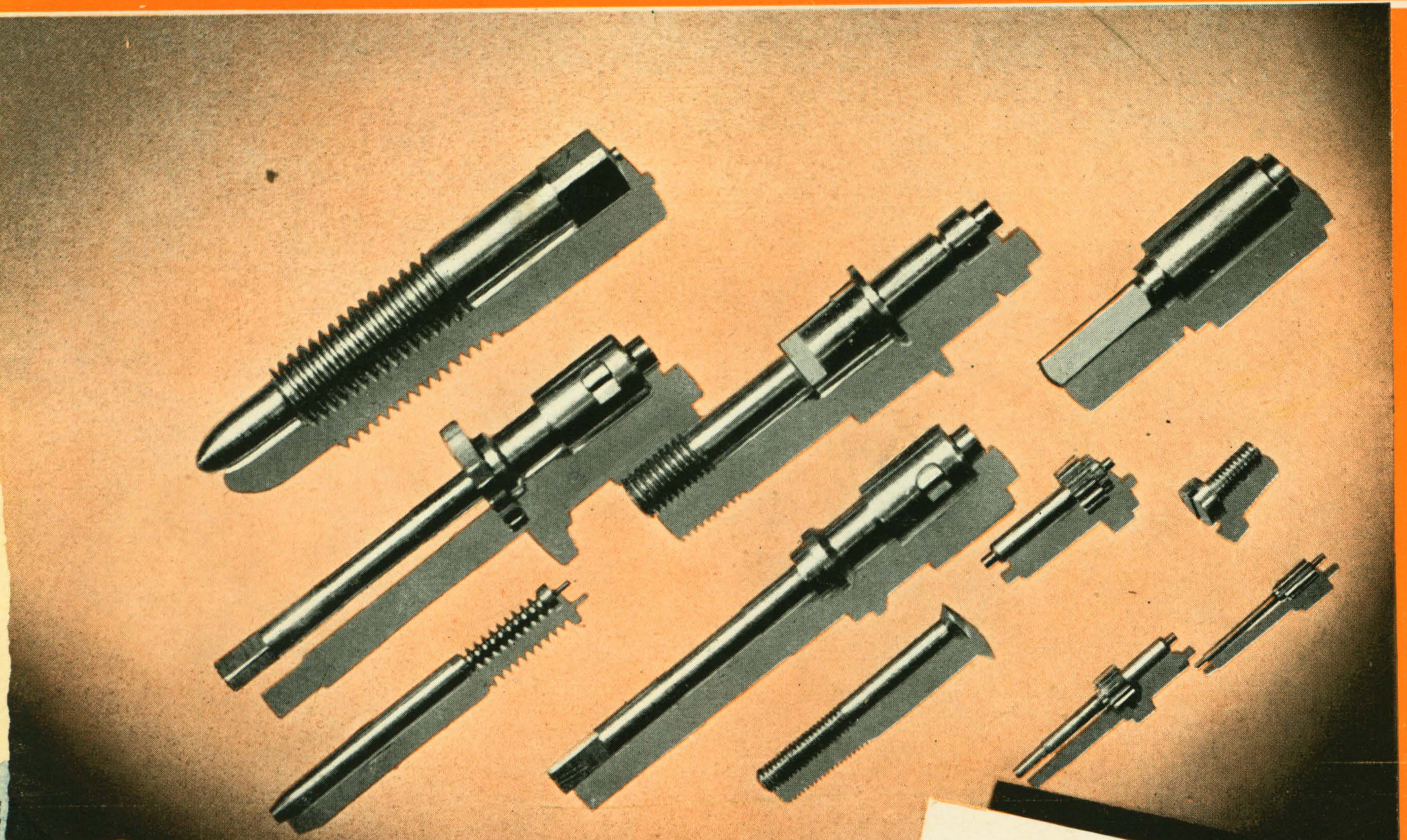
Aircraft Engineering

FOUNDED 1929 • OCTOBER 1948 • VOLUME XX • NUMBER 236 • HALF-A-CROWN

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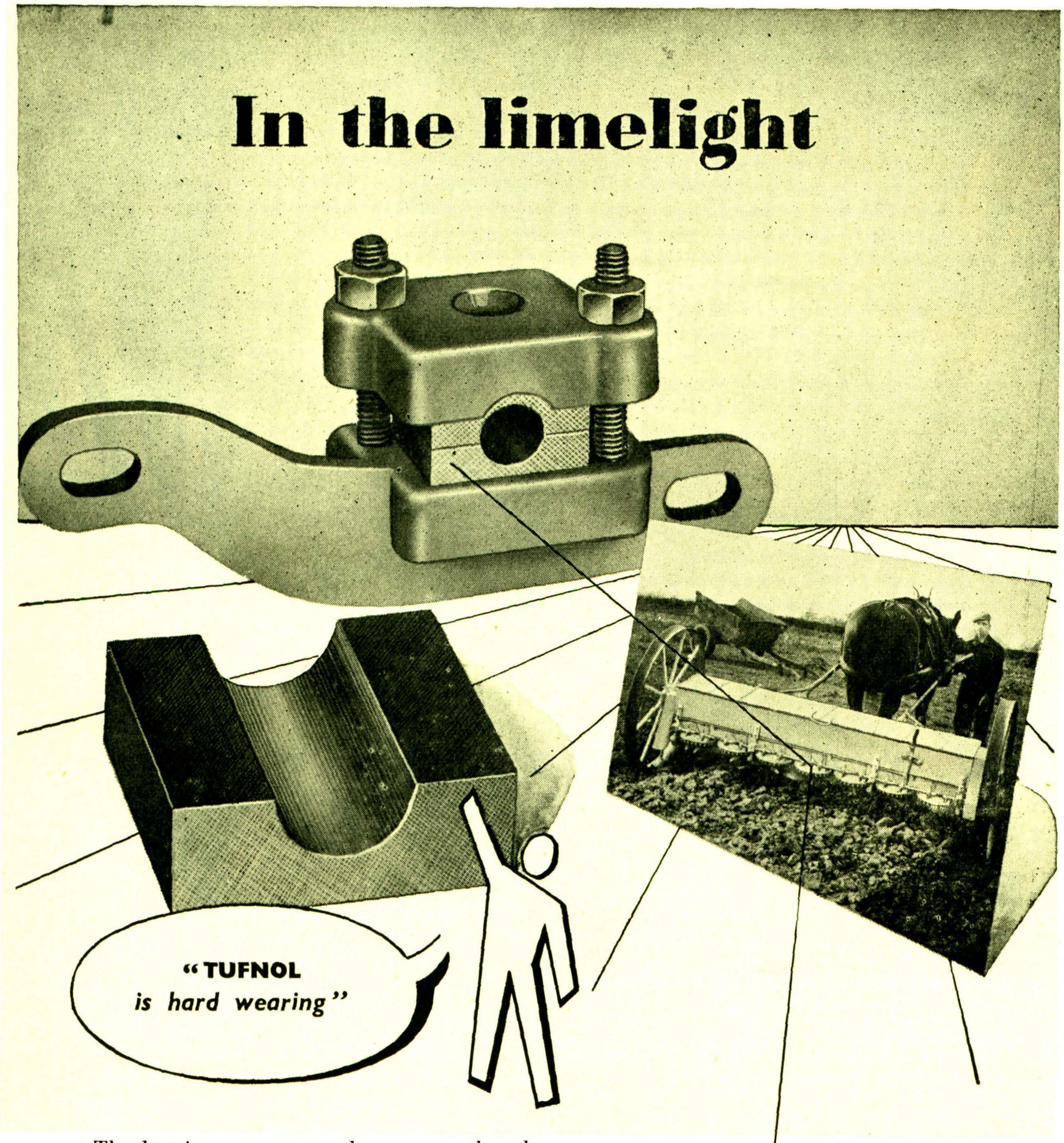

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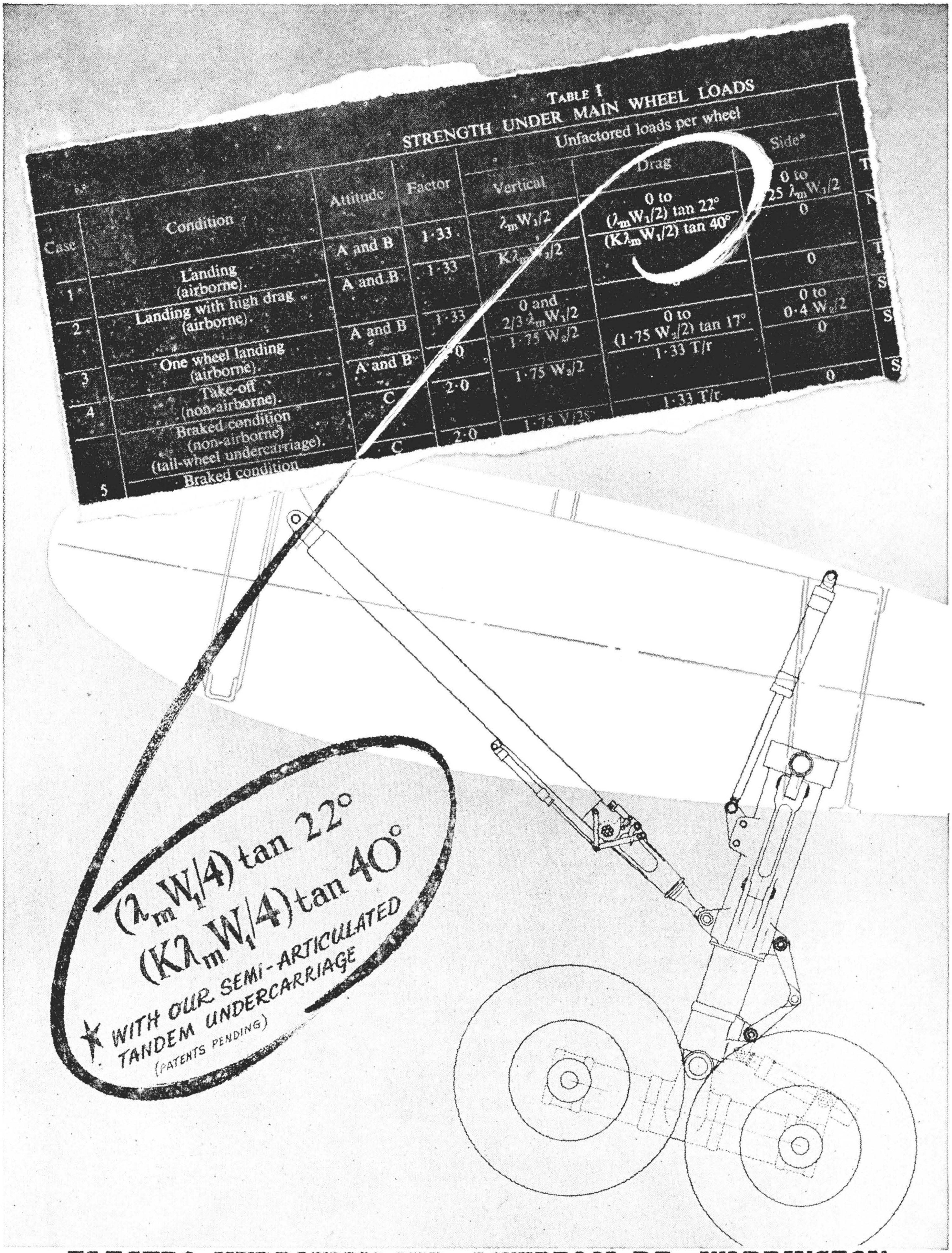

TABLE I

STRENGTH UNDER MAIN WHEEL LOADS

Case	Condition	Attitude	Factor	Unfactored loads per wheel Vertical	Drag	Side*
1	Landing (airborne).	A and B	1·33	$\lambda_m W_1/2$	0 to $(\lambda_m W_1/2)$ tan 22°	0 to 25 $\lambda_m W_1/2$
		A and B	1·33	$K\lambda_m W_1/2$	$(K\lambda_m W_1/2)$ tan 40°	0
2	Landing with high drag (airborne).	A and B	1·33	0 and 2/3 $\lambda_m W_1/2$		0
3	One wheel landing (airborne).	A and B	2·0	1·75 $W_2/2$	0 to $(1·75\ W_2/2)$ tan 17°	0 to 0·4 $W_2/2$
4	Take-off (non-airborne).	C	2·0	1·75 $W_2/2$	1·33 T/r	0
	Braked condition (non-airborne) (tail-wheel undercarriage).	C	2·0	1·75 V/2S	1·33 T/r	0
5	Braked condition					

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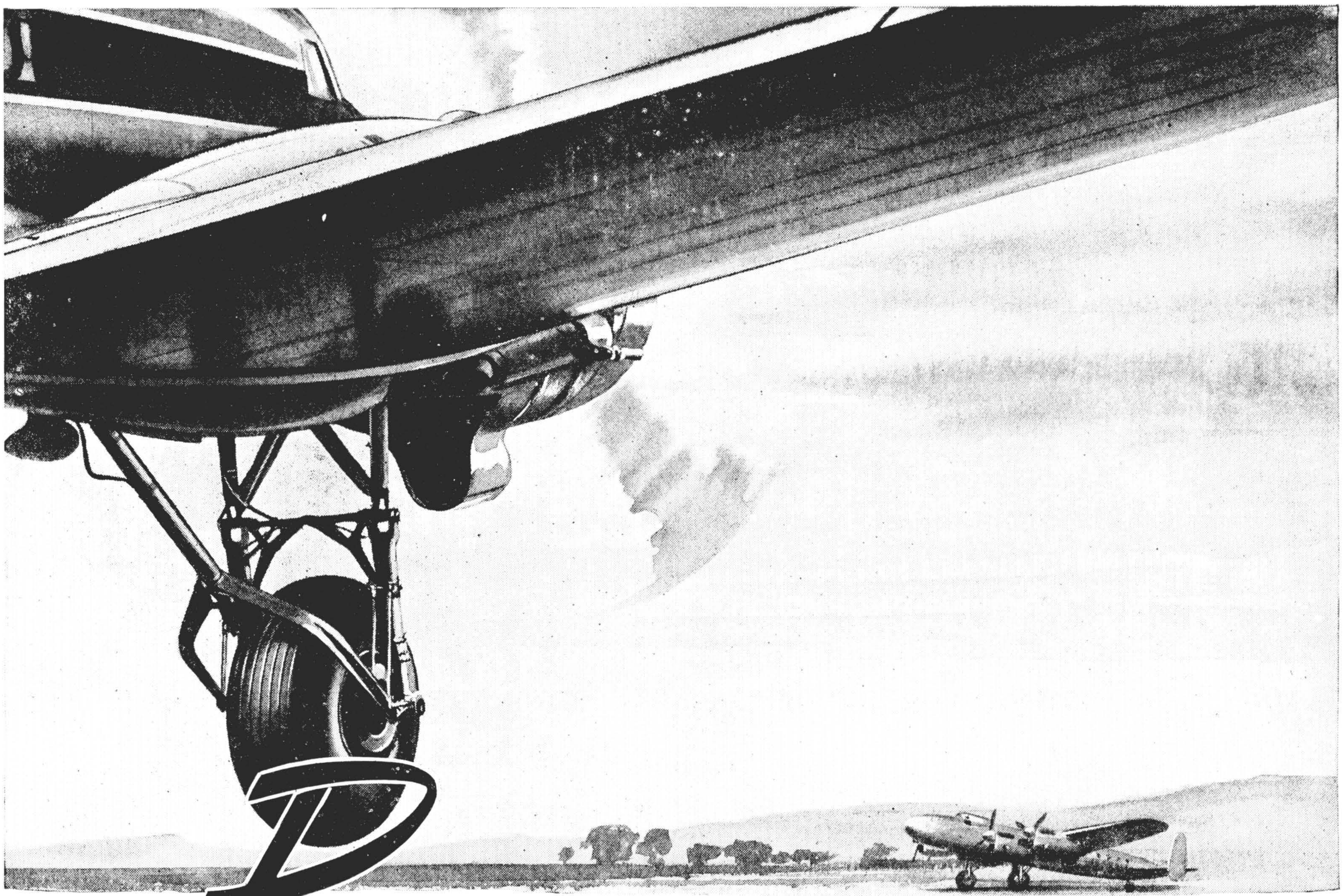

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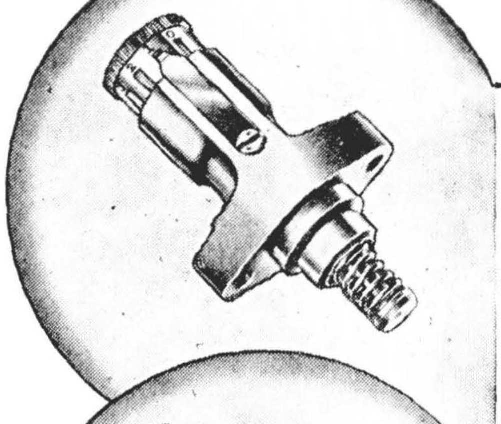

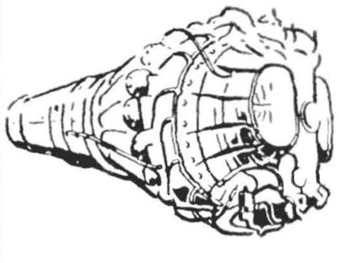

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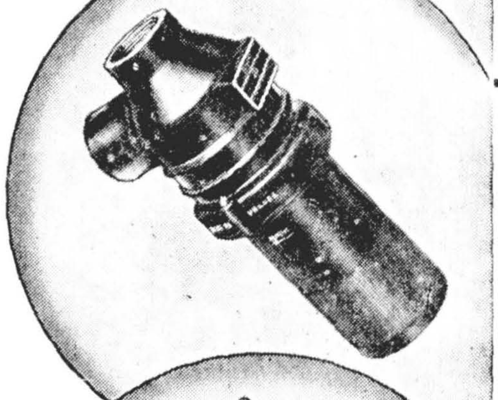

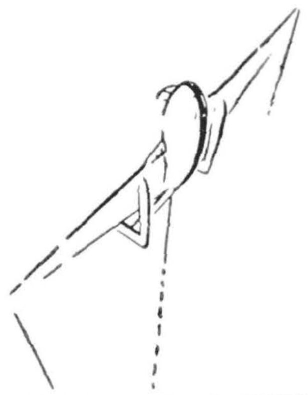

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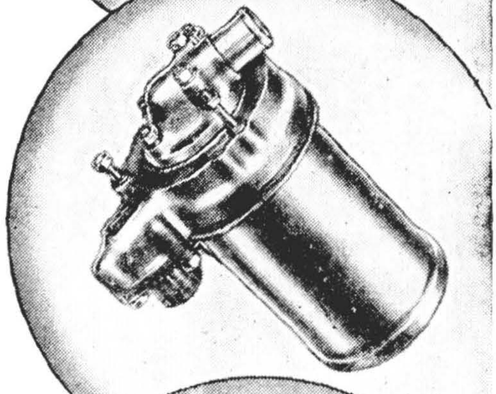

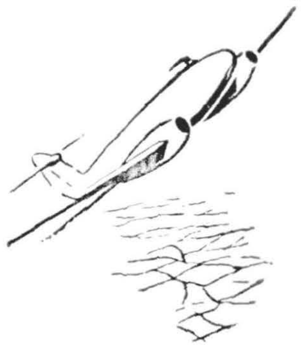

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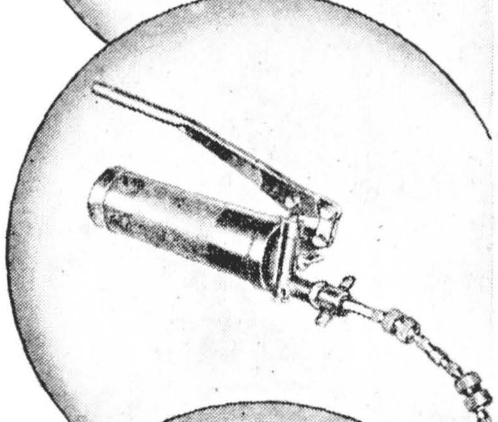

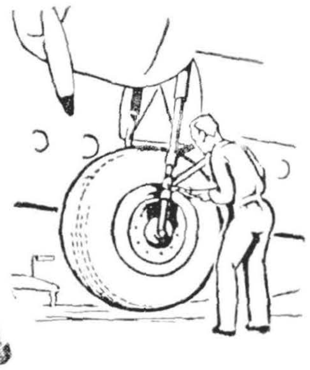

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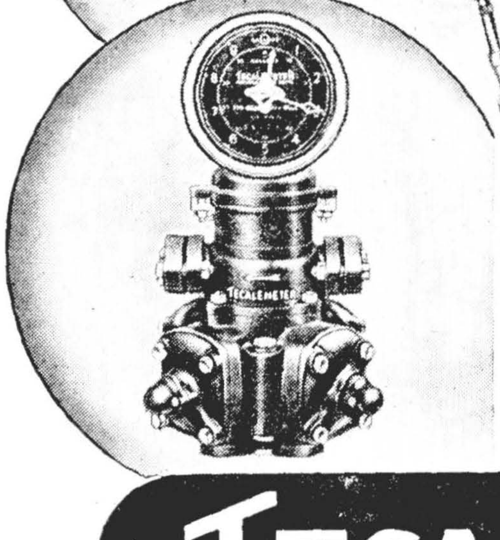

