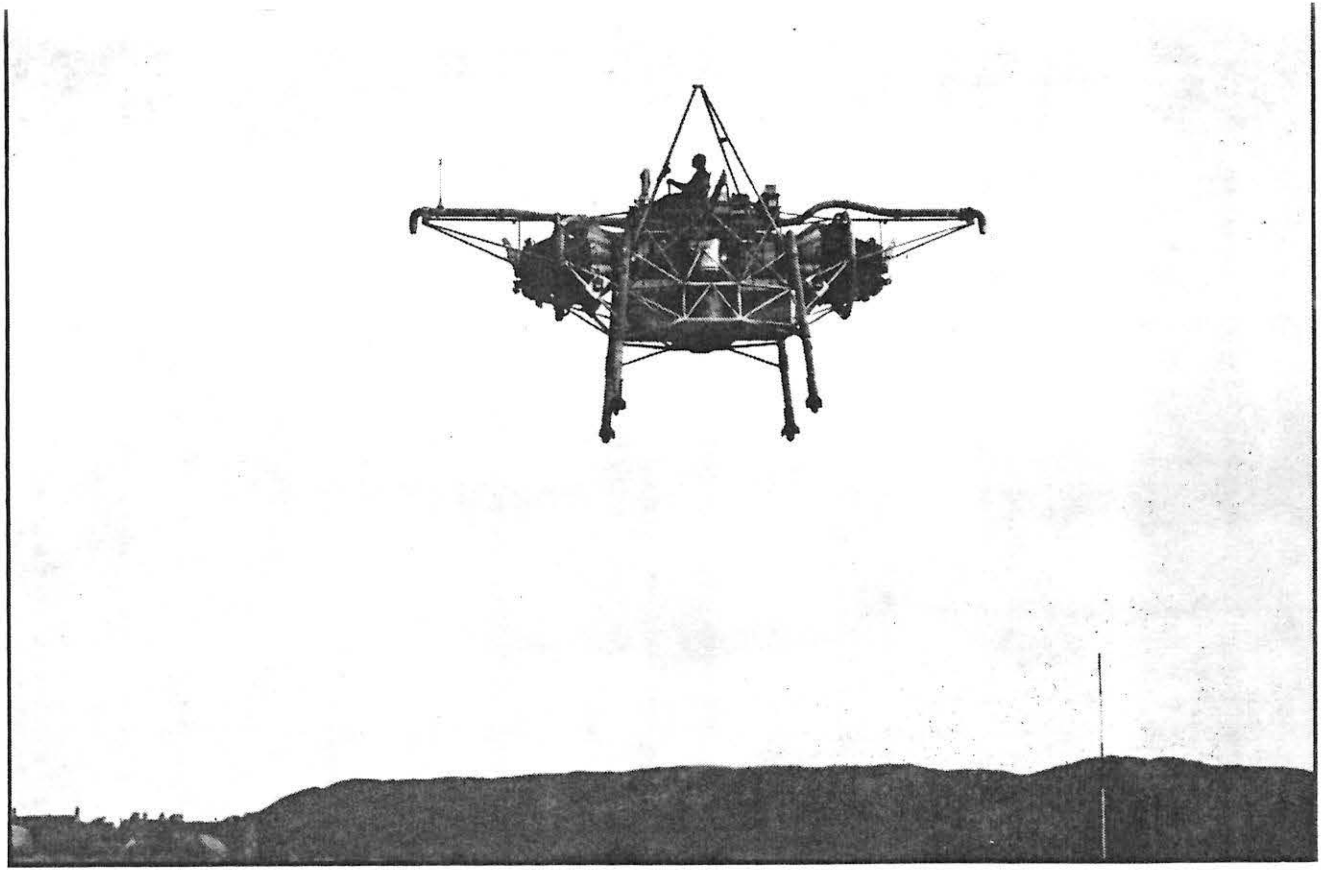


The Rolls-Royce "Flying Bedstead" can be regarded as a simple example of "airframe" and powerplant integration.

The Powerplant Problem

By GROUP CAPTAIN H. R. FOOTTIT

"It seems essential that airplane designers and engine designers get together early in the game. . . ."