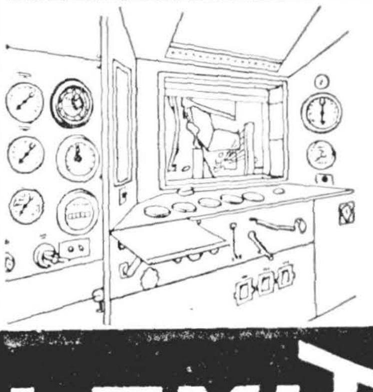

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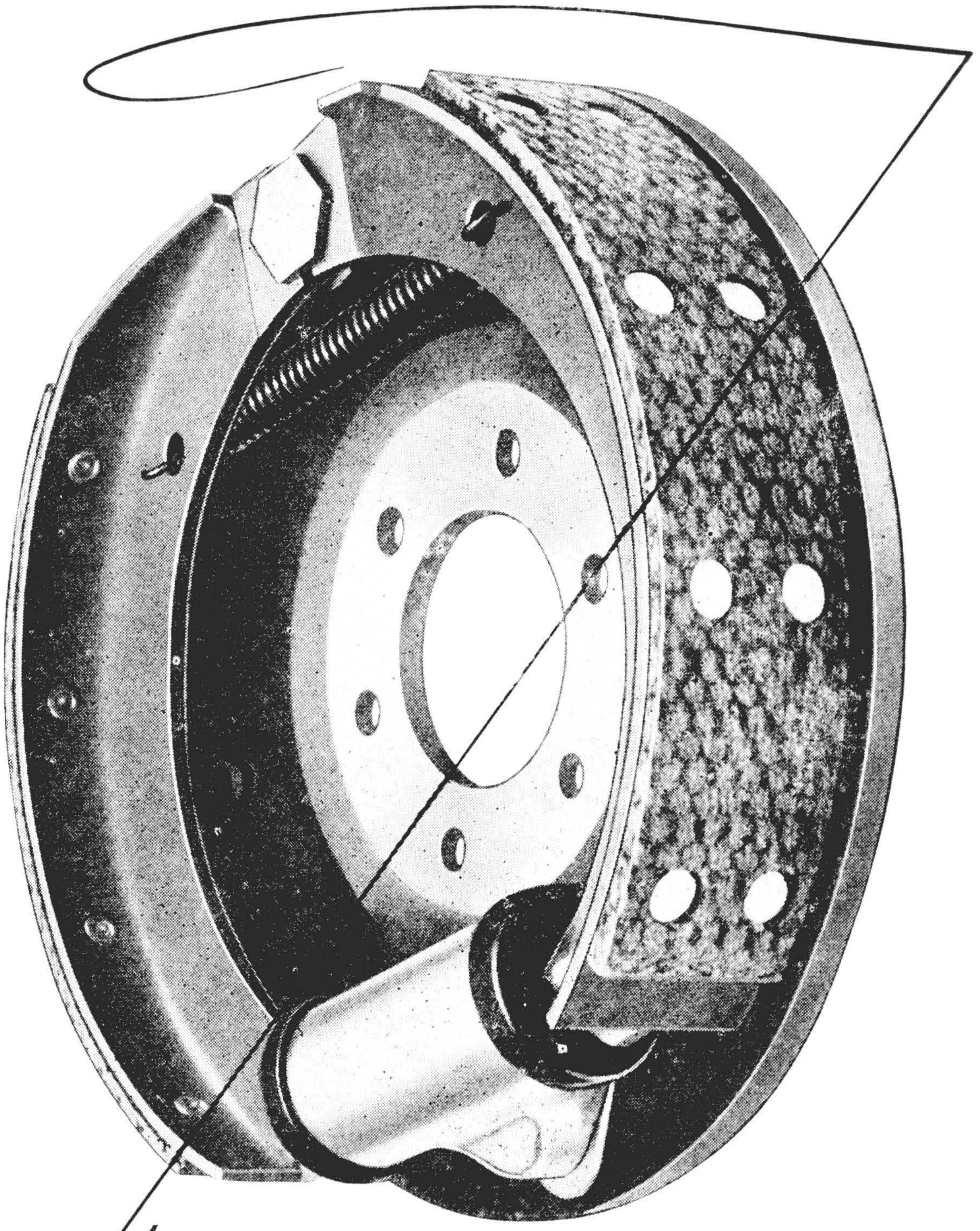

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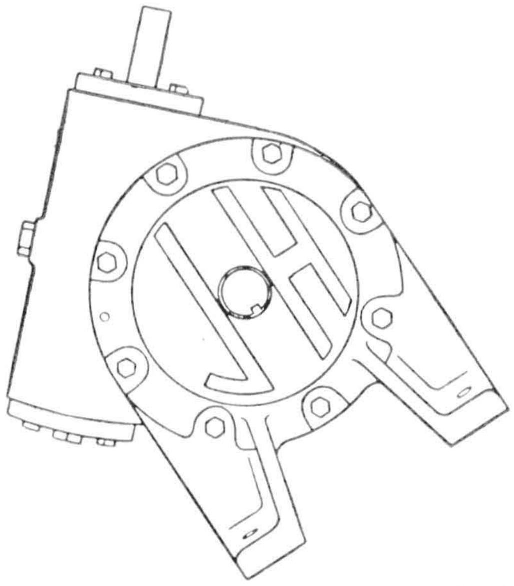

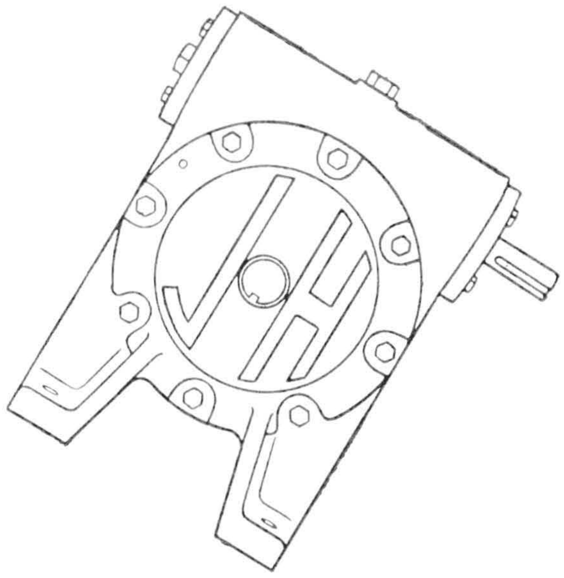

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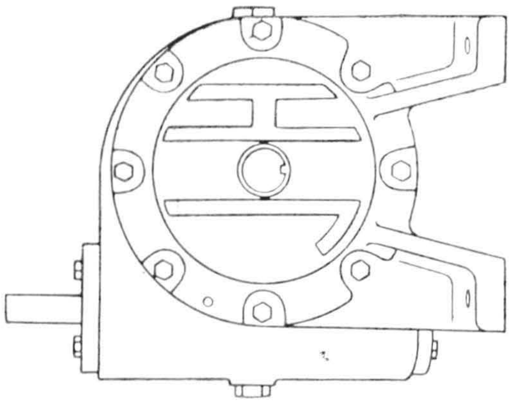

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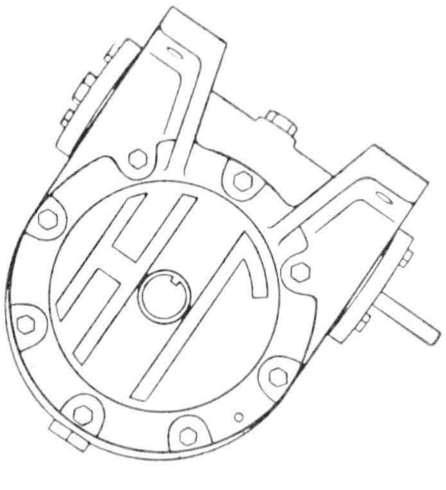

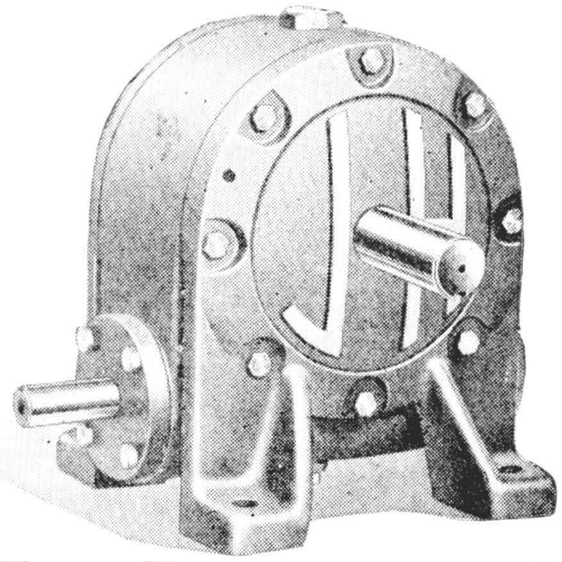

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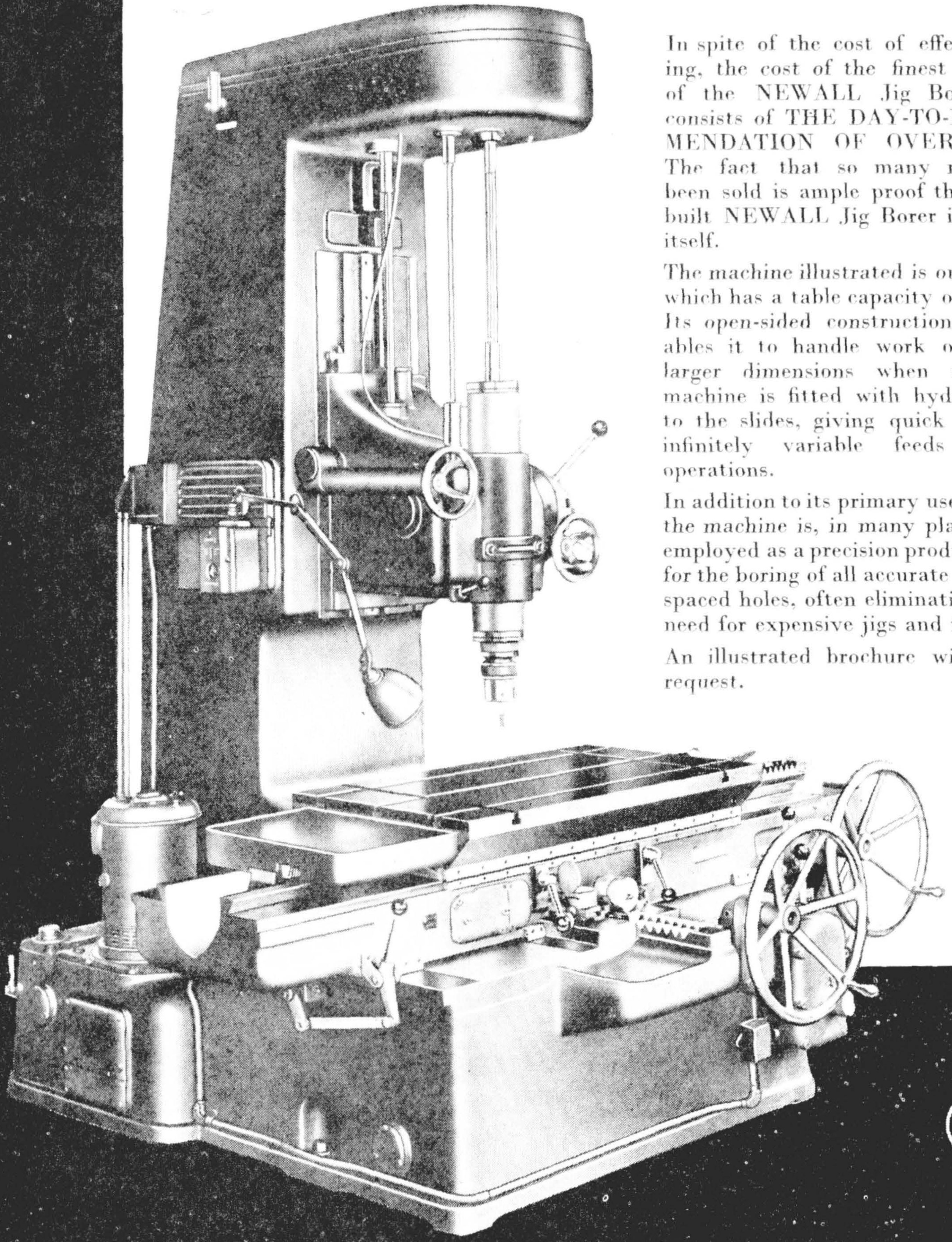

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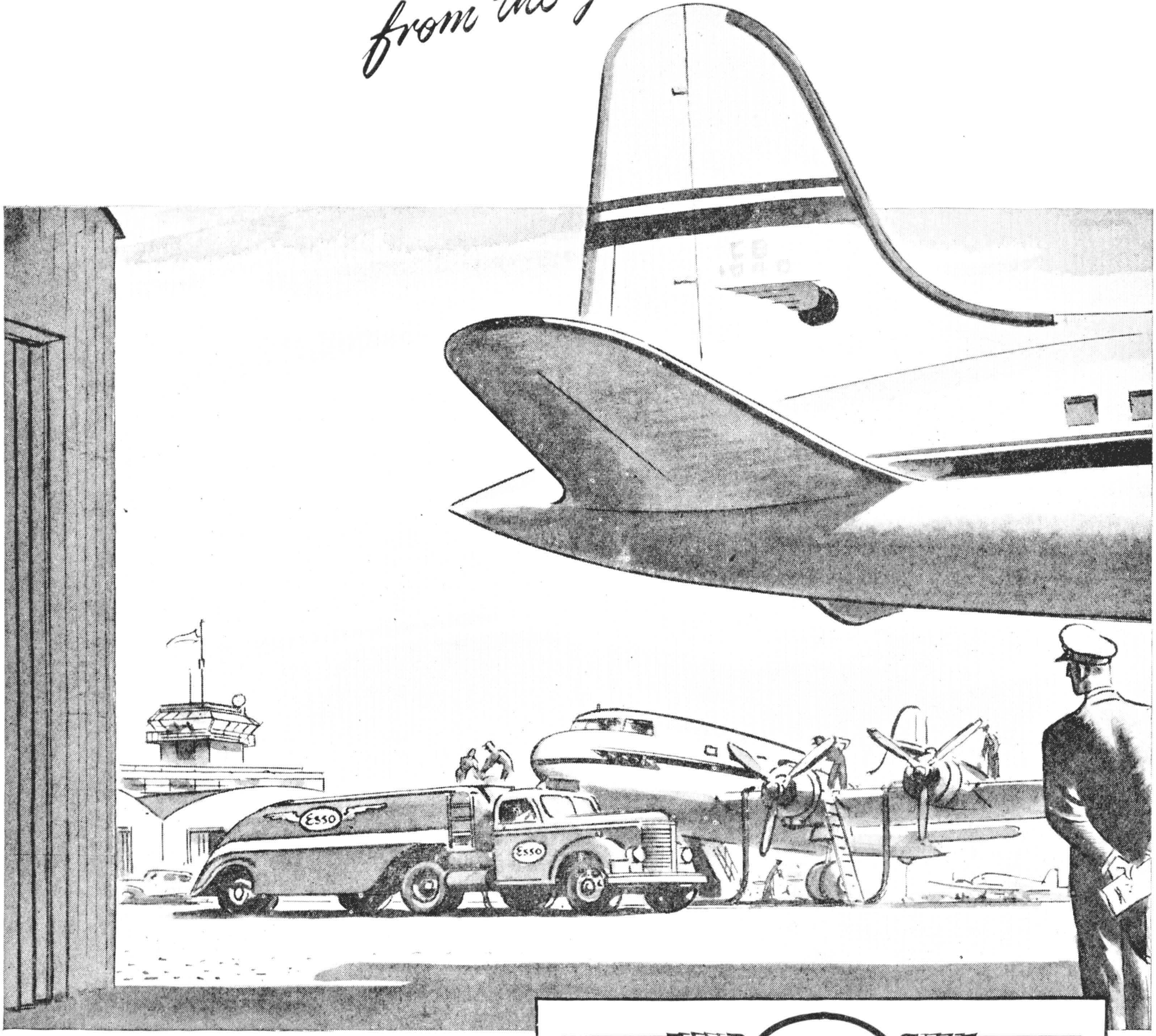

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THE HANDLEY PAGE
HERMES IV

Aircraft Engineering

FOUNDED 1929
OCTOBER 1948 VOL. XX NO. 236
EDITOR : LIEUT.-COL. W. LOCKWOOD MARSH, O.B.E., F.R.Ae.S., M.S.A.E., F.I.Ae.S.

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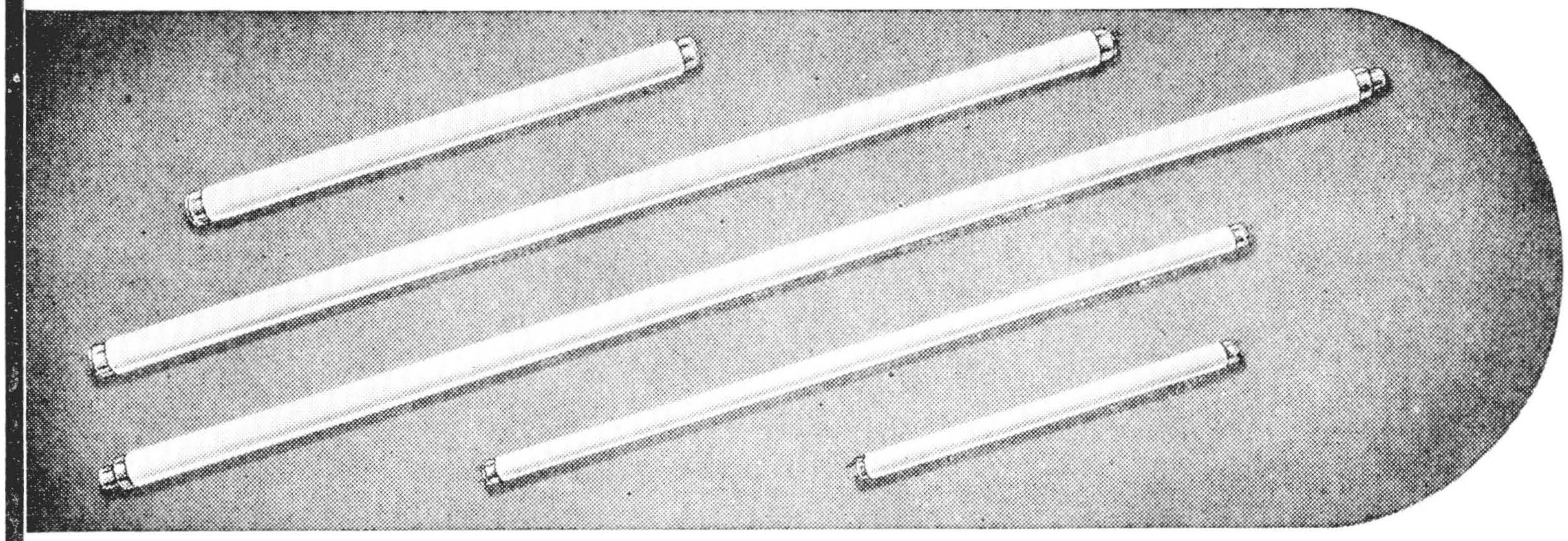

Painting by Doris Zinkeisen

TRADE WINDS No 8

EAST INDIAMEN

There was a lure and a fascination in the trade of the East Indies with its fabulous wealth in silks and spices, silver and gold, precious gems and splendid hard woods. Companies were formed in Holland, France, Denmark, Scotland, Spain, Austria and Sweden, but the most famous and romantic of these was the "Company of Merchants of London trading into the East Indies". It was granted its charter in 1600 with the prime object of competing with the Dutch, who were excellent seamen and colonists, and were rapidly penetrating the East and setting up their trading posts everywhere. Early voyages were undertaken separately by individual subscribers but after 1610 they were conducted on the joint stock system. This was then a novel device made possible by the increasing financial expertness of the City of London.

Until late in the 19th century no merchantman was able to sail unarmed. Vessels had to be prepared to fight pirates, privateers and the ships of rival ports and companies. East Indiamen were thus equipped to beat off their Dutch, French and Portuguese rivals as well as pirates. They carried great stores of arms and many fighting men. It was this call upon precious cargo space that prompted the Company to establish their own dockyard in Deptford in 1609 to build bigger and better ships.

The famous East Indiamen built in the Deptford yards held unquestioned eminence throughout the world. Built in 1830 the Buckinghamshire of 1,369 tons, was the last and greatest, being manned by 130 men and carrying 26 guns.

By 1611 the first English factories were established in India at Masulipatam and Pettapoli on the Bay of Bengal, and slowly but surely they became unrivalled. Dutch, French, Portuguese and other competitors were forced to seek their trade further East.

The Company developed India and penetrated upcountry on a semi-military, semi-trading basis. Generation after generation of English families gave their lives and services to the Company. The fortunate returned as "nabobs" with vast wealth but many more died of fever or in fighting for the Company. It governed India until Queen-Empress Victoria assumed control of British India and then the East India Company with all its vast resource and power became a romantic memory.

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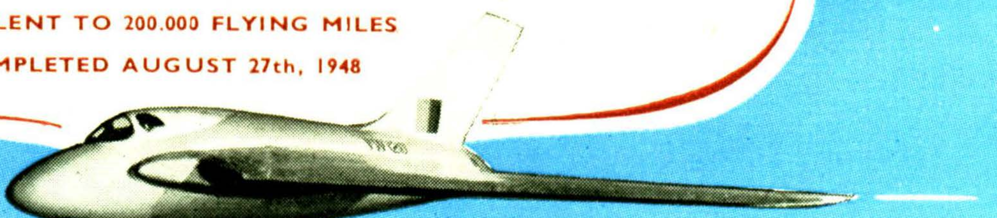

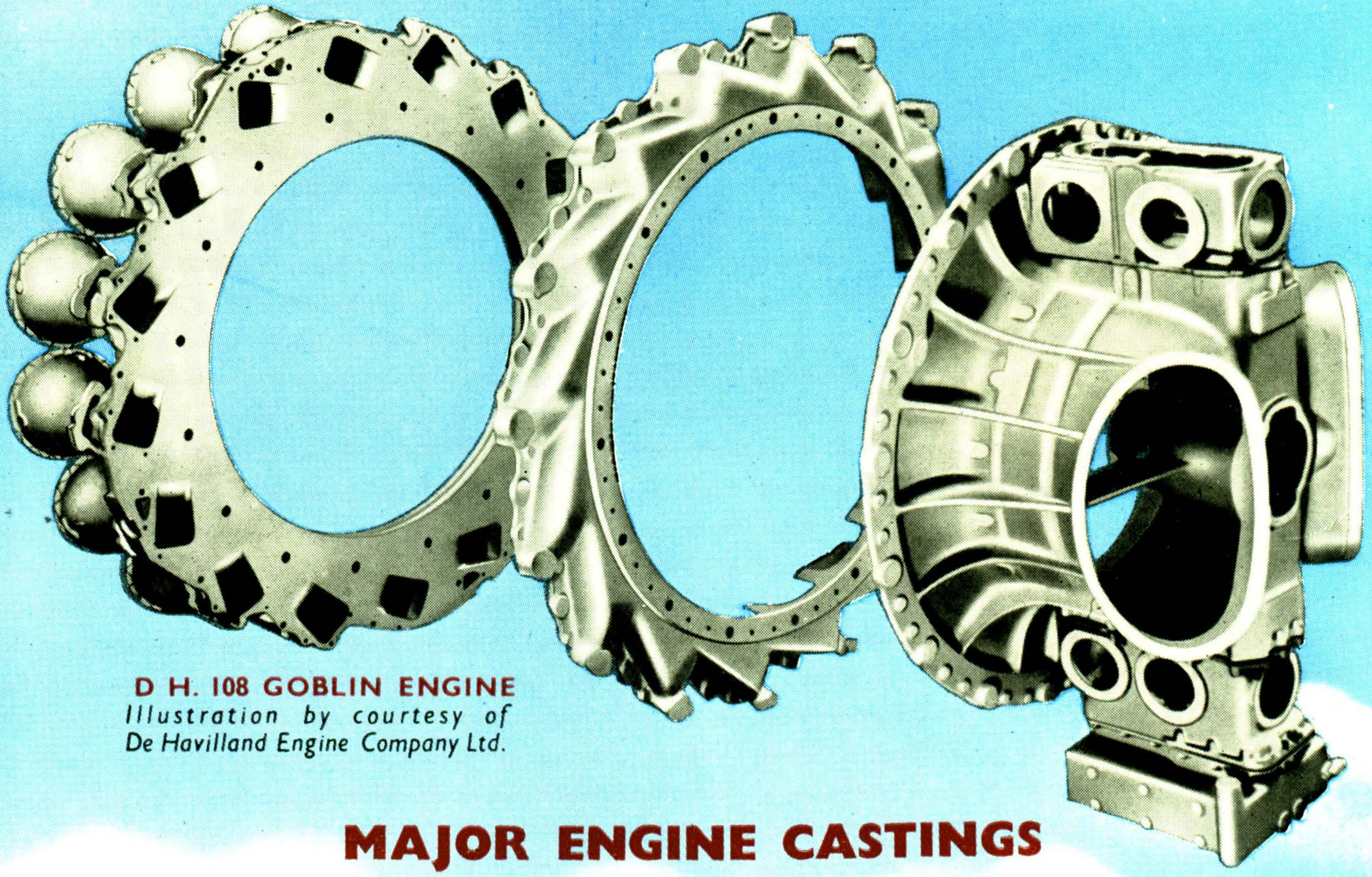

D H. 108 GOBLIN ENGINE
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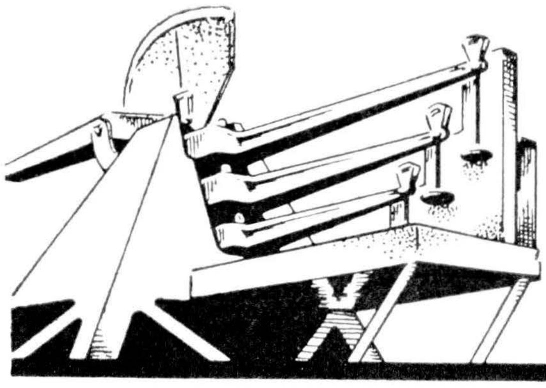

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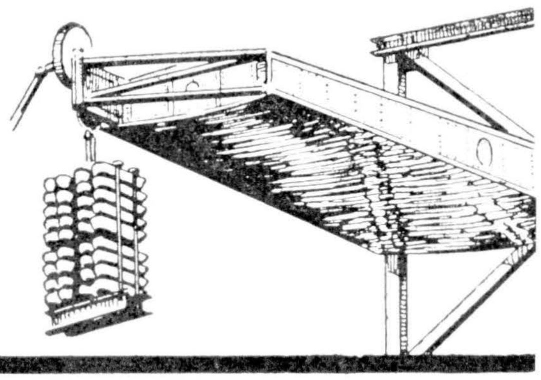


VOL XX No 236 OCTOBER 1948

In the Eyes of the World

AMID all the welter of previews, reviews and post-mortems on the S.B.A.C. Display we felt that if we were to enter the lists with still another domestic write-up of the exhibits the occasion would tend to savour too much of a mere opportunity for mutual back-slapping by the British Aircraft Industry and its supporters. We apprehended that we should be doing greater service to all concerned if we enlisted the aid of some outside contributor able to view the industry and its products from the unprejudiced viewpoint of a foreign outlook. We therefore invited M. CHARRIOU to write the survey of the exhibition which appears in this issue. He has the advantage for this purpose not only of being a well-known figure in French aviation circles, familiar with the industry of that country, but also of having recently visited and seen the products of the rest of Western Europe as well as of the United States of America. He has, consequently, been able to compare what he saw at Farnborough with contemporary aeroplanes and ancillary products of the principal aircraft-producing nations overseas.

Recorded Talks

Leaving M. CHARRIOU to speak for himself it may not be uninteresting for us to give here the general effect of the opinions that we picked up in the course of numerous conversations with other visitors from abroad. Here again, we feel that these are more helpful and informative than if we were to record merely our own impressions.

In the first place we found very general agreement that this year's Display constituted a real advance on the two previous post-war shows. Farnborough, apart from its distance from London, was agreed on all sides to be more suited to such an event than Radlett: particularly in view of the universally-approved decision to bring in the general public, for which purpose the aerodrome provides a natural arena. Several visitors with wide experience were filled with admiration for the organization of the actual flying, which, they said, surpassed anything they had hitherto seen in precision and smoothness of handling. An American commentator considered the Saro jet-boat and the Vampire both far in advance of any jet-propelled aeroplanes America possesses for manoeuvrability and controlability. The flying of these two machines, and, in a different style, of the Ambassador, undoubtedly aroused great admiration and that of the former, in particular, was obviously a complete revelation to most of the foreign onlookers.

There were some comments on the, obviously inevitable, drawback of having the static exhibition split up into two halls so widely distant from each other. In this connexion, several people to whom we talked were of the opinion that an annual Display gives little opportunity for the showing of much in the way of novelties in materials, components and accessories and expressed the view that to hold the event in future every other year, possibly to alternate with the Paris Aero Show, would be sufficient. Continuing to stage it annually would, they felt, inevitably result in a gradual falling off in interest; which would be a pity in view of the very definite enthusiasm that was noticeable this year, particularly in regard to the aeroplanes demonstrated.

Efficient Research

Many of the visitors from abroad took the opportunity of visiting the various firms and Government establishments such as the N.P.L. and experimental stations. One impression, voiced by the American visitor whom we have already quoted, is perhaps of particular interest. It was his first visit to England and the outstanding point that had struck him was the very small percentage of individuals engaged upon research, either Governmentally or in the industry, compared with the position in this respect in the United States. In spite of this, and the very much less elaborate equipment with which they were provided, it is his opinion that the results obtained from research here are of incomparably greater importance and value than those gained in America from very much larger resources. His intriguing explanation of this, on which he was most emphatic, is that if a scientist is given the most modern and lavish equipment with which he can be provided he is apt to fritter away his activities on devising still more elaborate 'tools'; whereas if he knows that he has to make do with what he is given he has nothing else to do but 'get on with the job' without distraction and therefore produces the results. He said that although he had been told of the very small number of research workers employed in this country he had not, on account of the volume of valuable work done, appreciated the true facts of the position until he saw it for himself and he was, in consequence, still more impressed by the quality of the results obtained here from the work of, by American standards, almost ludicrously small staffs.

Lack of Application

He had, however, one serious criticism, of the lack of use made of the wealth of information obtained. He recalled the fact that we have on more than one occasion complained that the published results of British research work remain at the level of the senior members of design staffs and do not reach the junior employees whose duty it should be to incorporate the new ideas into the detailed design of the aeroplanes on which they are engaged. Our informant said that he had been very much struck with the obvious soundness of this criticism and that he considered it a very serious blot on the organization of the design side of the British industry. The chief designer, he pointed out, should be responsible for the general design of the aeroplane, but it is the junior design staffs who should be familiar with the most recent knowledge obtained by research and ready to introduce it into the prototype of a new machine. Otherwise, he commented, progress will inevitably be less rapid than it could be, as the designer himself cannot possibly busy himself with the incorporation of the newest results of research into every detail of an aeroplane.

L'Exhibition de Farnborough Vue par un Français

An Appreciation of the Recent Display Organized by the Society of British Aircraft Constructors at Farnborough During the Week September 7th—12th

By André Charriou*

Introduction

I HAD the great pleasure of visiting for several days the excellent display organized by the S.B.A.C. at Farnborough.

I was all the more pleased as in the course of the last few years I have had the good fortune to travel around in Europe and America to examine progress in aviation achieved since the war by the principal nations—except U.S.S.R. Thus I have been able to follow step by step the aeronautical technique and construction development of the last three years in Great Britain as well as in Continental Europe and America. My intention therefore in this article is to give an account of what I think of the British conceptions and achievements in the field of aeronautics in comparison with what I have seen overseas.

Great Britain's Wonderful Effort

My greatest impression from my visit to Farnborough is astonishment at the remarkable effort in aeronautics accomplished in England since the end of World War II.

It is true that the aeronautical industry of this country during the years of the war has been greatly developed and that its means of production have been improved to a very high level. It is also true that, during the same years, scientific research has been very much encouraged and that the results, in most cases, were also available for other purposes than war. However, it is always a difficult problem to turn a war industrial economy into an industrial economy adapted to peace and in this matter England has shown great will and energy.

Although she has not yet been through all the obstacles, the main ones being of international character, England has succeeded in keeping herself in the first ranks of world aviation at the present time of peace, just as she used to be during the war, and this constitutes a very successful achievement.

In order to be able to dispose immediately of a certain number of particularly useful types of aeroplanes, to ensure the integrity of her Empire communication lines, the British aircraft industry tried, immediately after victory, to adapt available material, whether of old type or still being constructed, with some modifications and improvements. The results thus obtained have not always been successful, and I have been very pleased to see that such material is no longer in service. Experience has shown that satisfactory results were very seldom obtained with transformed older type aeroplanes, and we realize it very badly now in France where a great deal of money has been spent since 1944 on a policy of that kind which was based on political prestige rather than on any sounder reason. The result of this is that after four years of rather arduous work we have not yet got any suitable aeroplanes for our commercial air lines, as well as for the Air Force.

Radlett showed us what were Great Britain's tendencies and intentions; Farnborough shows us what she has been able to do, which is much better, as inventions have little value if they are not turned into practical achievement, and this last display gives us the right picture of the actual production possibilities of the British aircraft industry.

Jet Victory

At first sight, in comparison with last year, it does not seem that jet engines have made a notable advance. However, a great step forward has been made, as only a short time ago jet-propulsion was considered with some curiosity; now, not only has it become classic but it imposes itself victoriously so far as speed is concerned, and from now on it is possible to say that in the very near future all military or civil aeroplanes flying at speeds exceeding 600 km./hr. and altitudes over 6,000 m. will be jet-propelled.

The turbo-jet engines manufactured by Rolls-Royce and de Havilland assert their remarkable qualities and I can state with certainty that in this field, British production is of first-class quality. Although the general layout remains the same, many detail improvements have been embodied, especially concerning the quality of raw material: forged light metal alloy elements, produced by High Duty Alloys Ltd, particularly the aluminium alloys, which show a resistance of 40 T/sq. in. in stress analysis tests, while the best aluminium alloys usually employed only have a resistance of 33 T/sq. in. This, together with the 'Staybrite' high temperature resisting metals, gives a long operational duration and a great reliability.

I have also been greatly impressed by the engine installation designs which improve the facility of assembly, thus permitting a very quick engine replacement.

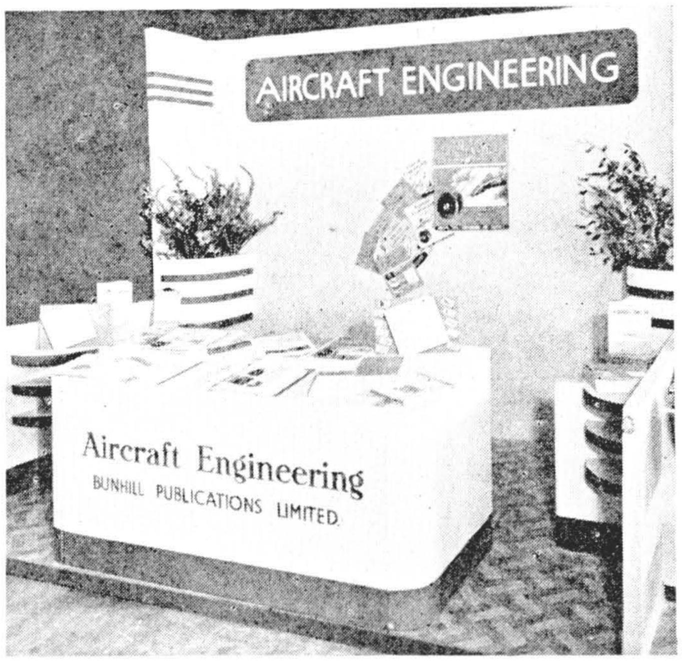
Very interesting also are the outside walls cooling systems and anti-ice formation devices. However, it seems that there is still more to do on the subject of air-intakes. When one just looks at one of the jet fighters with its two large lateral air-scoops or at those commercial jet-propelled machines, one cannot help wondering if there is not a way of arranging the air intake system along the leading edge of the wings or in the nose in order to reduce frontal areas. I believe that it would be advisable to take suggestions from one of the new transonic American aeroplanes.

I regret, on another side, that no improvement has been made in the energy efficiency of the turbo-jet; I know that it is a difficult problem, but it is of first importance to the future, deserving of the constructor's great attention.

Prop-Jet and Reciprocating Engine Rivalry

In the field of turbo-jet propulsion, the American constructors are working hard in order to catch up some two or three years lost on the British which they have not yet caught up, though they are now quite advanced.

On the contrary, so far as turbo-prop engines are concerned, the British constructors are absolutely the first in the world. I had never seen before any aeroplanes equipped with turbo-prop engines and I have been really charmed with the 'Viscount' and the 'Athena'.



Since the first appearance of the turbo-prop engine I understood that it would have a great future, but I believed that the reciprocating engines would fight a long battle before giving up the struggle. It seems now that I was somewhat too conservative in my estimate in view of what has already been achieved by Napiers, Armstrong-Siddeley, Rolls-Royce, Bristol, etc.; the piston engine has lost even before any attempt at reply.

This is the triumph of logic, as the piston engine is a real heresy. I have been able to appreciate the progress of the turbo-prop engine development even more than that of the turbo-jet. Worthy of note also are the improvements brought about in fuel intake and combustion systems, compressor and turbine blade designs, etc. The gear speed reducer still remains a delicate problem, though it seems to have been properly handled by Armstrong Siddeley on the 'Mamba' and 'Bristol' with the coupling of two Proteus with contra-rotating Brabazon SR/45 propellers.

Nevertheless, I consider that it would be foolish to avoid all the complications of a piston engine and fall into the difficulties involved in a too complicated turbo-speed reducer. I foresee that all geared speed reducers will be abandoned in favour of electrical speed-reducing devices which, when developed, will banish piston engines from aeronautical activity.

In the expectation of those days I have noted meanwhile the constant progress on the 500 h.p. 'Leonides' engine in the good arrangement of all its auxiliaries, inspection facility and easy servicing, as well as the adjustable cooling system, etc. This firm has also developed a special engine unit for helicopters. This is the first time that an engine has been specially designed for rotating wings; the cooling system by overhead fan is efficiently arranged and the same may be said of the exhausts. All the accessories are very harmoniously grouped below the engine.

Military Aeroplane Development

As far as fighters are concerned, Great Britain keeps marking points. The 'Gloster Meteor' is now an absolutely classical aircraft, but the two large power units, one on each wing, would produce much greater speed if the aeroplane could be equipped with more powerful engines; it can therefore be considered as a transition type, which will be outclassed in a few years' time.

The 'Vampire' continues to confirm its remarkable manoeuvrability, and with the 'Ghost', a more powerful jet-engine, it is capable of establishing very nice performances—in altitude for instance. This makes the 'Vampire' a very useful fighter, although I do not believe that its

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*Docteur-ès-Sciences, Lauréat de l'Académie des Sciences, Président de l'Union pour la Recherche Aéronautique, Technical Director of *L'Air*.

actual design would permit of much increase in speed. This means that for flying at a speed over 1,000 km. hr. other types of aeroplanes will have to be designed.

I was very much impressed by the speed of the new Hawker. This machine has very new design features; the fuselage is of very nice shape. For the aerodynamical section, perhaps a better position for the cockpit might have been found. The double air intake permits the fuselage to be quite narrow and thus to reduce the drag. I have been somewhat surprised with the double exhaust nozzle; such an arrangement provides good facilities for fuel tank installation in the fuselage, but I wonder whether it is the best way, as far as power efficiency and aerodynamics are concerned? It is quite possible, however, that the loss is quite negligible, if any!

The undercarriage may also be mentioned with its main wheels retracting in the fuselage, thus permitting a thin wing section. No doubt the Hawker fighter constitutes a notable progress in the speed competition, but it does not seem to be of a sufficiently revolutionary type to go through the sonic barrier, which remains the first object that the constructors are striving to reach. It is for this reason that I regret not having seen this year in England a type of aircraft with reverse dihedral swept-back wings, which is the solution strongly followed by the American constructors.

The de Havilland 108 'Flying Wing' displays a daring in conception far superior to other British jet aircraft and I am surprised that British engineers have not yet taken full advantage of this formula. I hope they may have something in store for us as a surprise in the near future, though I hasten to add that this remark does not diminish the merits, to my mind, of the British fighter constructor.

I would not say as much for bombers, which seem to be a completely neglected subject in the United Kingdom. In fact, the 'Lincoln' bomber, whether equipped with turbo-prop engines or turbo-jet, is only an experimental type and cannot be transformed into a modern bomber. Actually the U.S.A. are far ahead and I should say the only masters for that type of aircraft. However, an aeroplane such as the 'Tudor VIII' now presented as a transport could possibly compete with the American machines if it were a bomber version machine, as it is likely to be now under development.

Jet Propulsion for Transport Aircraft

The experiment carried out with turbo-jet engines on a heavy aeroplane such as the 'Lancastrian' represented the first step of its kind. The second and much more instructive phase was developed with the Vickers 'Nene Viking' whose flying from London to Paris in 34 minutes was quite sensational. The third and still more instructive phase was the achievement of the 'Tudor VIII', which I have already mentioned. Here is the first jet transport aeroplane and if the Americans are first for jet bombers the British have the leadership in jet transport.

The problems concerning jet propulsion for commercial planes are far from being readily solved: Neither 'Viking' nor 'Tudor' airframes are adapted for that kind of propulsion. Airframes with reduced drag have to be designed, this in order to get a better efficiency; that is to say require less fuel and carry increased pay load. The next step should be to find more efficient wing sections, adapted to high speeds, improvement of the fuselage nose shape and the use of a new kind of tail surface (V-type for instance!). Notwithstanding these remarks, these first British achievements show the way toward the most promising hopes.

Before finishing with jet aircraft I want to express my ideas on the subject of the flying wing AW-52, which I have not seen till now. There is no doubt that this machine is a great research achievement in which very interesting and original solutions have been developed; such as the extreme accuracy in workmanship in relation with aerodynamic effects on perfect section surfaces, and the wing tip boundary layer suction experiments. It is very instructive that such an interesting theoretical formula is experimented in practice and, from the scientific point of view, Sir W. B. Armstrong Whitworth Aircraft Ltd. must be congratulated just as their American colleague, Northrop, another flying wing constructor.

In order to get full aerodynamical advantages from a flying wing, any vertical surfaces ought to be suppressed. The AW-52 has fins at its wing tips causing drag, probably nearly as high as the tail surfaces on a classical aeroplane. In fact the problem consists in ensuring a sufficient stability without fins. Northrop achieved it on his propeller-driven flying wing, but he had to fit fins on its jet-propelled model. It appears therefore that this question seems to arouse quite some difficulties!

Other Novelties in Transport Aircraft

Till now Great Britain has not produced any air-liner capable of competing with the four-engined American transocean commercial types. Long experimental work has been required to achieve the 'Hermes IV' which seems now to be up to the proper level. One would not be surprised at this slow development, as it should be kept in mind that the 'Constellation' as well as the DC-6 have been brought very gradually to what they actually are.

Now I come to a point that raised my curiosity to a higher pitch and this is the 'Viscount', the first turbo-prop transport, with many new devices on it: double gap flaps, horizontal tail surface set at a high dihedral angle, the forward position of the propellers, the outside ones being slightly staggered.

This is really something new for commercial aviation, and I am awaiting impatiently the results of the first flight as it will be interesting to compare them with those of the 'Ambassador'. For the time being I believe that the last mentioned, with its two-piston engines, would be more economical, but with the expected improvement of the turbo-prop engine how long is it going to keep its superiority?

In any case, while awaiting the full achievement of turbo-prop air liners, British aviation can market the 'Ambassador', a very useful medium range aircraft. As far as airframe is concerned I find it superior to its American competitors--the 'Martin 202' and 'Convair 240'. The fuselage is better designed and its high wing facilitates taxying on the ground and visibility. The triple fin tail surface must provide a good stability even with one engine stopped.

Now the question of using the valveless Bristol engines on a regular transport liner has to be answered as far as reliability, duration and economy are concerned, as many different opinions have been expressed on this subject, though the arguments for and against seem to be based on little foundation.

In the category of small transport planes, the 'Prince' seems to fill the same purpose as the 'Dove', though it is equipped with more powerful engines and therefore has a larger and slightly more comfortable passengers' cabin. It also has some interesting ideas, such as the fuselage nose door, very large window-panels, altitude and speed indicators placed at each passenger's seat, the tricycle undercarriage with double wheels in front. The high wings are very advisable for that kind of craft, giving easy access to the fuselage, but unfortunately such a design makes a more difficult problem for the main landing gear retraction. These light transports can be very useful in lightly populated African, Asiatic and South American countries, although American constructors do not seem to be attracted by such a type of aeroplane.

I should say much the same of the 'Sealand' which fills the gap for countries possessing numerous water-alighting spaces. The lowering wheel system along the hull is quite ingenious but takes up too much space inside the cabin, as is the case with most amphibians; the access to the cabin is difficult and calls for some improvement in design.

Before leaving the subject of commercial aeroplanes, I would like to say how pleased I was to see the growing use made of reversible pitch propellers, which is the most logical solution for shortening landing distance.

I should not like to forget to speak of the 'Brabazon', which naturally could not be brought to Farnborough, but which I was able to see some time ago, during a visit to Bristol. I was able then to appreciate the great effort made for the achievement of such a huge machine. The most delicate problem is the one concerning the engines. The solution given in the 'Brabazon No. 1' is not quite appealing from the mechanical point of view, with its two contra-rotating propellers driven by two motors; I apprehend that it could become a source of vibration and I would recall that for such a reason the contra-rotating propellers have been replaced on the flying wing Northrop, by single propellers. In fact the 'Brabazon' should be equipped with 5,000 h.p. turbo-prop engines which the British industry cannot provide yet.

From another point of view I am wondering whether the arrival of jet transport aircraft will not diminish in a short time the interest given to huge propeller driven aeroplanes. I believe that in a period of ten years from now the Atlantic will be crossed in less than six hours by jet-propelled transports flying at altitudes around 35,000 feet and the public will always give preference to the fastest means of transportation. This is probably the reason why Lockheed, Douglas and Consolidated seem to renounce the construction of huge size commercial machines.

Helicopter Successes

In the development of helicopters, the British constructors have followed a very prudent and clever policy. They have very wisely taken lessons from the 'Sikorsky', one of the two most reliable American machines, which they are trying to improve.