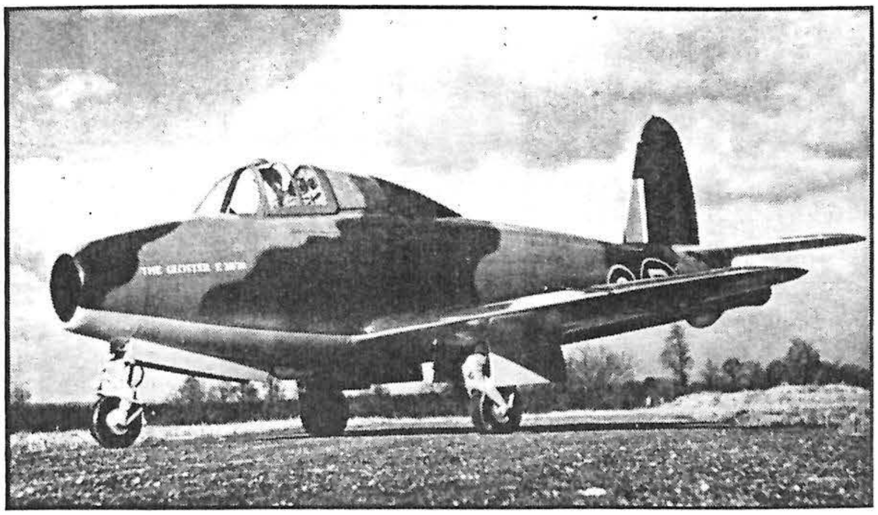
—Fredric Flader.

IT LOOKED like something right off the front cover of *Amazing Science Stories*. I first saw it when I was over in England a few years ago. It was sitting high and mighty in the center of the Rolls-Royce hangar, with a ring of ordinary airplanes around it. The open pilot's seat looked plain silly perched on the top of two longitudinally opposed Nene jet engines which were surrounded by an open framework of steel tubing. The whole contraption rested on four legs with small metal castors. It was no wonder that the Press promptly dubbed it the "Flying Bedstead" when they first heard about it in September 1954. Then, as its weird characteristic of direct jet lift hit the front page, this wingless wonder immediately caught the public eye. But it did a good job of useful work.

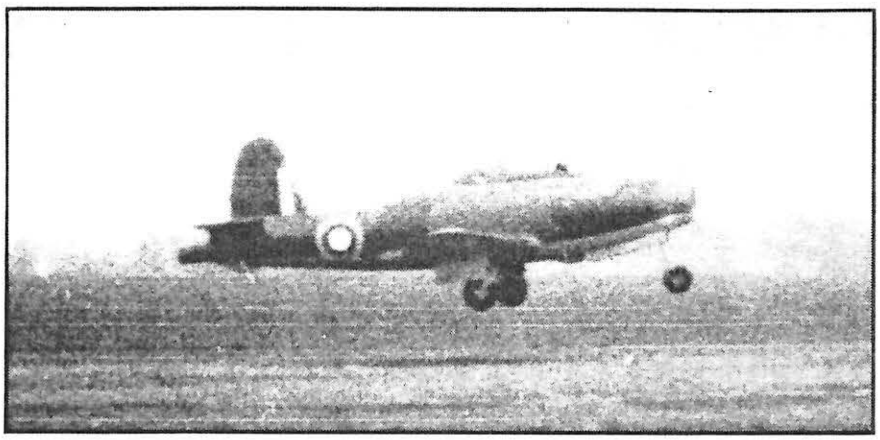
This, of course, was the famous Rolls-Royce flying test bed. It weighed 8,000 lb., and with a total of 10,000 lb., vertical thrust from the two Nenes, the pilot could lift the odd contraption 15 to 25 feet above the big concrete slab in front of the hangar. By dancing back and forth, in any direction, he could try out Rolls' latest ideas in vertical take-off control mechanisms. It wasn't long after that A. G. Elliott of the company was predicting that future airplanes would use this direct lift principle by installing special engines in the airframe for that purpose alone. Forward propulsion would be taken care of by another set of engines. He even forecast that the airplane should be a "narrow delta wing" type.

Away from Home: There is no doubt that the "Flying Bedstead" was a useful experiment. But when we look back over the horizon of history, it's somewhat surprising to find an engine manufacturer dabbling in flying machines and confidently charting the future. We don't blame him of course. But this is an age of blaring publicity on office systems, rail systems, airline systems and weapon systems. Consequently you might think that we would now consider a powerplant as part of a a complete aircraft "system" and a joint engine and airplane manufacturer's venture. Unfortunately we don't. We blithely build integrated airborne electronic systems and integrated instrument systems, but we still don't build integrated powerplant systems. The powerplant is still a separate entity that we carefully separate out for individual installation in the airframe.