Bristol have put all their care into mechanical details such as transmissions, controls, balance of the blades, and motor installation. Fairey did still better with the idea of removing the anti-torque propeller from the tail, and using it on the fuselage side for forward propulsion, thus increasing the speed and giving to the Fairey 'Gyrodyne' the helicopter speed record. This is an excellent idea which should increase the usefulness of that type of aircraft, providing performances approaching to those of classical type aeroplanes. It can be noted that with the Fairey system we partly come back to the autogiro conception which seemed to be abandoned.

I liked less the new Cierva 24-passenger helicopter, the choice of three rotors seems to create too many mechanical inconveniences On the other hand, precise knowledge on the aerodynamics or mechanics of rotating wings is still small; the processes of experimentation are difficult and theoretical calculations often remain very far from the realms of practicality. In these circumstances, I consider that to produce successful helicopters it is necessary to move step by step without trying to make a big advance in any new direction.

We have an example of this at the present time in France; engineers of remarkable gifts are launching out on the construction of helicopters on novel lines on the strength of theoretical calculations without having first submitted their conceptions for long enough to laboratory tests. This method of procedure has already led to several serious accidents. It is for this reason that

I am, on general principles, a little doubtful of the possibility of successfully producing a helicopter to carry 24 passengers at the present time.

From the Conventional to the Revolutionary in Light Aeroplanes

The visitor to Farnborough rather gets the impression that the British industry is not greatly interested in light aeroplanes. This is easily explained by the fact that Great Britain has preferred to concentrate its maximum effort on military and commercial aviation, which are indispensable to its security and economy. I think, however, that in the Dominions and Colonies there should be a number of potential buyers of light aeroplanes so long as they are offered machines that are strong, practical, safe and economical. If British light aeroplanes are designed to attract and satisfy 'sportsmen' they will not, as a rule, possess qualities likely to appeal to purchasers looking for an aeroplane that is a true vehicle of transport. I would add that, from this point of view, the English technician is lagging behind. Certain light aeroplanes of American, French (engines excepted) and Dutch origin provide more novelty and originality. The same applies to light engines; although the de Havilland 'Gipsy' and the Blackburn 'Cirrus' are well enough designed and constructed, I prefer the American horizontally-opposed cylinder types which are less refined but more economical and easier to build. I would make an exception of the Portsmouth 'Aerocar' which is an interesting solution so far as comfort, accessibility and view are concerned. Unfortunately the high wing carrying two engines gives the impression, more or less justifiable, of a liability to nose over on landing.

I would mention as quite in a class of its own the 'Planet Satellite', which is truly revolutionary in its conception; witness its fineness of fuselage lines, lack of wind-screen, location of the engine behind the cabin and propeller right at the tail, Y-shaped tail, simplified construction in magnesium, undercarriage, removability of the engine, etc.—all these ideas are extremely attractive and disclose genuine logic in design. On the other hand I would criticize the fitting of too low-powered an engine, although I must defer final judgment on this point pending results of trials in flight. If it flies satisfactorily it displays truly remarkable progress in light aeroplane design, but it remains to be seen whether it will do so. In any case, several of these novel features have still to be proved; some of them might reduce the cost of light aeroplanes, which is highly desirable.

In another direction I regret that British designers, like those of European countries, have not turned their attention to simplification of control, which is causing so much interest and is being actively investigated in the United States.

New Tendencies in Materials and Accessories

Among the numerous components, materials and accessories shown at Farnborough, I wish to pick out those which represent new tendencies which are most characteristic of aeronautical construction. I have already spoken of new materials so far as engines are concerned; this is most important for the improvement of the efficiency of turbo-jet and turbo-prop engines. It is conditioned, to a large extent, by the possibility of improving the mechanical strength and resistance to heat of the metals used in their construction. Extremely interesting results have been obtained in this direction for the development of new formulas of stainless steels, centrifugally-cast steels, aluminium and magnesium alloys, etc. I noticed, with satisfaction, throughout the range of materials shown the development of moulded components, such as those of Tufnol, composed of laminations bonded by synthetic resin glues which can be associated with a skin or leaves of light metal. The use of these materials in the structure of light aeroplanes should reduce the number of hours occupied in construction and thus reduce the price, which, as I have already hinted, is much too high for most purchasers.

I noticed that much work has been done on accessories for flight at high altitudes. In fact, if engines function satisfactorily and if airframes stand up to the stresses of high altitude flying, it is not so much the accessories which have been the cause of most accidents. Appreciable progress has been made in the equipment of pressurized cabins and in the manufacture of windows—I greatly admired the large oval windows provided in the 'Viscount'. Navigation is facilitated by numerous instruments such as the Hughes periscopic sextant, the Rotol automatic synchronism and, above all, the Smith and Sperry electric automatic pilots, much more simple, certain and less costly than the old pneumatic servo pilots. These automatic pilots are becoming so light that they could be installed in light aeroplanes, which is an excellent thing and makes it possible to hope that every aeroplane may, in the near future, be provided with an automatic pilot, to the considerable benefit of safety.

I was greatly impressed by the Goodyear cross-wind landing gear, for the possibility of landing across wind will give a considerable impetus to aviation. The progress of flying is, in truth, dependent on the development of landing grounds. With cross-wind landing there is no longer need for vast aerodromes with multiplicated runways and free from obstruction in all directions; strips of ground free from obstruction at their two extremities will suffice. The aerodromes could be much more numerous, for a strip of ground is manifestly easier to find than an immense area; the provision of ground facilities would be much less costly and airports could be situated close to towns, even in the centre of towns by the adaption of boulevards and river banks. The Goodyear landing gear provides a displacement of 25 degrees on each side, which is sufficient for landing or taking off without danger of ground looping in quite a strong side wind. It seems certain that within a few years devices of this kind will be adopted for all aeroplanes without exception and that people will be asking why we put up for so long with aeroplanes with non-swivelling undercarriages.

Reflexions and Suggestions

This exhibition at Farnborough did the greatest credit to the British Aircraft Industry. Great Britain, unlike the United States, does not employ immense aircraft factories full of formidable equipment. Her methods of research and experiment are more restrained than those of America, but she knows well how to utilize her resources and draw from them excellent results. If the United States is the premier aeronautical nation of the world, Great Britain follows very close on its heels and in certain respects shows the way—which is very satisfactory for the Old World. None the less, progress in aviation becomes daily more difficult and the problems to be solved constantly demand more work and more money. In order to maintain her lead in certain fields of aeroplane construction Great Britain may well be forced to neglect others. It is illogical that in several countries at the same time the same scientific researches and the same identical experiments should be undertaken. At a time when America and Western Europe are united in helping each other economically I wonder if it would not be equally opportune for the same countries to come together over aeronautical research and construction. I believe that such co-operation would not only be extremely favourable for the progress of aviation but also would help in maintaining peace in the world.

Professional Publications

Under this heading are given each month the principal articles of aeronautical interests appearing in the current issues of the Journals of the leading Professional Societies and Institutions

The Royal Aeronautical Society
JOURNAL (Monthly)
Vol. 52, No. 452, August 1948

Flight Research at High Subsonic Speeds. H. Davies

Influence of Recent Civil Airworthiness Requirements on Aircraft Design. W. Tye

Maintenance Design Questions. T. E. G. Bowden

Vol. 52, No. 453, September 1948

The Art of the Aviation Engine. F. R. Banks

The Elements of the Buckling of Curved Plates. H. L. Cox and E. Pribram

Institute of the Aeronautical Sciences (U.S.A.)
JOURNAL OF THE AERONAUTICAL SCIENCES (Monthly)
Vol. 15, No. 8, August 1948

A Wing-Body Problem in a Supersonic Conical Flow. S. H. Browne, L. Friedman and I. Hodes

Helicopter Control and Stability in Hovering Flight. R. H. Miller

The Flow of a Perfect Fluid Through an Axial Turbomachine with Prescribed Blade Loading. F. E. Marble

Theoretical Pressure Distributions for a Thin Airfoil Oscillating in Incompressible Flow. E. E. Postel and E. L. Leppert, Jr.

Stability of Boundary Layers and of Flow in Entrance Section of a Channel. E. Hahneman, J. C. Freeman and M. Finston

Chordwise and Beamwise Bending Frequencies of Hinged Rotor Blades. G. Horvay

AERONAUTICAL ENGINEERING REVIEW (Monthly)
Vol. 7, No. 7, July 1948

Automatic Aircraft Control. J. L. Anast

Loss Prevention Programmes in Civil Aviation. J. Lederer

The Application of Gas Turbines to Aircraft. A. N. Tifford

External Sound Levels of Aircraft. R. L. Field, T. M. Edwards P. Kangas and G. L. Pigeman

Vol. 7, No. 8, August 1948

Meeting on Wings

The Helicopter Control Rotor. J. Stuart

Flight Path Control. P. A. Noxon

Society of Automotive Engineers (U.S.A.)
TRANSACTIONS (Quarterly)
Vol. 2, No. 2, April 1948

Fuel Injection versus Carburetion for Personal Aeroplane Engines. G. M. Lange

Research on Aircraft Hydraulic Packings. T. J. McCuistion, F. E. Clark, R. A. Clark and L. E. Cheyney

Electronic Analog Studies for Turboprop Control Systems. G. A. Philbrick, W. T. Stark and W. C. Schaffer

Factors Affecting Functioning of Spark Plugs.W. A. Bychinsky

Engine Installation Problems in the XP-84 Aeroplane. R. R. Higginbotham

Engine Compounding for Power and Efficiency. E. F. Pierce and H. W. Welsh

Allison V-1710 Compounded Engine. D. Gerdan and J. M. Wetzler

S.A.E. JOURNAL (Monthly)
Vol. 56, No. 8, August 1948
Summaries:

Flight Beyond the Earth's Atmosphere. F. H. Clauser

What Price Structural Testing? S. A. Gordon and G. E. Holback

Pre-ignition and its Deleterious Effects in Aircraft Engines. A. Hundere and J. A. Bert

Jet Aircraft Cabin Temperature Control. D. O. Moeller and O. A. Sanne

European Landing Gear Developments. H. G. Conway

The Institution of Engineering Inspection
ENGINEERING INSPECTION (Quarterly)
Vol. 12, No. 2, Summer 1948

Some Notes on Materials. S. G. E. Nash

Electronics as Applied to Inspection and Testing. L. G. Ward

The Helicopter Association of Great Britain
JOURNAL (Quarterly)
Vol. 2, No. 1, April-May-June 1948

A Description of the Bristol Type 171, Mk. I. R. Hafner

Some Technical Aspects of W.9 Development. J. S. Shapiro

The American Society of Automotive Engineers
MECHANICAL ENGINEERING (Monthly)
Vol. 70, No. 8, August 1948

Fluid-Flow Diagrams. G. P. Loweke

Aircraft Hydraulic Packings. L. E. Cheyney and T. J. McCuistion

A Graphical Determination of the Flow in Nozzles

A Study by the Service du Documentation
et d'Information Technique of the French Air Ministry
By Pierre Richard, Ancien Eléve de l'Ecole Polytechnique,
Ingenieur Civil de l'Aeronautique
Translated by Lionel Mote, F.I.L.

1. INTRODUCTION

1–1 The Problem

THE flow of gases in nozzles has been considered by many authors. The results are usually shown in the form of curves or tables of figures. Practical use of these diagrams or tables is, however, made difficult by the large number of variables concerned and the difficulty of finding convenient scales.

The objects of this present work are therefore:

the selection of the variables most easily used;

the consideration of the method of representation;

the development of a graphical method of calculation.

The method to be described will allow all problems concerning tuned nozzles (for definition see paragraph 3–1–2–1) to be solved with a minimum of calculation. It will also allow, in a particular case, the determination of the position and the amplitude of the shock wave.

Several examples will be given of the application of the method to nozzles whether tuned or un-tuned.

1–2 Hypotheses

Let us consider the flow 'by sections' of a perfect fluid (the fluid characteristics being constant in one section of the nozzle).

Apart from shock waves, the flow is assumed isentropic, or adiabatic (without heat transfer to the external medium or to neighbouring sections) and reversible. Between the fronts of the shock waves the transformation is only adiabatic.

The condition of reversibility implies that the losses are negligible.

1–3 Symbols

1–3–1 *Conditions in Any Section of the Nozzle*

p = pressure
ρ = specific gravity
T = temperature
a = speed of sound
v = flow velocity
$M = \frac{v}{a}$ = Mach number
S = section of nozzle
$D = \rho S v$ rate of discharge from nozzle
R = gas constant for perfect gas
$\gamma = \frac{c_p}{c_v}$ ratio of specific heats.

In particular sections the above notation is used in conjunction with the indices:

O = inlet section
I = exit section
C = critical section (where $v_c = a_c$ or $M_c = 1$).

If there is a shock wave the conditions downstream are indicated by a dash.

1–3–2 Variables

The variables relating to the conditions in the critical sections are:

$\pi = p/p_c$ $\quad \alpha = a/a_c$
$r = \rho/\rho_c$ $\quad \nu = v/v_c$
$\tau = T/T_c$ $\quad \sigma = S/S_c$

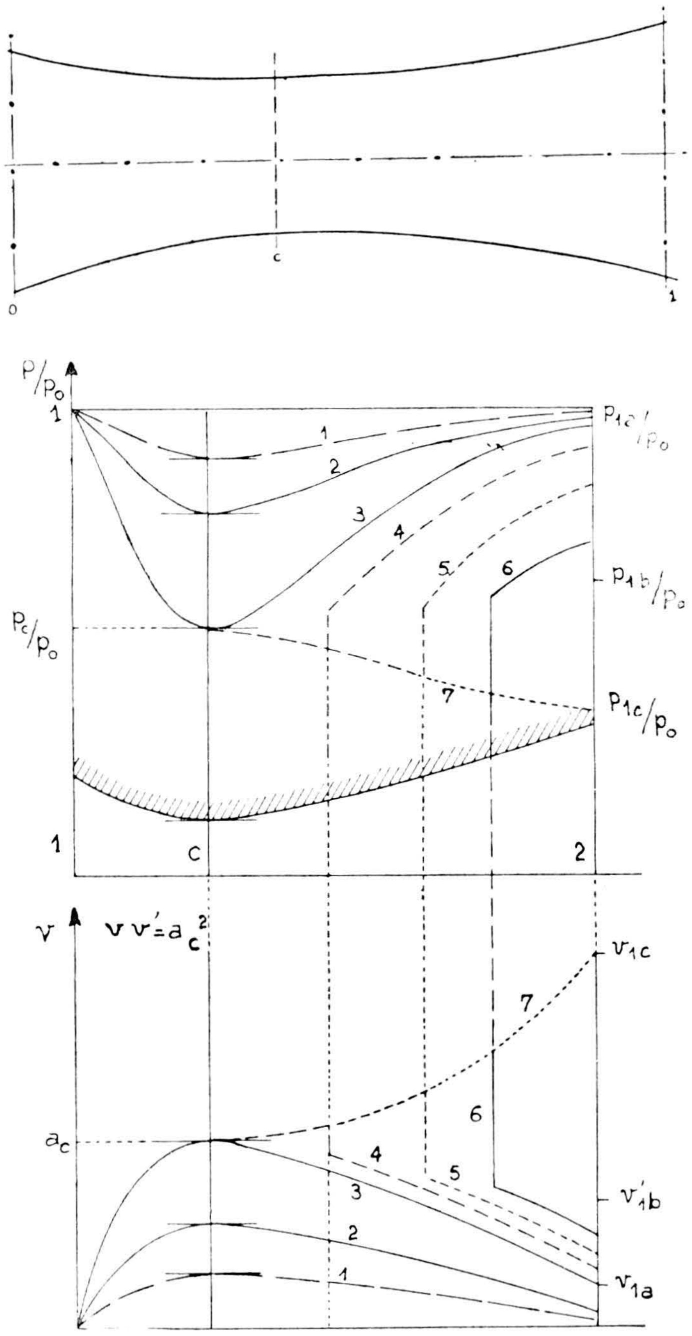

Fig. 1

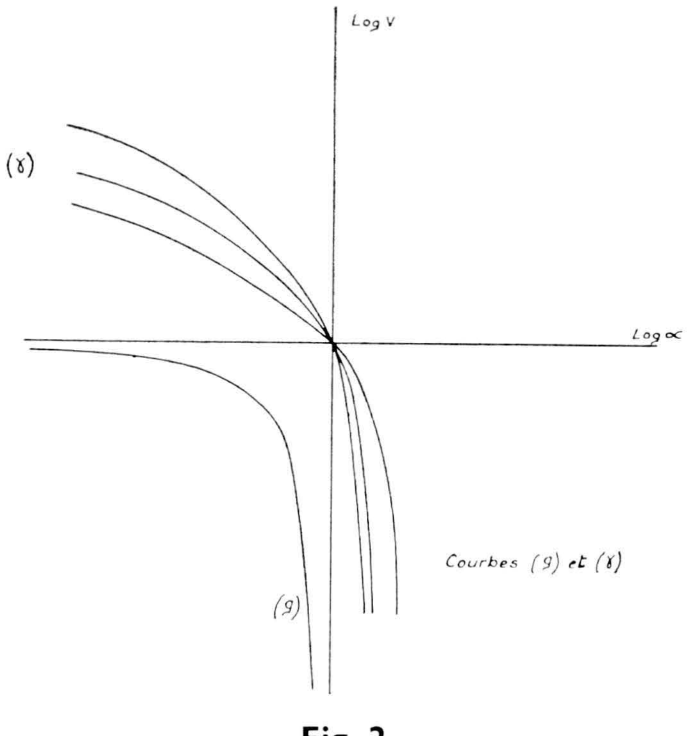

Fig. 2

2. EXPLANATION OF THE METHOD

2–1 Basis of Calculation

The fundamental equations are:
that of Saint Venant (conservation of energy)

(1) $a^2 + \frac{\gamma - 1}{2} v^2 = \frac{\gamma + 1}{2} a_c^2$

that of Gay-Lussac (perfect gases)

(2) $p : \rho R T$

that of Poisson (isentropic flow)

(3) $\frac{p}{p_c} = (\rho/\rho_c)^\gamma$

the equation of continuity

(4) $D = \rho S v$

the Mach number

(5) $M = \frac{v}{a}$

By using the variables:
$\pi = p/p_c$, $r = \rho/\rho_c$, $\tau = T/T_c$, $\alpha = a/a_c$, $\sigma = S/S_c$, $\nu = \frac{v}{v_c}$

equations (1) to (5) may be written

(6) $\alpha^2 + \frac{\gamma - 1}{2} \nu^2 = \frac{\gamma + 1}{2}$

(7) $\pi = r\gamma \quad \tau^{\gamma/\gamma - 1} = \alpha^{2\gamma/\gamma - 1}$

(8) $r\sigma\nu = 1$

(9) $M = \frac{\nu}{\alpha}$

2–2 The Selection of the Method of Representation

In a system of logarithmic co-ordinates equations (7), (8) and (9) are represented by straight lines so that it is natural to use this system.

Let the co-ordinates be α and ν. Once the (γ) curves of equation (6) have been plotted, the subsequent construction may be made with a ruler.

2–3 Plotting the Curves

In the usual system of co-ordinates equation (6) may also be written

(10) $\alpha^2 / \frac{\gamma + 1}{2} + \nu^2 / \frac{\gamma + 1}{\gamma - 1} = 1$

and represents an ellipse (Γ), but by changing the co-ordinates to

$$\alpha = \sqrt{\frac{\gamma + 1}{2}}\,\bar{\alpha} \qquad \nu = \sqrt{\frac{\gamma + 1}{\gamma - 1}}\,\bar{\nu}$$

equation (10) becomes

(11) $\bar{\alpha}^2 + \bar{\nu}^2 = 1$

This equation represents a circle (G) in the plane $\bar{\alpha}$, $\bar{\nu}$

If now we adopt logarithmic co-ordinates the corresponding curve (g) may be easily constructed by putting

$$\bar{\alpha} = \sin \phi$$
$$\nu = \cos \phi$$

ϕ being any angle.

The (γ) curves may be deduced from the curve (g) by changing the co-ordinates

$$\log \alpha = \log \sqrt{\frac{\gamma + 1}{2}} + \log \bar{\alpha},$$

$$\log \bar{\nu} = \log \sqrt{\frac{\gamma + 1}{\gamma - 1}} + \log \bar{\nu}$$

that is by a translation defined by the vector

$$\log \sqrt{\frac{\gamma + 1}{2}} \qquad \log \sqrt{\frac{\gamma + 1}{\gamma - 1}}$$

All the (γ) curves are equal. To construct the whole family it is therefore only necessary to plot (g); the remainder may then be traced. The (γ) curves obviously pass through the point ($\alpha = 1$, $\nu = 1$).

The range $\binom{\nu < 1}{\alpha > 1}$ corresponds to subsonic conditions and $\binom{\alpha < 1}{\nu > 1}$ to the supersonic conditions.

2–4 The Curves M = Constant

From (9)

$$\log \nu = \log M + \log \alpha.$$

The curves M = constant are therefore straight lines of slope +1, the ordinate at the origin being $\log M$. FIG. 3 shows the construction at the point P ($M = 2{\cdot}2$) on the curve (γ).

2–5 The Curves σ = constant

From (7) and (8)

$$\log \nu = -\log r - \log \sigma = \frac{2}{\gamma - 1} \log \alpha + \log \frac{1}{\sigma}$$

On a (γ) curve the points P (subsonic range) and P′ (supersonic range), where σ has a given value, fall on the straight line having a slope $-2/\gamma-1$ and the ordinate $\log 1/\sigma$ at the origin.

By varying (γ), the curves σ = constant may be plotted point by point.

2-6 The Practical Construction of the Diagram

On a sheet of logarithmic-scale graph paper, plot the (γ) curves as described. (Paragraph 2–3, FIG. 5 and PLATE I.)

For the convenience the α scale may be about eight times greater than the ν scale.

Using the same scales, plot on transparent paper, the straight lines (d) passing through the same point 0 and of slopes $\frac{-2}{\gamma-1}$ for the usual values of (γ), and a straight line of slope +1. This second sheet of paper need not be graduated; it being sufficient to indicate the co-ordinate axes (FIG. 6 and PLATE II).