In the mid 1940's Hall Hibbard, Vice-President, Engineering, for Lockheed Aircraft, was pensively predicting that in ten years all airplanes, from Piper Cubs to supersonic fighters, would be turbine powered with either a turboprop or a turbojet engine. He was obviously off on his time scale. But his words are true. The piston powerplant is dead. And with the coming of the turbine we've got to forget about separate piston powerplant packages, and start doing far more tailoring of the airplane to the engine and vice versa. Further in the future we may even see the engine integrated with the airframe. So the sooner we get the engine designers in with the airplane designers, from the



The Gloster Whittle E28/39 pioneer jet aircraft represented an integration of airframe and powerplant. Powered by one of the first Whittle turbojet engines, the E28/39 was the forerunner of the thousands of jet powered aircraft that are flying in the world today. The picture below shows the E28/39 taking off on one of its early flights. First flight actually took place May 15, 1941.



first line on paper to the finished product, the sooner we'll produce the better airplanes of tomorrow. After 50 years of piston engines and packaged powerplant thinking, this is no easy feat. To bring it about is one of the pressing problems of today. This is the power plant problem.

In my experience in Canada, the U.S. and the U.K., there is a gaping gulf between engine companies and airplane companies. True, they get together on installation problems during the early days of a project. But as it progresses they tend to plan and produce apart. Even when the airplane manufacturer and the engine manufacturer are under the same corporate roof, there seems to be more difficulty than when each are independent companies. But the day is dawning when all this must change. And the catalyst that will force the fusion of the engine designer with the airframe designer, in the future, will be the wide spread use of turbine engines.

Getting Complicated: I listened to a heated discussion on engine design, the other night, between F. H. Keast, Deputy Chief Engineer of Orenda Engines Ltd., B. A. Avery, Chief Design Engineer at Orenda, and W. Hurley, Assistant to the President of Avro Aircraft. The discussion centered around getting the best rotational speed to give the lightest weight jet engine. It all got rather complicated. But it reminded me of Burt Avery's statement in a talk he gave some time ago. Said he, "The turbojet engine began existence as quite a simple piece of equipment, but through the years it has evolved into a more and more complex machine." Yet oddly enough when these simple jet engines were first introduced to the Western World we went out of our way to match one engine to one airframe.

Remember the Gloster E28/39 aircraft? This squat little single seater was first wheeled out from Gloster's hangar in England in May, 1941. It was the first jet engined airplane in the U.K. and it attracted the attention of all the local residents with its strange intake in the fuselage nose, the lack of a propeller, and the stubby landing gear. Behind the pilot was the big wartime secret—a Whittle jet engine.

The engine designers and the airframe designers had worked closely together to turn out this special test vehicle. It was nothing more than this. But it produced big results. From this grew the famed Meteor jet fighter which first flew from Gloster's airport in 1943, and did some sterling service during the following year chasing Hitler's V-1 buzz bombs as they winged their way to Target London.

Growing Apart: As turbines have become more complex, however, we seem to have drifted back to the piston era separation of the engine and the airframe. In fact, it has been only quite recently that there have been rumblings in the technical press about mating a particular jet to a particular supersonic fighter in the design stage to achieve an optimization of performance. But the future landscape is much broader than this as the pin points from the past now indicate.

In the early 1930's, for example, we have one of the earlier inklings of this new trend. It happened on a small airport, Hadley Field, New Jersey, in 1934. A U.S. research report had recently been written about the high lifts that could be generated by blowing or sucking air from over the wings. This was boundary layer control as it was called. The airplane on the flight line at Hadley Field had been converted to take advantage of this new theory.

It was a low wing, side-by-side, two seater, with a piston powerplant in the nose. Inside the fuselage was a separate motorcycle engine driving an air pump. Along each wing there was a long, spanwise slot. Through this slot the motorcycle engine pumped extra air over the wings. A similar scheme took care of the tail. The whole contraption was invented by a German immigrant and it cost him $4,000 to put together.

Theory Good: Unfortunately it was too crude to produce good results and actually never flown with the boundary layer control operating. But the theoretical gains from such a system still nagged aircraft designers. Even the U.S. Army Air Force got interested. In 1944 they arranged for the conversion of one of their piston-engined liaison airplanes. They had a suction mechanism installed which drew air from the wing surface through two spanwise slots. This experimental craft was redesigned to follow the ideas of Professor Stalker, formerly of the University of Michigan, and one of the pioneers in boundary layer control theory. But the experiment ended in disaster. The airplane crashed and the pilot was killed before the system could be tried out. The Army Air Force cancelled the project.