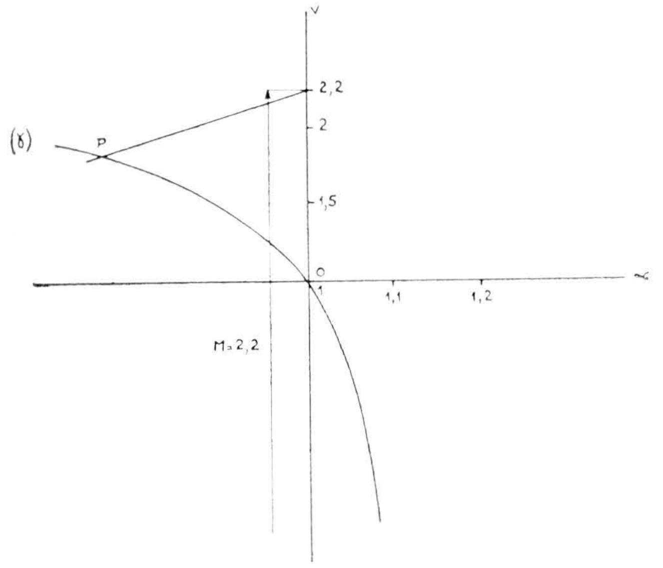

Fig. 3.—Construction of the point M = 2·2

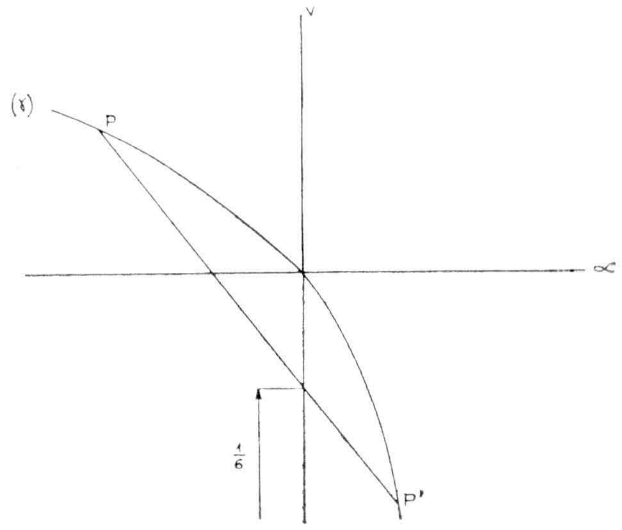

Fig. 4.—Construction of the point σ = constant

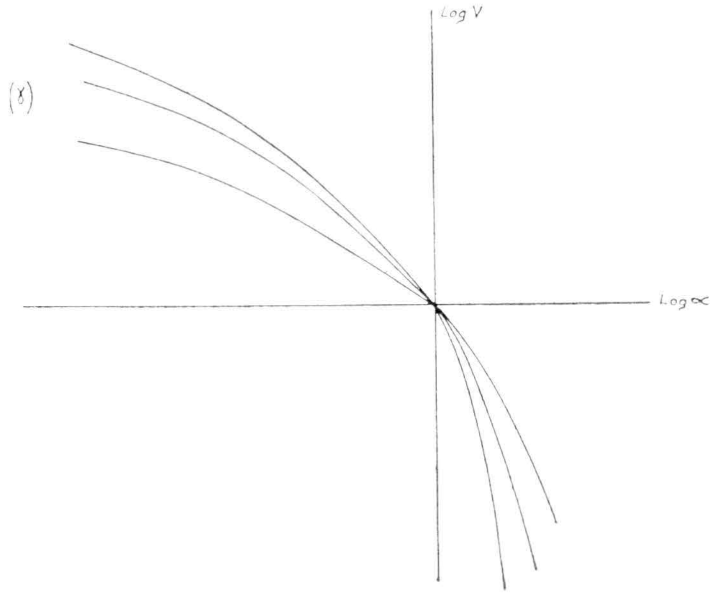

Fig. 5.—Family of γ curves

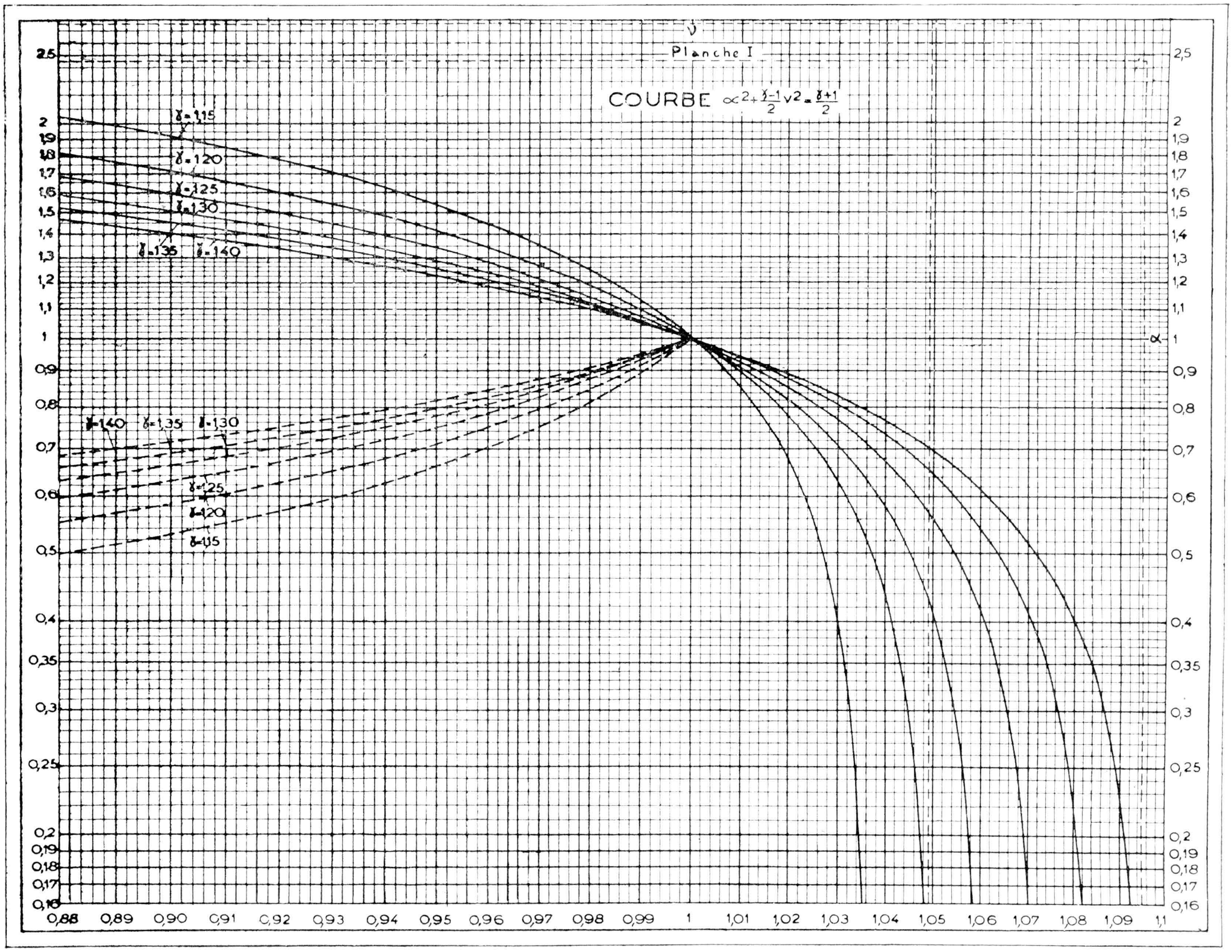

Plate I

The constructions described in paragraphs 2–4 and 2–5 are then effected simply by superimposing the two diagrams, the point 0 being placed wherever required on the ν axis.

In order to be able to calculate rapidly $\pi\rho\tau$ as a function of α trace on another logarithmic diagram the straight lines

$$\pi=\alpha^{\frac{2\gamma}{\gamma-1}},\qquad \rho=\alpha^{\frac{2}{\gamma-1}},\qquad \tau=\alpha^2$$

$$\log \pi=\frac{2\gamma}{\gamma-1}\log \alpha,\ \log \rho=\frac{2}{\gamma-1}\log \alpha,$$

$$\log \tau=2\log \alpha$$

(see FIG. 7).

3. EXAMPLES OF THE USE OF THE GRAPHICAL METHOD

3–1 The Flow in a Nozzle under Known Conditions

3–1–1 *Principle of Construction*

Knowing the initial conditions

a_0 v_0 ρ_0 p_0 S_0 and γ (FIG. 1)

it is necessary to determine

a v ρ p

at any point in the nozzle, as a function of S.

The entire flow can be determined by the construction described in paragraphs 2–4 and 2–5 if the conditions in a critical section a_c ρ_c p_c S_c are known.

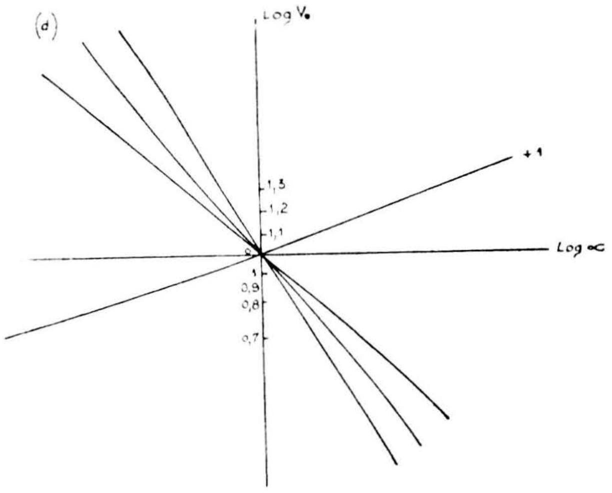

Fig. 6.—Transparency

This determination is simple since the Mach number at the intake is known:

$$M_0=v_0/a_0$$

(paragraph 2–4 and FIG. 8).

The values α_0 and ν_0 are read from FIG. 8, from which

$$a_c=a_0/\alpha_0=v_0/\nu_0.$$

The curves in FIG. 7 give

$$\rho_c=\rho_0/\alpha_0^{\frac{2}{\gamma-1}}\qquad p_c=p_0/\alpha_0^{\frac{2\gamma}{\gamma-1}}$$

Starting from P_0, the construction in paragraph 2–5 allows the determination of $1/\sigma_0$ (FIG. 9) from which

$$S_c=S_0/\sigma_0.$$

3–1–2 *Tuned Nozzles*

3–1–2–1 *Definition*

A nozzle is said to be tuned to a pressure ratio and to a given rate of discharge if there is no formation of shock waves, either inside the nozzle or at the exit section.

3–1–3 *Untuned Nozzles*

3–1–3–1 *Definition*

A nozzle is not tuned if a shock wave is produced in it or at the cross-section at the exit. This shock wave is due to the fact that the downstream pressure p_e is incompatible with an isentropic flow in the nozzle. This can only occur in supersonic flow.

FIGS. 1, *b* and *c* show the curves for the velocity and pressure in a convergent-divergent nozzle for different values of the exit pressure p_1, the inlet pressure p_0 being constant. Three different flow conditions are possible.

$p_e>p_{1a}$ (curves 1, 2 and 3). Flow always subsonic.

Tuned nozzle

$p_{1a}>p_e>p_{1b}$ (curves 4, 5 and 6).

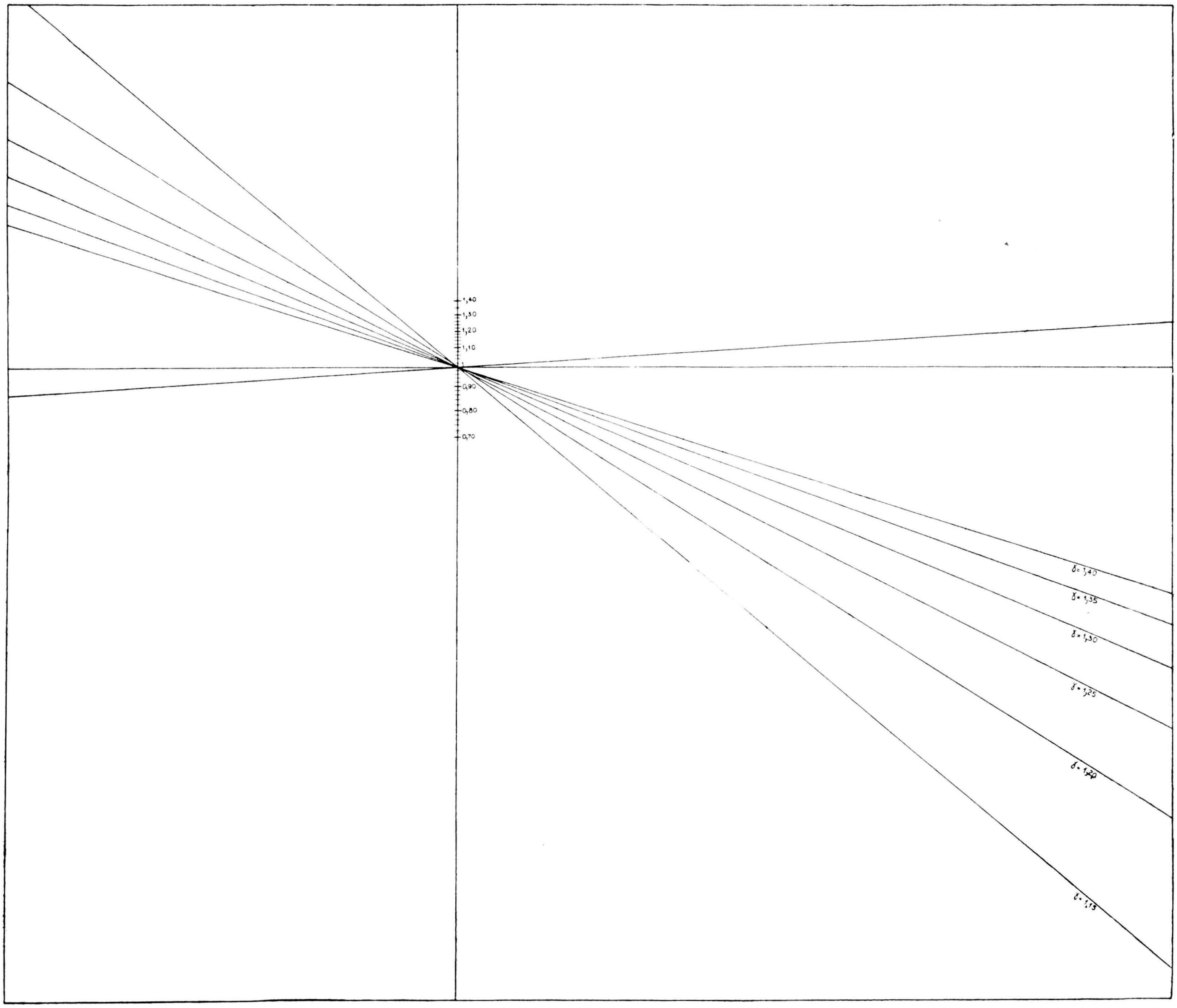

Plate II.—Transparency

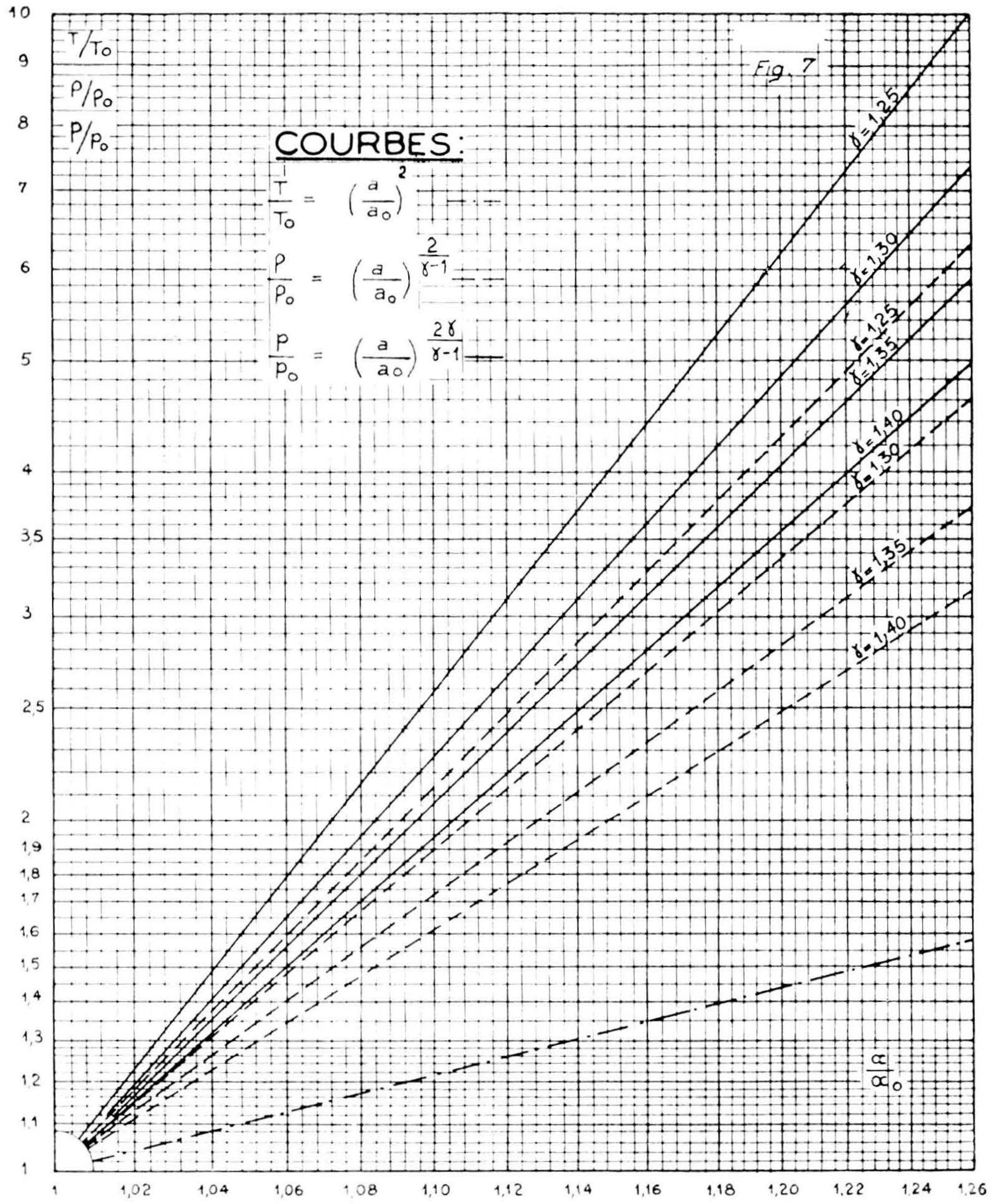

Fig. 7

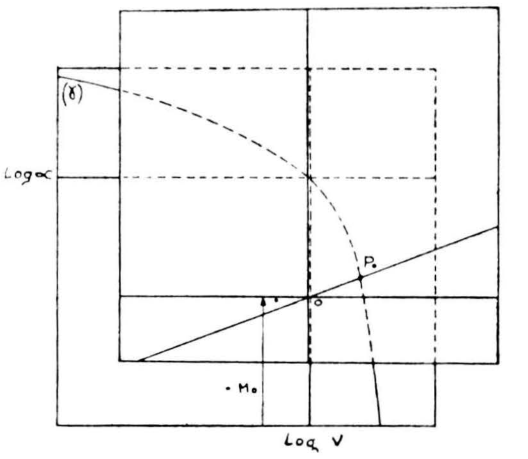

Fig. 8.—Construction of characteristic point P_o at the entry to the nozzle

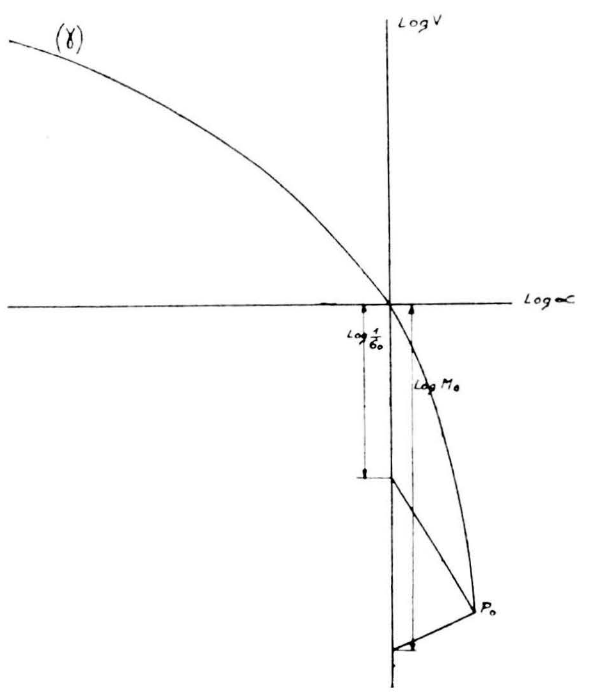

Fig. 12.—Supersonic nozzle determination of M_o

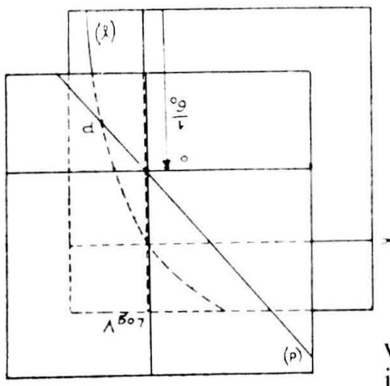

Fig. 9.—Construction of σ

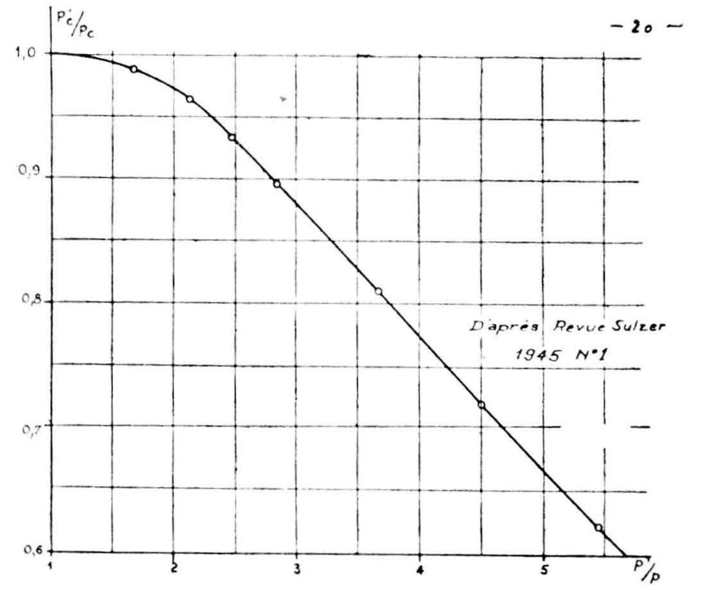

Fig. 10.—Ratio of critical pressures before and after shock. (Sulzer Review, No. 1, 1945)

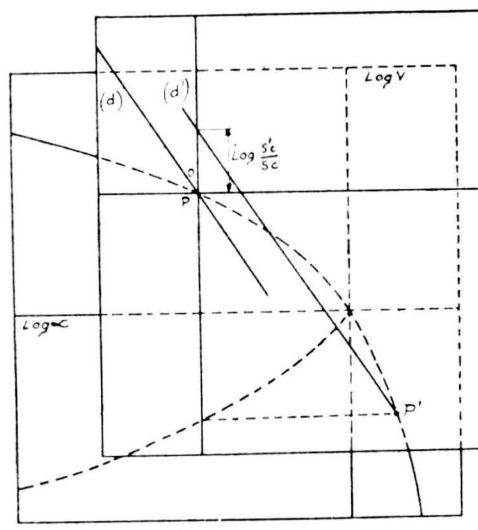

Fig. 11.—Construction of shock wave

After the throat the velocity exceeds that of sound but there is a recompression shock in the divergent section.

$p_{1b}>p_e>p_{1c}$ (curve 7).

For $p_e=p_{1b}$ a shock wave is produced in the exit section.

p_{1b} is determined in the following manner:

We know v'_{1b} from the Prandtl equation (paragraphs 3–1 and 3–2–1)

p_{1b} can then be deduced, using the Hugoniot equation.

For $p_{1b}>p_e>p_{1c}$, p_1 is constant and equal to p_{1c}; there is a compression wave in the exit section

$$p_e=p_{1c} \text{ (curve 7).}$$

Supersonic flow in the divergent section (tuned nozzle)

$$p_e<p_{1c} \text{ (curve 7).}$$

There is an expansion wave in the exit section.

3–1–3–2 *Construction of the Shock Wave*

3–1–3–2–1 *Principle*

The transformation between the two fronts of a shock wave being adiabatic but not isentropic, Poisson's law does not apply. On the other hand, Saint Venant's law (expressing the conservation of energy), Gay-Lussac's law and the equation of continuity are confirmed.

$$(1)\ a^2+\frac{\gamma-1}{2}v^2=\frac{\gamma+1}{2}a_c^2$$

$$(2)\ \phi=\rho RT$$

$$(4)\ D=\rho Sv=\rho_c S_c v_c.$$

The position of the shock wave will be entirely determined by equations (1), (2) and (4) and the Prandtl equation (11) which gives the relation of the velocities v before the shock wave and v' after it, to the velocity a_c in the critical section.

$$(11)\ vv'=a_c^2.$$

Using the variables mentioned in paragraph 1–3–2, the equations (1), (2), (4) and (11) may be written

$$(6)\ \alpha^2+\frac{\gamma-1}{2}\nu^2=\frac{\gamma+1}{2}$$

$$(7)\ \pi=r\tau$$

$$(8)\ r\sigma\nu=1$$

$$(12)\ \nu\nu'=1.$$

The problem to be solved is then:

to determine the position of the shock wave and to determine the flow after the shock wave.

In what follows, the conditions after the shock wave will be indicated by a dash, and the pressure in the exit section will be

$$p_1'=p_e$$

The shock wave produces an increase in entropy which results in a modification of the conditions in the critical section. However, according to equation (1)

$$\frac{\gamma+1}{2}a_c^2=a^2+\frac{\gamma-1}{2}v^2=a'^2+\frac{\gamma-1}{2}v'^2=\frac{\gamma+1}{2}a'^2_c$$

from which $a_c=a'_c$ $\qquad T_c=T'_c$.

But

$$p'_c<p_c, \qquad \rho'_c<\rho_c, \qquad S'_c>S_c.$$

However, for relatively small values of p'/p (less than 2·5, see FIG. 10), p'_c/p_c is very near a value of 1, which implies that the assumption of isentropic flow is very close to reality.

The course to be followed for the determination of the shock wave is then:

A preliminary determination of the shock wave (isentropic flow) allows the calculation of a first value of p'/p, and from it, p'_c/p_c, $\rho'_c/\rho_c=(p'_c/p_c)^{\frac{1}{\gamma}}$, S'_c/S_c, so that, knowing

$$a'_c=a_c \qquad T'_c=T_c \qquad p'_c\ \rho'_c\ S'_c$$

it is possible to obtain the second approximation.

With a sufficient number of approximations the position of the shock wave will be obtained with any accuracy desired.

In practice the first approximation will be sufficient for shock waves of small amplitude $p'/p<2{\cdot}5$). It is rarely necessary to have to use the third approximation.

3–1–3–2–2 *The Method of Construction*

3–1–3–2–2–1 *First approximation*

The conditions at the throat being known as well as the pressure at the exit p'_1, we may deduce, under the assumption of isentropic flow:

$$\alpha'_1=(p'/p_c)^{\frac{\gamma-1}{2\gamma}}$$

and the point ρ'_1 on the (γ) curve which will determine σ' (FIG. 10).

As S'_1 is known we may deduce

$$S'_c=S'_1/\sigma_1'.$$

The shock wave will be produced at a point PP' (P upstream of the shock, P' downstream) for a section S.

The values of σ (upstream of the shock) and of σ (downstream of the shock) are

$\sigma=S/S_c \quad \sigma'=S/S'_c$ from which $\sigma'/\sigma=S_c/S'_c$ and $\log\sigma'-\log\sigma=\log S_c/S'_c$.

The point PP' is defined by the condition (12) $\nu\nu'=1$.

The construction is effected in the following manner:

On the transparent paper previously used a straight line (d') is drawn parallel to (d) (FIGS. 6

(*Concluded on p.* 314)

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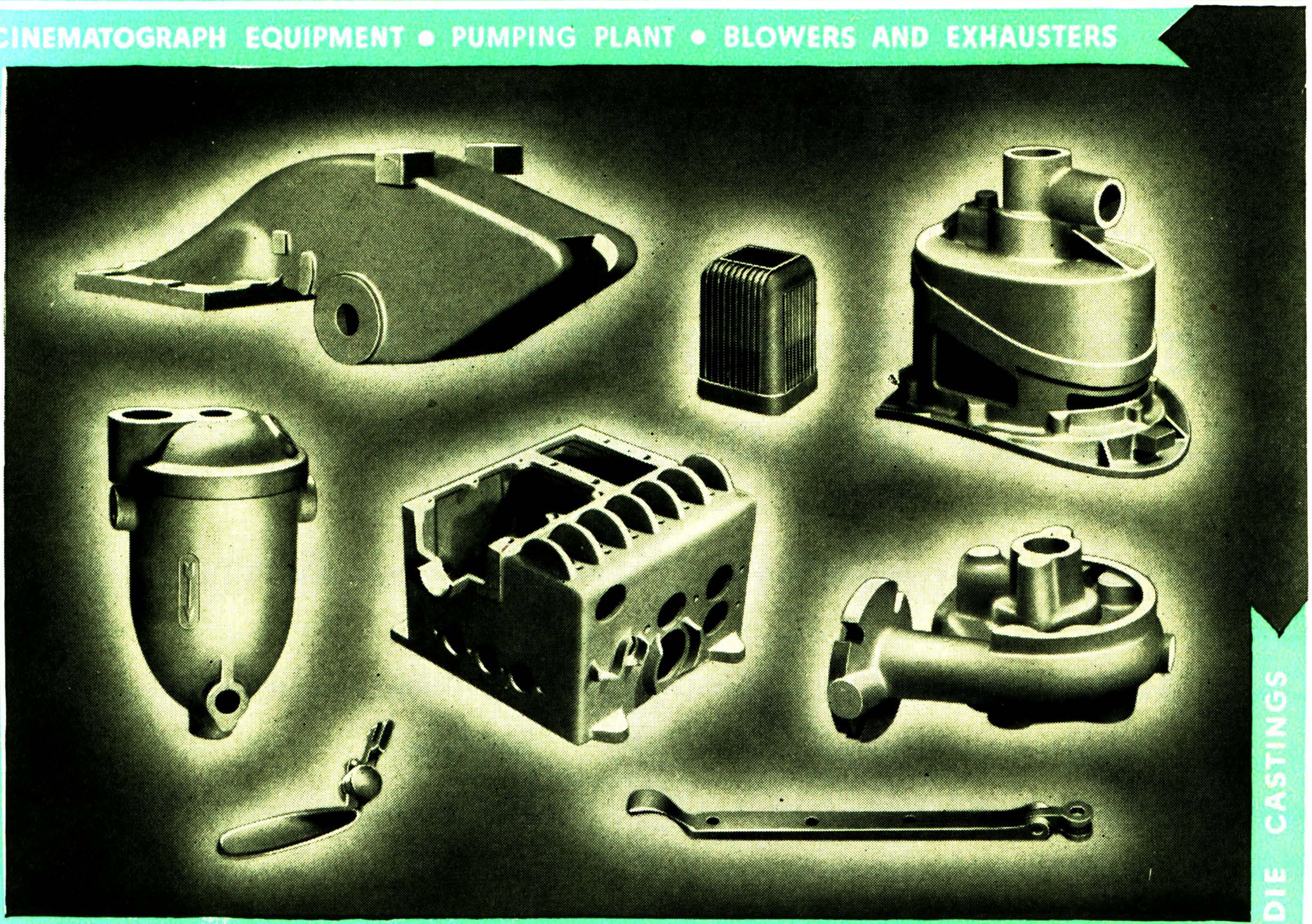

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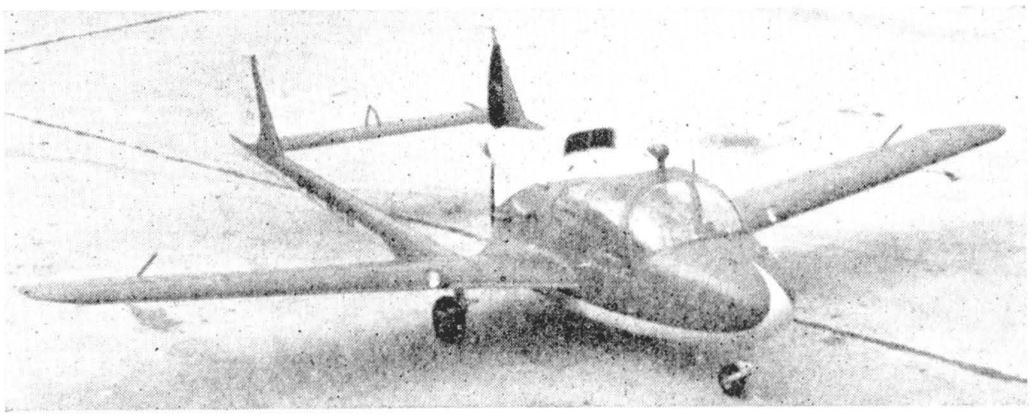
Aircraft Manufacture in the Netherlands

An Account by the Technical Editor of the Activities of the Reconstituted Aircraft Industry, with Particular Reference to the Manufacture of the Fokker Promotor



We have already given particulars of the post-war organization of the Netherlands aircraft industry in AIRCRAFT ENGINEERING: how the types to be produced are decided upon by a board, the Nederlands Instituut voor Vliegtuigontwikkeling, and are then developed and built by the factories of the centralized company N.V. Verenigde Nederlandse Vliegtuigfabrieken 'Fokker', consisting of the works of Fokker, Aviolanda and de Schelde.* This arrangement was adopted in order to avoid duplication and also to allow the State to help toward the high cost of the development of the modern prototype.

The reorganized Fokker company retains most of the technical staff of the firm whose products were in world-wide use before the war. It will be recalled that, in addition to building their own designs, the company had the European licence for the Douglas DC-3. Now, in the post-war phase, much of their initial work has consisted in the overhaul and conversion of Dakotas, Skymasters and Beechcraft for civil use. In addition, the firm has acquired the European licence for the North American Harvard and part of their works is occupied with machines of this type that are being overhauled and modified. Other licences are those for our own Hawker Sea Fury and the Gloster Meteor, which are both being built as part of the plan for the unification of equipment in the forces of Western Europe.

Part of the works has also been engaged in that trusty stand-by of the aircraft industry, the manufacture of bus bodies, and a high output of very smart buses is still being delivered from the factory. In addition to this productive work, which was put in hand as soon as the devastated factories had been rebuilt in 1946, the company has large overhaul contracts for the Dutch Army and Navy Air Services and the Norwegian, Belgian and Swiss Air Forces. Further, a large number of sailplanes and gliders has been built.

Design work, too, has not been allowed to lapse and, in addition to the series production of the Promotor, the S.11 trainer has been completed and flown. Design work is also in hand on a twin-engined trainer and a jet trainer, while studies have been made on several civil projects.

Part of the organization of the Netherlands aircraft industry provides for the repair of all large aircraft by Fokker, while the smaller machines are serviced by an associated company, Avio Diepen N.V. of Ypenburg, near the Hague. This latter company also handles all small engine overhauls and repairs (large engines go to the workshops of K.L.M.) and acts as the selling agent for the Promotor to private owners.

In point of fact, the Promotor was built to the requirements of Mr F. Diepen, managing director of Avio Diepen and Aero-Holland, who wanted it for air-taxi work. During the occupation a machine of similar layout was built secretly in a garage by an engineer working for Mr Diepen. This aeroplane, the Difoga, was a two-seater pusher with a converted Ford Vee-eight engine and, while it was too underpowered to be practicable, it did prove the suitability of the tail boom low-wing layout for taxi work. One of the features that both Fokker and Avio Diepen were determined to achieve was to build a small aeroplane which could be entered without the contortions and effort usually required. This result has been admirably achieved in the Promotor and we feel that it was an end that was well worth the sacrifice of some performance. In addition to easy entry, the cabin is exceptionally comfortable, and the view is quite outstanding, both for pilot and passengers.

With an initial order for the taxi fleet of Avio Diepen, the Fokker works went ahead with the prototype F.25, which was shown at the 1946 Paris Salon, where it created a very favourable impression.† After extensive flight trials the machine was put into production and only when a representative production machine was available did the firm send it on a demonstration tour in Europe during the past summer. Recently, through the courtesy of the Fokker company, we had the privilege of seeing the manufacture of the Promotor and also of flying their demonstrator.

Conditions in Europe are too unsettled for the marketing of small aircraft on a large scale, and although the Promotor is wanted in several countries, the difficulties of import licences precluded the preparation of a large series. Even so, the production methods employed are of considerable interest and the following notes give a fairly complete picture of the work.

Structural Design

The Promotor is of composite construction. The one-piece wing is of wood and has a D-spar torsion box, light lattice ribs and plywood covering aft with a light rear spar carrying the ailerons and split flaps. The fuselage is also of wood, with a strong floor cell and lighter upper sections. The tail plane and elevator, rudder and ailerons are of wood, while the fin, tail booms, flaps and power unit are metal. The general construction of all the parts can be seen from the photographs.

The Wing

The wing structure is reminiscent of the pre-war Fokker wooden wings and is based upon a sturdy box spar made with booms of 10 mm. thick pine laminations and diagonal birch-ply webs. After completion as a unit, the ply angle gussets for the ribs are attached in the final jig and, after key

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* See AIRCRAFT ENGINEERING, Vol. XVIII, December 1946, p. 407.

† See 'The Seventeenth Salon', AIRCRAFT ENGINEERING, Vol. XIX, Jan. 1947, pp. 4-5.

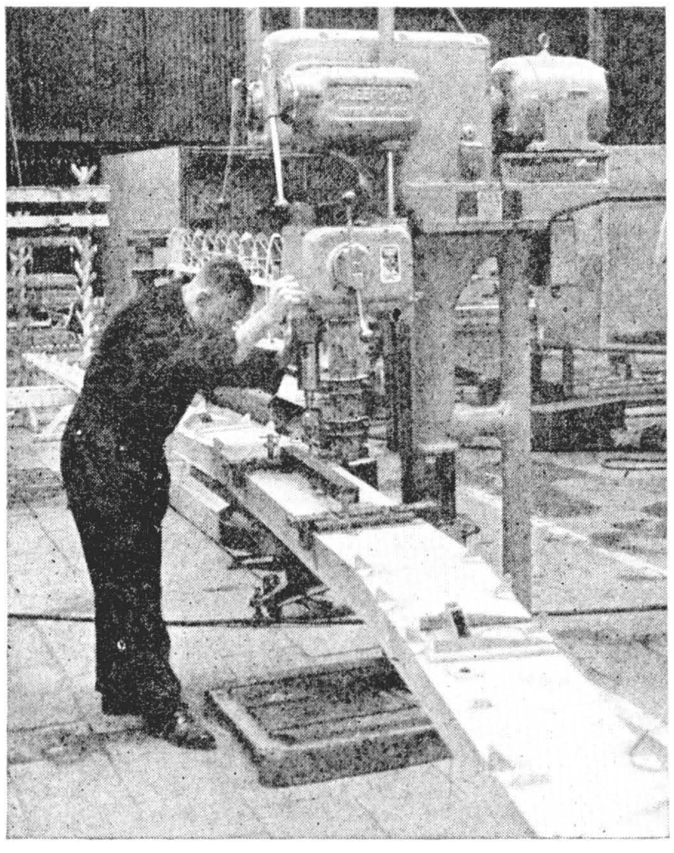
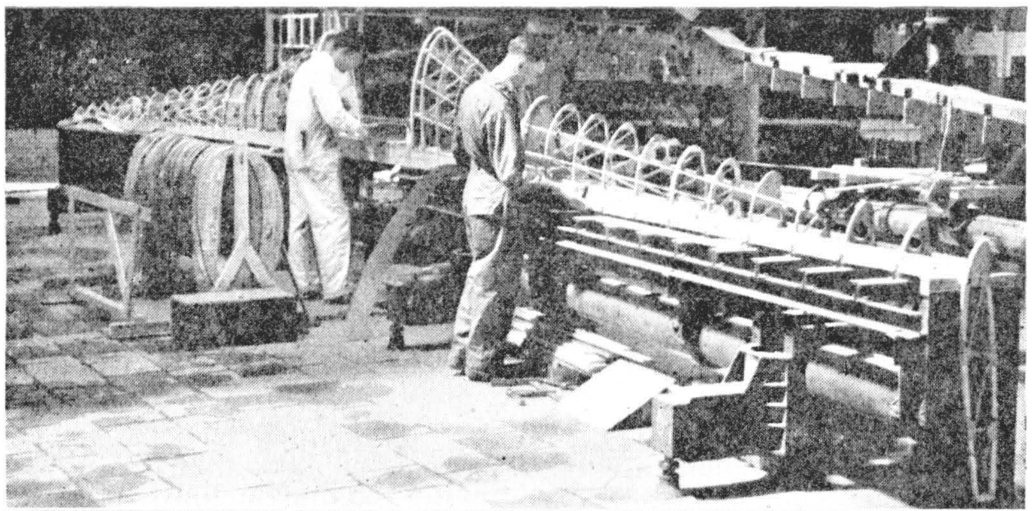
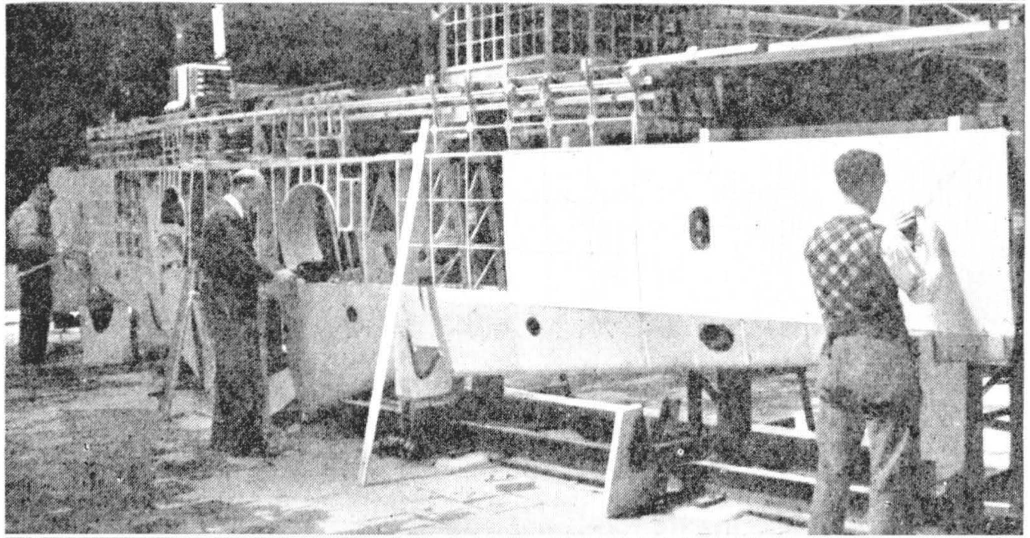


Fig. 1.—Jig drilling the fuselage attachment fitting bolt holes in the pine and birch ply box main spar of the Fokker Promotor

PRINCIPAL CHARACTERISTICS

Engine	Lycoming O-435-A
Type	air-cooled, horizontally-opposed, six cylinder
Max. output, sea level	190 b.h.p. at 2,550 r.p.m.
Propeller	Aeromatic, automatically variable pitch
Dimensions and Weights	
Span	12·0 m. (39 ft. 4 in.)
Length	8·5 m. (28 ft. 0 in.)
Height	2·64 m. (8 ft. 8 in.)
Wing Area	17·9 sq. in. (193 sq. ft.)
Tare Weight	960 kg. (2,115 lb.)
Fuel and Oil	125 kg. (278 lb.)
Pilot, Passengers and baggage	340 kg. (747 lb.)
Gross weight	1,425 kg. (3,140 lb.)
Performance	
Max. speed, sea level	227 km.p.h. (141 m.p.h.)
Cruising speed, 1,000 m. (3,300 ft.)—	
at 75 per cent power	209 km.p.h. (130 m.p.h.)
at 60 per cent power	185 km.p.h. (115 m.p.h.)
Stalling speed	85 km.p.h. (53 m.p.h.)
Range	790-950 km.p.h. (490-590 miles)
Climb to 1,000 m. (3,300 ft.)	6·2 min.
,, ,, 2,000 m. (6,550 ft.)	15·1 min.
,, ,, 3,000 (9,800 ft.)	30·1 min.
Service ceiling	3,400 m. (11,150 ft.)
Take-off to clear 15 m. (50 ft.), no wind	540 m. (1,770 ft.)
Landing over 15 m. (50 ft.), no wind	350 m. (1,150 ft.)