These are only two of the many experiments that were conducted to try and control the air immediately adjacent to the wing. They were all done with airplanes using piston powerplants. The engines were heavy, and the air blowing or sucking system had to include another heavy engine for pumping. No wonder, then, that the results were never startling. But along came the light turbine powerplant and the whole picture changed. Moreover, the gas turbine has a big air pump built right into it—the engine compressor, which raises the pressure of the air before it goes into the combustion cans. Here was a ready made powerplant for true boundary layer control. All there was to do was to tap the engine compressor and send the air out over the wings through spanwise slots.

Unfortunately, it's not as simple as that. The gas turbine's compressor, with its mated turbine wheel, can only be tapped for so much air. If you tap off more than the design maximum the combustion cans will starve. Consequently if we are to take advantage of the engine's capacity to supply pressurized air for such devices as wing slots, we must match the turbine power plant to the particular airframe. Since wings come in all shapes and sizes, this makes it almost mandatory that the engine man knows, from the first blueprint, exactly what airframe his engine is mated to. He will then know how to design the compressor so it can supply just the right amount of air to combustion cans and wing slots. This will be a real integration of airframe and engine, and it will have to start in the earliest design phase.

Universal Application: Those principles will apply, in the future, on all sizes of aircraft from the two place light trainer to the large intercontinental transport. The gains in performance will be fantastic. The U.S. research agency, the National Advisory Committee for Aeronautics, has done

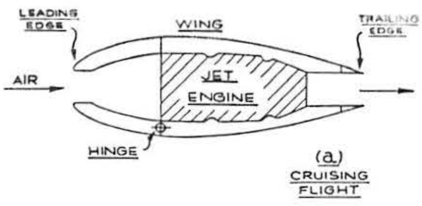


FIGURE 1
PROPULSIVE WING

some performance estimating on a flap with this boundary layer control. On a 300,000 lb. jet transport, (about the size of the Douglas DC-8 and Boeing 707 jet liners) they were able to reduce the take-off speed and the landing speed 35 mph. At the same time the take off run was cut from 8500 feet to 4500 feet, and the landing distance from 7000 feet to 3700 feet. These are phenomenal improvements in performance. And these come from a flap with boundary layer control. Even more could be achieved with boundary layer control on a complete wing.

This particular NACA scheme happened to use the exhaust from the transport's turbojet engines. However, whether we use exhaust or compressor air, there is certain to be a closer coordination between airframe and engine if we are to achieve these big performance pay-offs. I asked J. C. M. Frost, Chief Designer for Avro Aircraft's Special Products Division, about the far future of our airframe and engine combinations. John Frost, incidentally, supervised the design of the early CF-100 jet fighter. Since then he has been directing the USAF's design study with Avro, which, as the USAF have said, may result in a disc shaped airplane. He is therefore used to pondering the future, and is probably one of Canada's most advanced thinkers in the overall art and science of aeronautics.

Frost's detailed analysis of where we are now, and where we're going, in the airliner business, leads him to support the podded engine installation for transports for some time to come. But as he points out, "It is interesting to

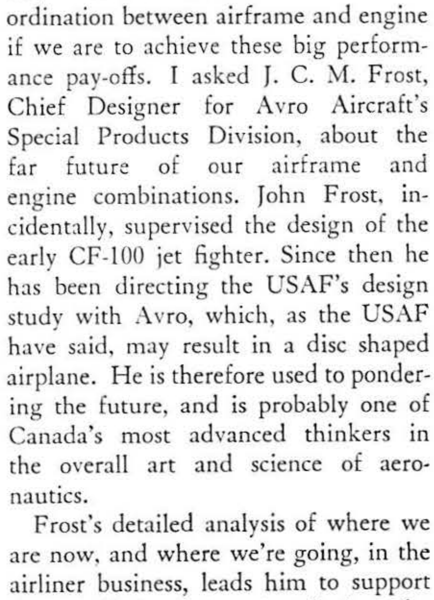


FIGURE 2
PROPULSIVE WING

note that engines usually start life by being designed to go into fighters, later graduate to bombers, and then to transports." To peer into the far future, then, we've got to decide what will happen first in the fighter field and then we'll see what will come about at a later date in bomber, trainer and transport airplanes.

Made for Each Other: According to Frost if we're really going to take big steps forward, we've got to take some drastic action and "make the engine take the shape of the airframe, or vice versa." For example, a future fighter could have the best aerodynamic shape unhindered by bulges and curves that are often necessary now because of the fixed engine shape. Frost's engine would be fitted piecemeal into any odd corners of the airframe. He got some of this idea from a sturdy he made of the CF-100 fighter. From this he brought out the term "aircraft volumetric efficiency." While this sounds rather complicated it's quite simple. It's just a percentage figure for the space inside the airframe that is usefully employed.

As Frost explains: "Some time ago I made a study of the volumetric efficiency of the CF-100, and I was surprised to find that the aircraft was less than 50% efficient. By this I mean that there were large spaces in the rear fuselage and in the nacelles around the jet pipes, which are not used for anything. All the outer wings beyond the fuel tanks—the ailerons, the flaps, the empennage—are empty. This figure of 50% volumetric efficiency I would expect is fairly general for most aircraft of this type." All this, of course, means added weight and more drag, so that a larger engine is needed to drive all this useless space through the air.

What John Frost wants to do is to make the airframe to the best possible, minimum size, aerodynamic shape. Then he will install the engine and equipment into the interior so all the space is filled. If he could arrange it so there are no vacant cavities he'd achieve his figure of 100% volumetric efficiency. As he says, "If large advances are to be made, something radical should take place in the form of this engine-airframe integration. If an engine could be designed to fit into these empty places, then the overall efficiency of the vehicle would be enormously improved. This would

(Continued on page 74)

temperatures of —30° F. Both the airplane and the equipment have functioned normally under these conditions. Heating and pressurization units have performed according to specifications. The airplane has flown with ground temperatures near zero with engines starting immediately without the use of external power sources.

On IGY Liaison

A Vancouver officer, Major Mark Holmes, of the Royal Canadian Aritillery, is serving as liaison officer at Fort Churchill, Man., with U.S. troops and scientists who will carry out a complicated series of rocket tests at the northern base. The tests are designed to explore the upper atmosphere of the Arctic as part of the International Geophysical Year.

As did the majority of the men handling the rocket tests, Major Holmes trained at the White Sands Proving Grounds in New Mexico before taking over his present duties at Churchill. The U.S. rocket site at Churchill was constructed at the invitation of the Canadian government because of its accessibility by rail, air and water, and its location in the Arctic auroral belt.

LETTERS TO THE EDITOR

Civil Air Patrol

Sir:

On February 27, 1957, a nucleus of pilots and aircraft owners (civilian), held a meeting, at Civil Defence Headquarters in Winnipeg (following the second CD orientation lecture for pilots), and formed the "Volunteer Air Patrol" (Manitoba), of which I . . . was elected provincial head.

The function of this air group is to assist Civil Defence, the RCAF, the Red Cross, and other organizations, in searches, etc., and emergencies occuring during peace and war time. This group (the VAP), will be, and is a definite asset to Canada, as is the CAP to the United States.

We hope to get a grant from the Civil Defence, to help out on a charter, uniforms, crests, wings, etc., so that we may expand and serve Canada to the utmost of our ability.

The Volunteer Air Patrol has had quite a bit of advertising in Winnipeg newspapers, TV and radio, and a great deal of interest is being shown in its formation, to date.

Our membership cards are being printed now ($3.00 a year), and crests and wings are on the way. The VAP emblem is a yellow background and outline of the province of Manitoba, with the words "Volunteer Air Patrol", a small aircraft and border in black.

Civil Defence, the RCAF, the Red Cross and Flying Clubs across the Dominion have been notified in writing, of the formation of the Volunteer Air Patrol in Manitoba.

LOUIS McPHILLIPS

Winnipeg

POWERPLANT PROBLEM

(Continued from page 33)

probably mean that airframe and engine structures would be common, which in addition, must constitute a definite weight saving."