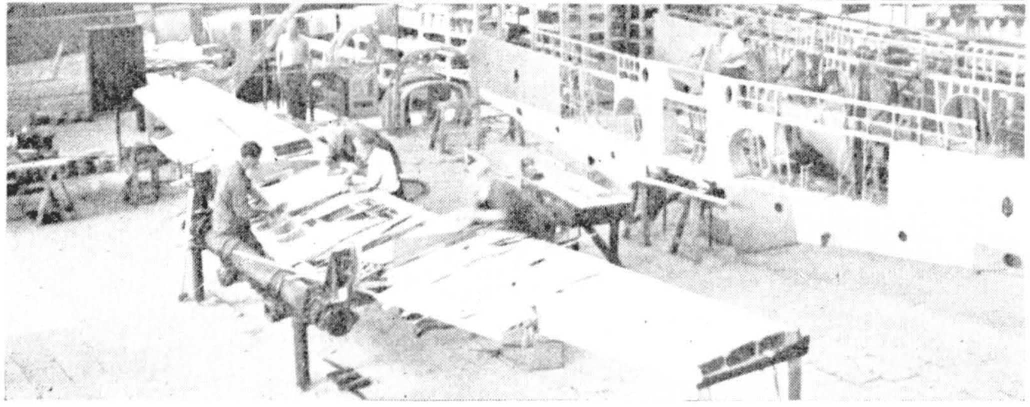


Fig. 2 (top).—Henschel standard type of jig used for the assembly of the leading edge torsion section to the box spar. Note that the tip rib is a one-piece part

Fig. 3 (centre).—With the leading edge inverted the ribs, spanwise stringers and rear spar are built on to the front spar and skinned with diagonal ply

Fig. 4 (bottom).—The wing is turned into flying position for the finishing work, which includes the completion and skinning of the upper surface of the centre section and the building up of the tail boom roots

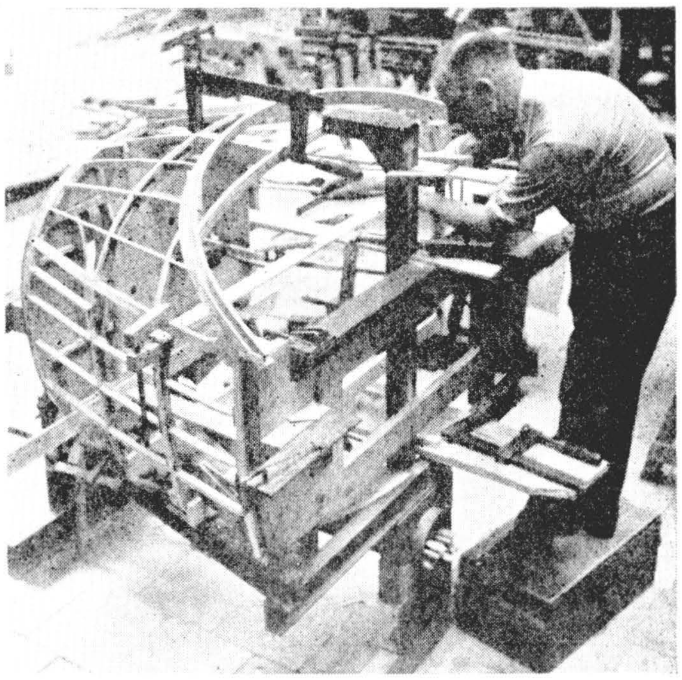


Fig. 5.—The fuselage nose is built on a rigid metal jig to ensure perfect interchangeability; the structure is fairly normal wooden practice

location points such as the fuselage attachment and the undercarriage bracket holes have been jig drilled (FIG. 1), the spar is put into the leading edge assembly jig, FIG. 2. Here the leading edge ribs—mainly pine lattice ones, but with full birch-ply webs at strong points—are lined up and glued to the ply-angle gussets. The stringers are next fitted and the preformed diagonal plywood skin is strapped down for gluing—the Aerolite gluing process being used on this as on all similar joints. The nose skin is 1·2 mm. thick, with an increase to 2·5 mm. on the swept forward portion at the root where the loads are taken from the wheel openings aft of the spar.

Digressing for a moment, it will be noticed that the leading edge assembly jig is mounted on a tubular frame and standard feet of the Henschel type.* Throughout the Fokker works the standardized Henschel tubes, feet and clamps are in general use for the main framework of jigs, although the smaller details are made up from channels, angles, etc., as in this country. It will be recalled that in France, too, the Henschel 'standards' are in fairly general use for the basic framework of jigs.

When the leading edge has been completed it is inverted and placed in the main assembly jig (FIG. 3) where the light rear spar and ribs are built on to it. The wheel opening is built up on this jig, but the two heavy ribs that form a box carrying the undercarriage loads are made up first as a unit. After attachment of the lateral stringer strips, the diagonal birch-ply skin is glued and held down by slats and brads, which are afterwards removed. General skin thickness is only 0·8 mm., but a very high standard of workmanship has resulted in a very good flat surface.

For finishing, the wing is put into the horizontal fixture shown in FIG. 4, where it is supported by trestles at the tips and is held firmly by the fuselage attachment points and tail boom locations. The central support of this jig is also made from Henschel units and it is worth noting that, because of the rigidity of the large diameter tubes and the adjustable feet on the uprights, no grouting is necessary even for a jig of key importance such as this. As can be seen from the photograph, the top skin of the central part of the wing is completed here and the tail boom roots are built into place. Over

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* See 'Henschel Theories on Production', Vol. XI, Oct. 1939, pp. 395-397, and 'The Jigging of Modern Airframes', Vol. XIII, April 1941, pp. 112-114.

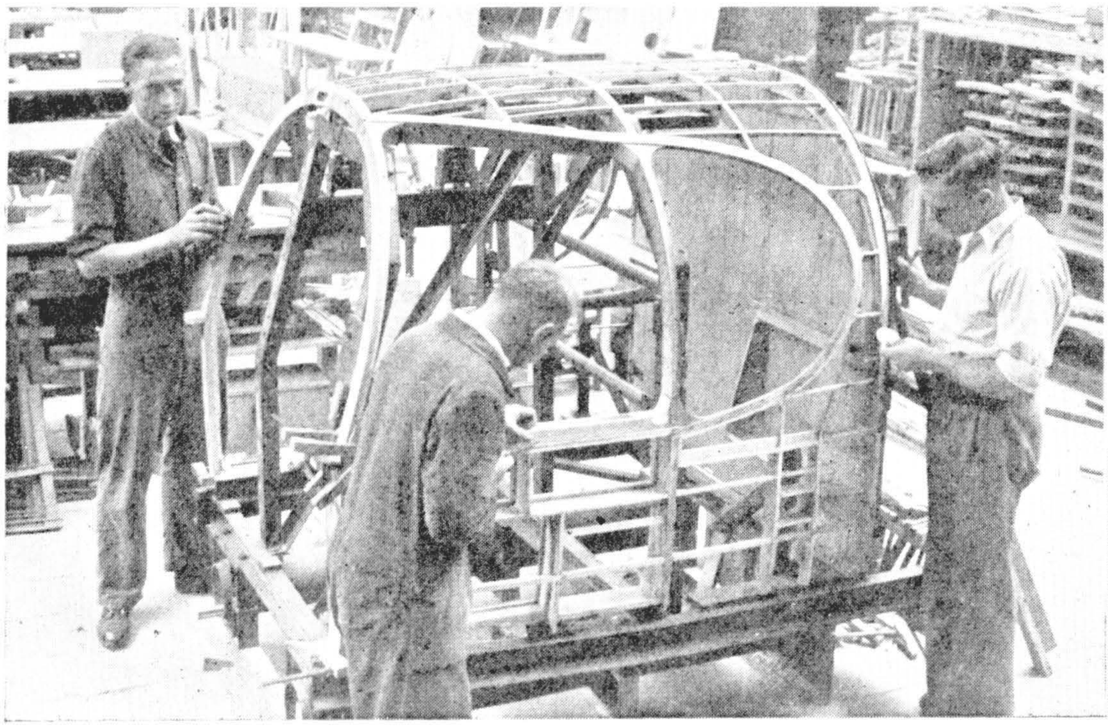


Fig. 6.—The jig for the cabin supports the parts from the inside. This photograph shows the structure clearly, in particular the complicated curved laminated window and door frames

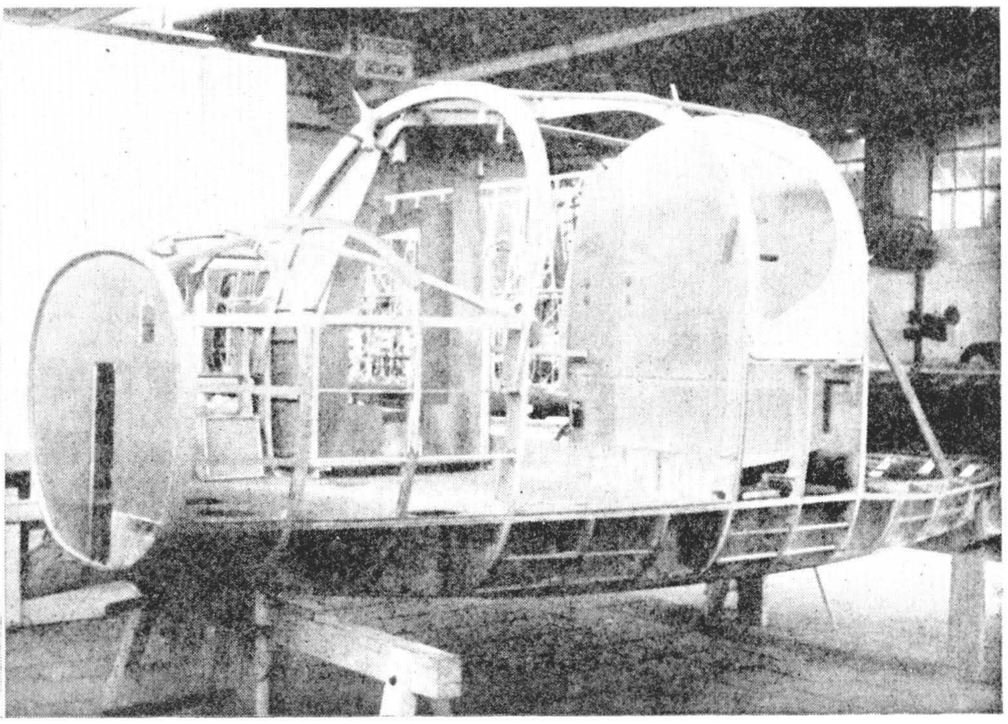


Fig. 7.—This photograph shows the prototype fuselage assembled before skinning; the keel members in particular should be noted

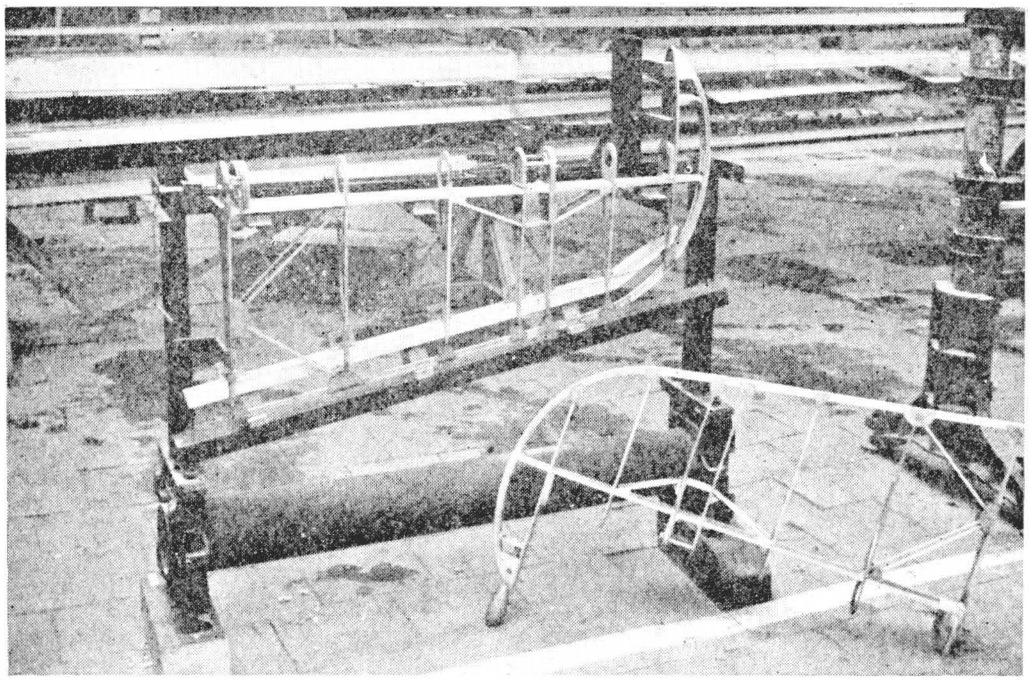
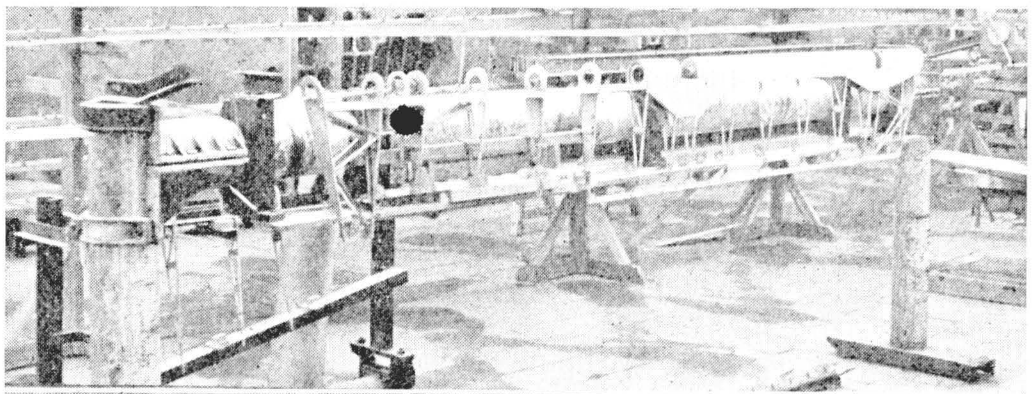


Fig. 8.—The conventional wooden rudder framework is built on a jig made from Henschel units



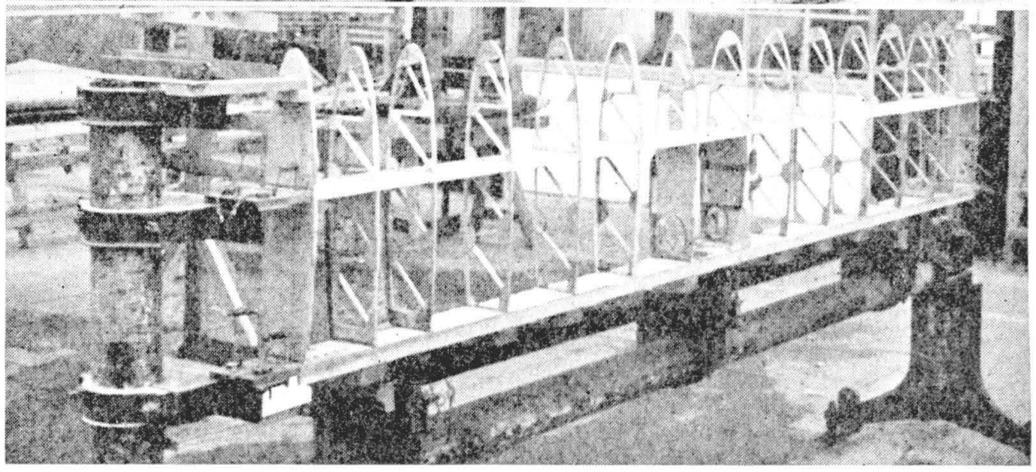


Fig. 9 (top).—This partially completed elevator in its jig shows that the structure is similar to that of the rudder

Fig. 10 (bottom).—The lattice ribs of the tail plane are threaded over the front spar and are spaced by capping strips. The jig controls the component from the spar end fittings and the control hinges and bracket

the top of the wing at the fuselage bays is placed a turned steel and asbestos fireproof shield.

The Fuselage

There are three jig-drilled units that form the fuselage: floor, nose and cabin. The floor has been designed as the main load-carrying unit and is considered to be strong enough to act as a skid in the crash-landing case. There are two keel members running the whole length that are built up like wing box spars with laminated pine booms and birch-ply webs. In the top boom the laminations are horizontal throughout, but in the lower one, because of a double curvature, they change from horizontal to vertical half-way, the joint between the two being a long scarf. Cross members of the floor are mainly box ribs between the keel, with lighter ones outside. The floor itself is fitted in the assembly jig, but the skinning is not done until final assembly of the fuselage.

The nose of the fuselage is made up in a metal jig, FIG. 5, with a plywood front bulkhead, built-up wooden frames, the laminated coaming arch and pine stringers. Here it might be mentioned that jigging of wing ribs, formers and bulkheads is, like their structure, conventional enough. The laminated curved members, such as this coaming and the door frames, are clamped to wooden formers by closely spaced C-clamps while the glue sets. The parts are then hand finished to templates.

In FIG. 6 can be seen the main portion of fuselage under manufacture. This is similar to the nose, save for being more complicated because of the curved door and window frame-members. The framework is built up piece by piece on to the plywood and tinned steel firewall at the rear. Normally the unit, like the nose section, is completed and skinned before being removed from the jig. The photograph that makes FIG. 7 is not of a production fuselage, but is of the prototype; final assembly of the three fuselage units on production takes place when they are fully complete as components, see FIG. 18. The main juncture is made by bolting together by metal fittings attached to the main frame members. After bolting together the components, the joints are covered by broad plywood strips scarfed to the skin. Finishing work then starts, with the lining of the shell by glass-wool blankets and the fitting of control brackets, etc.

Two interesting details on the fuselage are the use of large diameter hollow bolts on attachment fittings between the fuselage components and the bushing of the wing attachment holes in the fuselage keels with light alloy tubing—both simple methods of increasing bearing area in the wood.

Flying Controls and Tail Plane

The flying controls and the tail plane are all of wooden construction, FIGS. 8, 9 and 10. The tail plane is quite conventional, with two single webbed pine and ply spars and one-piece lattice ribs. Solid web ply ribs are used at the ends and in the centre to take the control loads. The tail plane is controlled during assembly by the end fittings, hinges and control bracket. After assembly of the ribs to the spars the skin of diagonal birch ply is glued in place in sections—the trailing edge being left proud for the forming of the elevator shroud after removal from the jig.

The elevator and rudder, which have radiused leading edges, are typical wooden components, as may be seen from FIGS. 8 and 9. The simple ply and pine spar is threaded with the ribs and capping strips are glued to the booms to bring them level with the rib booms. The leading edge is wrapped with ply and the whole covered with fabric. The tubular jigs for these

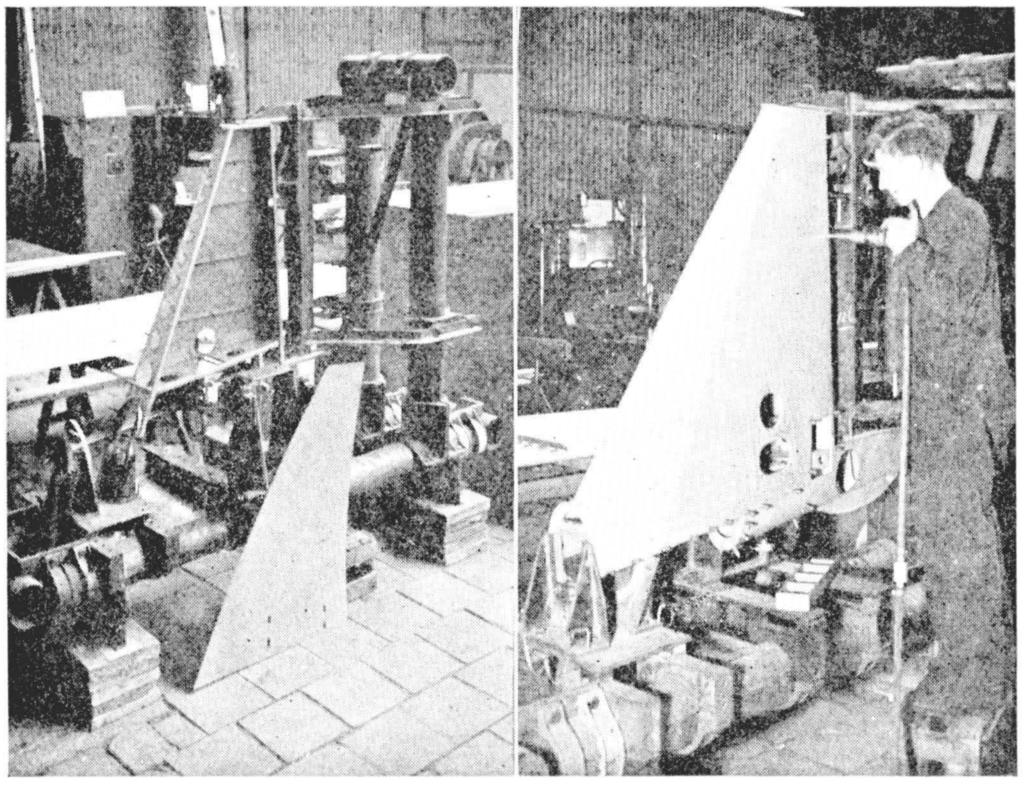


Fig. 11.—The fin structure is an interesting example of simplification. The two spars and two ribs, jig drilled as details, are assembled before being put into this jig where they are skinned and the leading edge and lower portion (bumper) are added

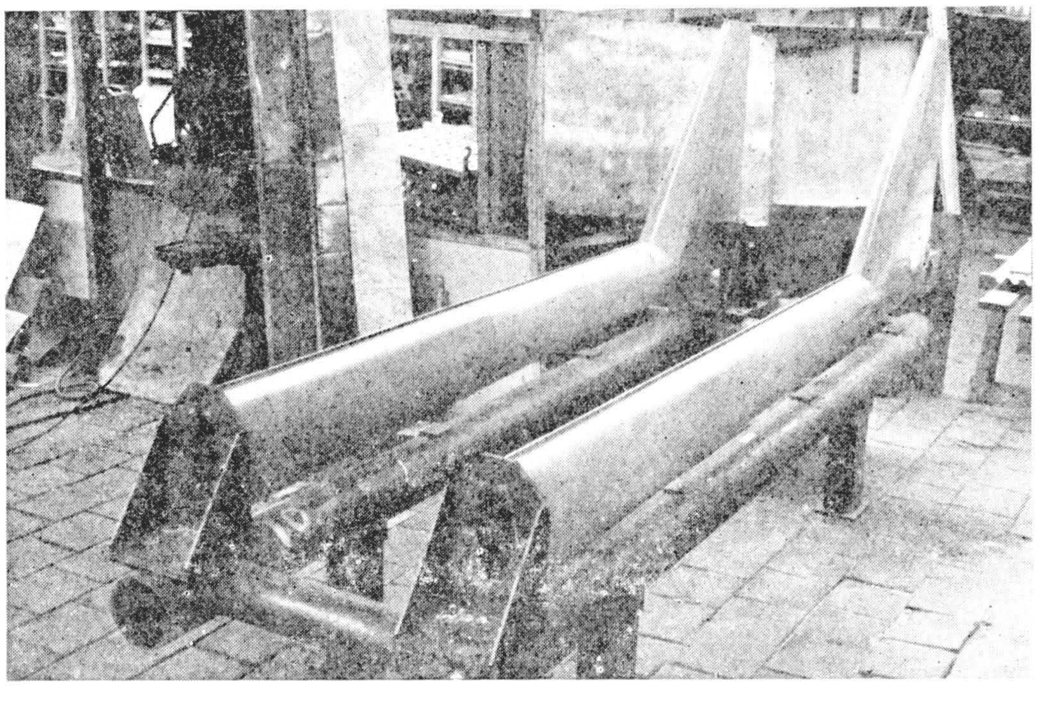


Fig. 12.—Final assembly jig for the fins and tail booms; although generally symmetrical, the access doors to the controls and the tail plane fittings make the parts handed, so that two jigs are required

Fig. 13.—The door is large and of a rather complex shape, so that careful jigging is necessary

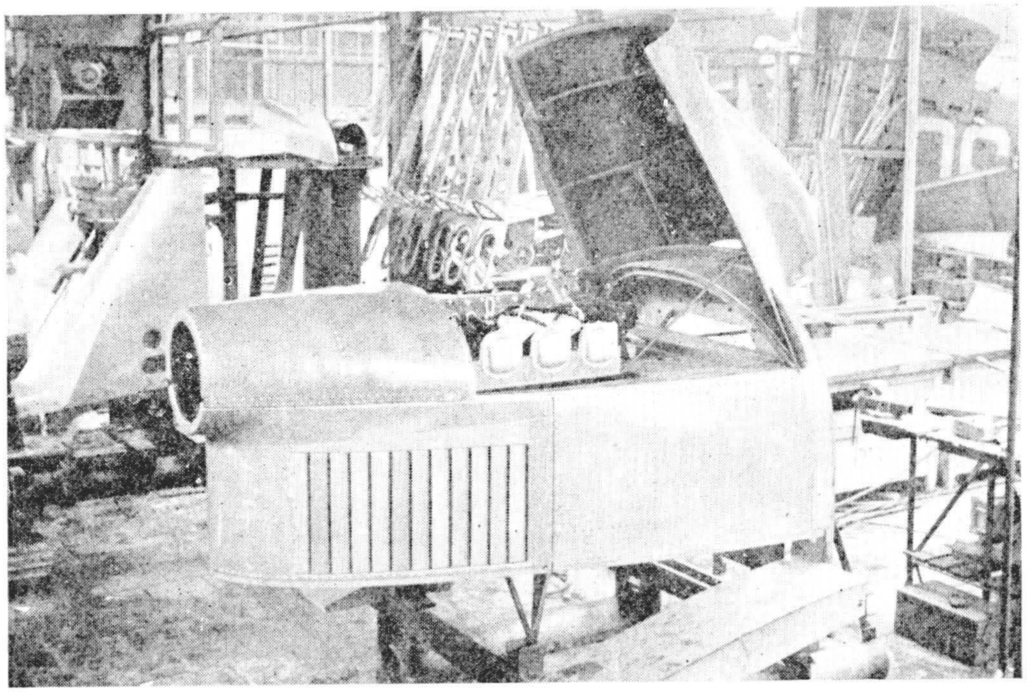


Fig. 14.—The power plant is an exceptionally neat and compact unit. The engine is held by four bolts and the engine mounting is itself attached to the airframe by four bolts. The power unit can be taken complete from this final assembly jig and mounted direct on the airframe

components look startlingly massive in comparison with the slender wooden structures they support, but it must be remembered that some 90 per cent of the jig is ready for re-use and that its assembly was merely the bolting together of the standards.