Only Way: To carry through any such future project a single engine and airframe design team would be absolutely necessary. How else could you ensure the precise integration and strength of the combined structure? In fact, it would be impossible to do it any other way. While this is truly an advanced idea, I find that others have been looking at similar possibilities. In glancing through an old copy of the Canadian Aeronautical Journal I noticed an article by F. C. Phillips and K. Irbitis, Chief of Aerodynamics and Preliminary Design Engineer of Canadair, respectively. These two engineers were reviewing possible lift and thrust systems of their application to short take-off and vertical take-off airplanes. One of the schemes they considered was a "propulsive wing". This wing has an engine, or a series of engines built into it. In cruising flight the leading edge of the wing is the intake and the trailing edge the exhaust, as shown in Figure 1. In the take off and landing condition, the whole rear of the wing including the engine, tilts down to provide high lift as shown in Figure 2. As the authors point out in their conclusions, "In the short take off and landing category the possibility of the high-lift propulsive wing should be examined."

Leading aeronautical designers and engineers have generally agreed that the turbine powerplant—either turboprop or turbojet—will be the prime mover for the majority of our airplanes for decades to come. In the immediate future we'll undoubtedly see boundary layer control schemes come into existence. These will necessitate a close tie between the airframe and engine from the first drawing produced. In the far future we may see almost complete integration of the airframe and engine, as Frost has proposed. Or we may see partial integration along the lines of Phillip's and Irbitis' ideas. In either case we're going to have to weld the engine designer and the airframe designer into almost a single team. As yet we haven't succeeded in coming even close to this ideal. This is our power plant problem.

and this we must solve.

Ferdric Flader has suggested that the least we could do now is to bring them together "early in the game." But E. H. Heinemann, top engineer for Douglas, stresses the time aspect. In discussing the integration of engine designers with airframe designers he says, "The consideration of practical aspects during the design stage is most important, and it may actually short cut a large amount of detailed and meaningless analysis, as well as developmental work."

WEEKEND WARRIORS

(Continued from page 27)

one of the Canadian squadrons based there.

But even while Canada's citizen-fighter pilots are relearning their deadly contrail-trade, the same voices that were raised before are heard again. The same squadron leader is still standing at the bar, older now, but still repeating it. The tune is familiar. Though the words have changed a bit: "They'll never hack Sabres. Those bombs are too hot for part-time jet jockeys."

Unimpressed with carpers, the Auxiliary squadrons are going ahead with it. There is an increasing flow to the Auxiliaries of trained Sabre pilots who have completed their term in the Regular and are returning to Civilian Street. Strengthened by these men and re-equipped with an advanced type of airplane, the Warriors are proving that they can "hack it".

CF-100 SIMULATOR

(Continued from page 25)

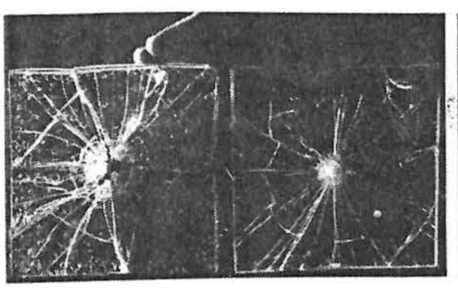
flight and weapons systems simulator is the first to be developed by an exclusively Canadian company. In accuracy of radar simulation, it is believed to be the finest in the world. According to a CAE spokesman, the United States Air Force "has expressed great interest in the integrated weapons system." As for the RCAF, the main advantage lies in the fact that the simulator provides special training in operational roles where training would naturally be limited.

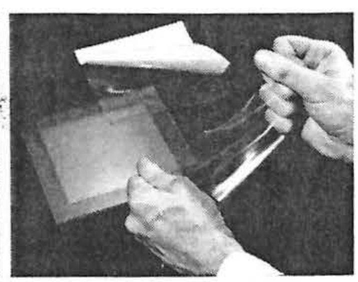
On February 12th, the first production model was turned over to the RCAF. This was the first installment of CAE's contract which calls for one prototype and 11 production models of the simulator. CAE has also recently received from Canadian Pacific Airlines, a $755,000 order for a DC-6B flight simulator.

BRITANNIA

(Continued from page 19)

The alternators have two three-phase outputs: one at 208 volts and the other supplying, at a lower voltage, 112 volt and 28 volt rectifiers. Although sharing a common magnetic circuit, which is excited and regulated by the 208 volt output, the two windings are electrically independent. A synchronous booster on the same shaft, with its wind-





RUBBER GLASS: New type of Dow Corning safety glass for supersonic aircraft, based on silicone rubber, stays clear and shatterproof at temperatures of 350°F. Above, ordinary safety glass bubbles and oozes out the edges (left); top right, illustrates elasticity and strength of Silastic Type K interlayer; right, panel of new Dow Corning glass held before pilot's face shows outstanding clarity feature.