The aileron, of which, unfortunately, we have no photograph, is more unusual in construction. It has a 'square' leading edge, being hinged to the wing at the upper surface, and the spar and two skins form a triangular box without internal structure. The spar is a ply web with pine booms and to it are glued the two flat skins, upon the inner surfaces of which are glued chordwise pine stiffener strips.

Metal Components

If the aileron is a wooden counterpart of the modern 'simplified structure', the fin is a good example of it in metal, FIG. 11. The kingpost and front spar are simple flanged alclad blanks, and with two end ribs of similar form and two skins with four L-section chordwise stiffeners they form a complete torsion box. The blanks are routed and hand formed on blocks, because the production run of Promotors scarcely warranted the making of press tools. Built into the bottom of the fin are the ground bumper and the end of the tail boom structure. In the second view in FIG. 11 the row of rivets at the bottom secures one flange of an Ω-section longitudinal stiffener continued from the boom.

The tail booms, FIG. 12, have to be particularly carefully jigged since the slightest error would throw the whole tail unit out. Each boom consists of two half shells with three intermediate half ribs to stabilize the skin. The half shells are made from 24 ST Alclad rolled to shape and with the keel flanges turned up on a folding press. This shell is put into a jig, where it is held by profile boards while the half ribs and longitudinal Ω-section stiffener are secured to it by pin and latch clamps for drilling and riveting. The keel flanges of the two halves are joined by riveting and at each end a complete oval former is riveted in place. The boom is then put up in the jig shown in FIG. 12 where it is joined to the fin.

The cabin door (FIG. 13) is another carefully jigged metal component, since it has to be an interchangeable spare, as well as to fit perfectly. The channel sections that form the greater proportion of the parts are formed by hand on bending blocks, being afterwards trimmed to templates. The jig illustrated is for final assembly. The nose-wheel door, adjustable pilot's seat and passengers' seats are made in a similar fashion from hand-formed parts with careful assembly jigging.

The power plant is a unit consisting of the welded tubular engine mounting, extension shaft and its welded supporting framework, horizontal cooling baffle and a series of hinged or removable cowling panels. The whole is assembled on a jig, FIG. 14, before being put into the airframe. The welded mounting is conventional and carries the flat-six Lycoming engine high above the wing so that there is ample space for accessories and the whole interior of the power plant is remarkably accessible. The airscrew extension shaft—necessitated by the need for refining the lines of the rear fuselage—is a machined steel unit consisting of a short female-splined shaft with a four-point spider universal coupling to a further male-splined shaft upon which the airscrew hub is mounted. The welded support (FIG. 15) for the rear bearing is attached to the engine crankcase by four bolts.

Cooling air is taken in by the scoop at the top and after passing over the engine is drawn out by the louvers in the lower rear cowling panel. Both rear panels are easily removable, while the three front ones are hinged at their forward ends and open easily to give exceptionally easy access to the whole engine bay. The fasteners on the power plant, and on most other panels on the Promotor, are of the Dzus type.

The split flaps are of the simplest possible design. Since they are parallel in chord, the sheet can be cut on a guillotine and the spar is a simple folded Z-section that is riveted, together with the piano hinge, to the leading edge. The trailing edge is again folded from strip, this time to a J-section, and the ribs are simple Z-sections. Assembly of this simple structure by riveting is quite straightforward.

An excellent maintenance feature of the Promotor is its lift-up fuselage nose that lays bare the nose-wheel mechanism, electro-hydraulic unit, flying controls and the rear of the instrument panel. This nose panel is made from two light alloy spinnings (FIG. 16) riveted together and stiffened by internal angle members. The nose of the fuselage with the cowling

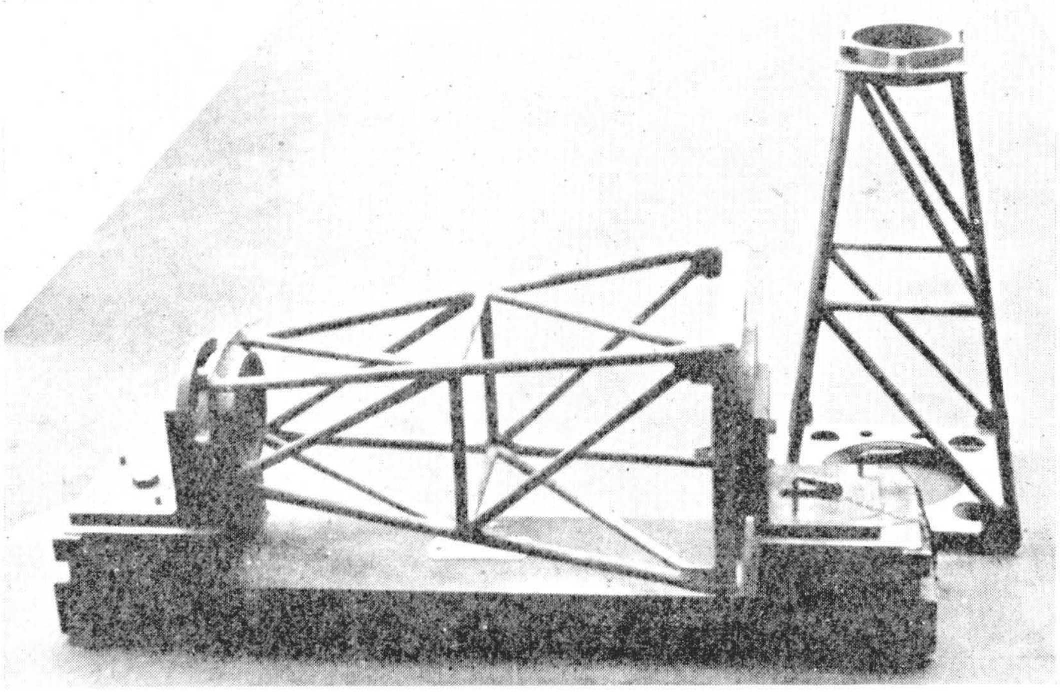


Fig. 15.—Final checking jig for the airscrew extension shaft supporting structure

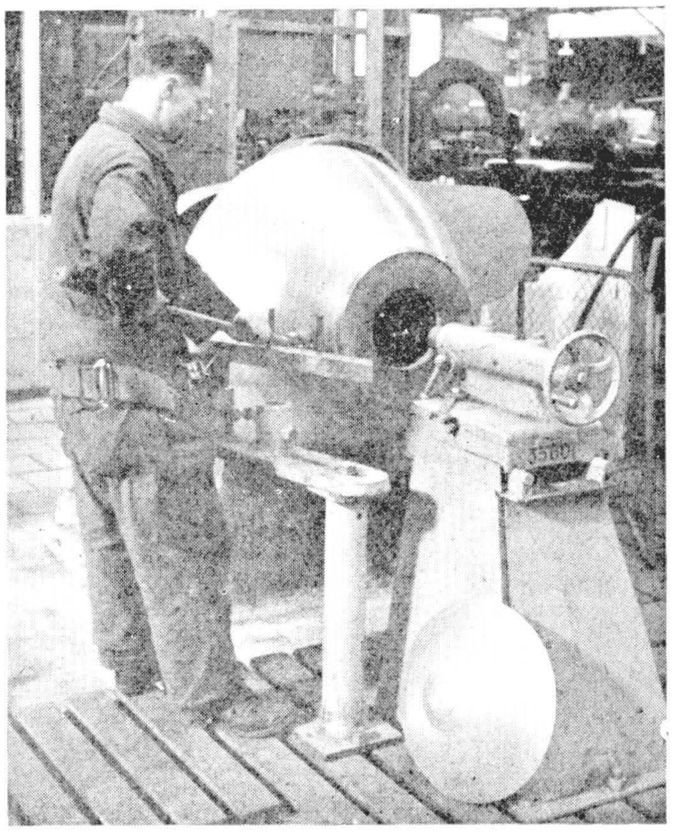


Fig. 16.—Spinning the main part of the nose cowling. The actual front plate is shown in the foreground

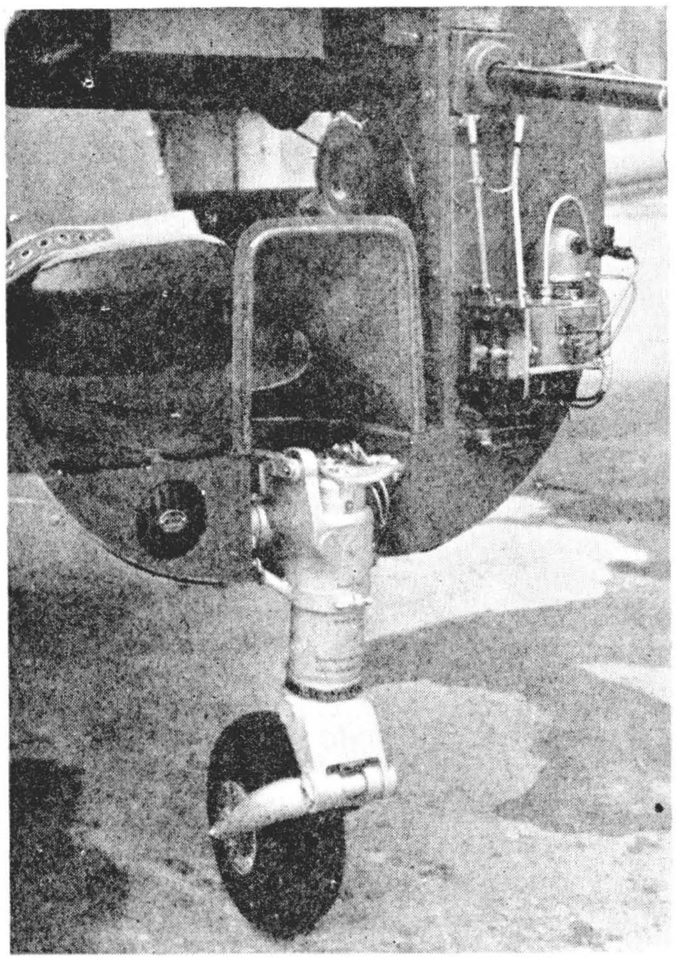


Fig. 17.—The front bulkhead of the fuselage, showing the electro-hydraulic pump unit, Dowty nose-wheel leg and mounting and the end of the control column

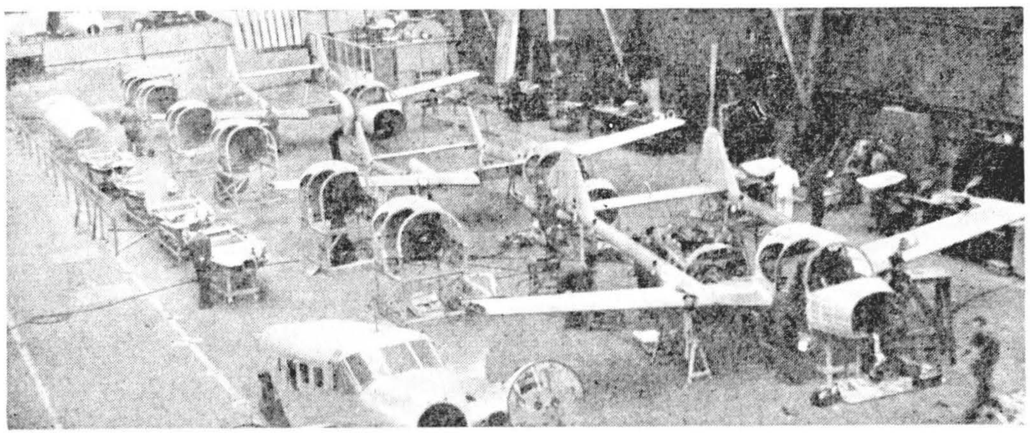


Fig. 18.—The fuselage assembly line and part of the final assembly line for the Promotor. The power plant, in this case with the cowling panels removed, is about to be mounted on the machine in the foreground

lifted is shown in FIG. 17. This view shows how neatly the equipment is fitted. During assembly the controls and other units are made up as assemblies wherever possible and are complete when installed. The Dowty nose-wheel leg, for instance, is made up complete with its sand-cast magnesium mounting bracket and the retraction assembly before installation. In passing, it might be mentioned that such fittings as the rudder pedals and brackets, control hinge brackets, etc., are magnesium sand castings.

Final Assembly

FIG. 18 is a general view of the final assembly line—alongside which can be seen the assembly line for the fuselage. The wing is first mounted in flying position and then the tail booms and tail plane are bolted together before the whole is offered up to the wing and joined to it by the rings of bolts at the boom juncture. Next the finished fuselage is bolted to the wing to complete the main structure.

Control surfaces and flying control cables are next added; pulleys and all brackets, etc., are inserted in the sub-assembly stage. The Goodyear Pliocel flexible fuel tank, which rests in a well-ventilated cell under the passenger's seat, is added and then the interior finishing of the fuselage proceeds. The Dowty undercarriage and the flaps are operated by an American electro-hydraulic system designed by the Adel Precision Products Co. The electric motor and pump are mounted on the front fuselage bulkhead (FIG. 17); the 12-volt motor provides a working pressure of 300 lb./sq. in. The undercarriage is raised and lowered by direct operating jacks, while the flaps are worked by a central jack that actuates toggle linkages through a push-pull tube. Points of interest in the undercarriage are the steerable nose-wheel, that is disconnected for take-off and landing, and the pedal operated Goodyear single-disk brakes on the main wheels. As the machine proceeds down the assembly line it is kept jacked up in flying position high enough to allow retraction tests, etc. Although there are a lot of operations on this final assembly line—power plant assembly with its Graviner fire extinguisher, electrical installation, hydraulics, final preparation for painting, etc.—the machines did not appear unduly crowded and work seemed to be going ahead smoothly and at a good pace. One's general impression throughout the Fokker works was the industrious way in which the work was carried out and, in particular, we were impressed by the artisan quality of the woodwork.

In conclusion we should like to express our thanks to the directors and staff of N.V. Verenigde Nederlandse Vliegtuigfabrieken Fokker for their kindness in granting us facilities for our visit and for supplying us with the photographs which form the illustrations to this article.

JAMES HAY STEVENS

R.Ae.S. LECTURE PROGRAMME

THE following programme of lectures for the Autumn 1948 Session has been arranged by the Royal Aeronautical Society.

Unless otherwise stated, lectures will be held at 6 p.m. in the Lecture Hall of the Institution of Civil Engineers, Great George Street, London, S.W.1 (by permission of the Council of the Institution). Tea will be served at 5.30 p.m.

Thursday, October 21: Cold Weather Operation of Aircraft by G. W. Wilson and Sqdn-Ldr E. P. Bridgland.

Thursday, October 28: Aircraft Engineering and Production by a member of the staff of Handley Page Ltd.

Saturday, November 20: Full day discussion on Helicopters. (Joint Meeting with the Helicopter Association.)

Morning Session

11 a.m.: The Operational Point of View by Wing-Comdr R. A. C. Brie

11.30 a.m.: The Technical Point of View by Capt R. N. Liptrot

12 noon: Discussion

1 p.m.—2.30 p.m.: Luncheon Interval (Members should make their own arrangements)

Afternoon Session

2.30 p.m.: The Fairey Gyrodyne by Dr J. A. J. Bennett

3 p.m.: The Bristol 171 Helicopter

3.30 p.m. The Cierva Air Horse by J. S. Shapiro

4 p.m.: Discussion

4.30 p.m.—5 p.m.: Tea Interval (Tea will be provided at the Lecture Hall)

Evening Session

5—6.30 p.m : General Discussion and summing-up by the Lecturers and the Chairman.

Thursday, November 25: Development of the Armstrong Siddeley Mamba Engine by W. H. Lindsey

Thursday, December 2: Problems in the Development of a New Aeroplane by G. R. Edwards

Thursday, December 16: Present Thoughts on the Use of Powered Flying Controls in Aircraft by D. J. Lyons

S.B.A.C. SCHOLARSHIPS AND GRANTS

The Society of British Aircraft Constructors announces that the following candidates have been successful in obtaining the Society's 1948 University scholarships and Educational Grants:

University Scholarships: A. H. Eldridge (A. V. Roe & Co. Ltd.), J. E. Hart (Boulton Paul Aircraft Ltd.), and C. Faulkner (Saunders-Roe Ltd.), all to the College of Aeronautics; D. L. Lofts (De Havilland Engine Co. Ltd.), to the City and Guilds College.

Educational Grants: Miss J. A. Rowland, winner of the Society's 1948 Amy Johnson Scholarship, is to be apprenticed to the English Electric Co. Ltd.; Miss M. O. Legg, already employed as a technical assistant in the Aerodynamics Department of Vickers-Armstrong's Supermarine works, will continue her training with the company; D. J. Leahy (Sir Nigel Norman Scholarship) is to be apprenticed to Vickers-Armstrongs Ltd., Weybridge. The Selection Committee recommended that K. L. C. Legg and J. Speechley, who were awarded scholarships last year, take the Second Year Course at the College of Aeronautics.

In the selection of candidates for the Educational Grants and administration of the awards, the Society is assisted by the Royal Aeronautical Society.

The Educational Grants, first awarded in 1937, are intended to encourage the recruitment of engineering apprentices to the aircraft industry.

University Scholarships assist those engineering or student apprentices in the aircraft industry who, because of their outstanding ability, are selected to be sent on to a university. So far, 91 awards have been made. Of these, 86 have been for men, eight being University Scholarships, and five have been for women, including three Amy Johnson Scholarships.

The Amy Johnson Scholarship was instituted in 1945 after discussions between the Women's Engineering Society and the S.B.A.C., and was the first women's scholarship to be offered by an engineering industry. It is awarded annually to help the selected woman train as an aeronautical engineer over a period of four to five years. With all the awards goes a reasonable living allowance.

The Library Shelf

Theory of Limit Design. By John A. van den Broek [John Wiley: Chapman & Hall. 30*s.*]

Reviewed by W. S. Hemp

THE 'Theory of Limit Design' is a theory whose philosophy and methods will be familiar to most aeronautical engineers. The term 'Limit Design' may not be familiar and so it is probably necessary, before making comments upon the theory, to give a short résumé.

Résumé of the Theory

The 'Theory of Limit Design' is a theory of the design of structures under their ultimate loads. Like the Theory of Elasticity, it bases itself upon considerations of equilibrium and continuity of displacement, but replaces the simple Hooke's Law by a generalization, which allows for unlimited ductility at a 'yield stress'. The stress-strain diagram is thus assumed to consist of two straight lines—one with a slope equal to Young's Modulus passing through the origin, while the other is a line of constant stress equal to the yield stress.

Application of the basic assumptions is usually made *only* to conditions of ultimate load. Thus, in the case of a bar in tension, eccentricities, minor defects and initial stresses are ignored, and when ultimate conditions are reached, a uniform distribution of stress across the section is assumed, equal, of course, to the yield stress. Similar conditions of uniformity are assumed in way of a bolt hole. Where the Theory of Elasticity gives magnification factors, the Theory of Limit Design supposes that ductility has removed the lack of uniformity, before the ultimate load is reached. In the same way a line of rivets is assumed to share the transmitted load equally, whereas Elasticity Theory concentrates the load at the ends.

In the case of a beam, the usual assumption of linear variation of direct strain leads ultimately to a condition in which the section divides into two regions of constant stress, one tensile and one compressive and both equal to the yield stress. When this condition is effectively reached at a section, further increase in curvature will take place at *constant* bending moment. This result may be applied to redundant systems—for example, doubly clamped or continuous beams. In the former case, when the loading is uniform the conclusion is reached that ultimately the bending moment at the centre will equal the clamping moments, both being equal to the limiting moment for the section. This is again in contradiction to Elasticity Theory.

Similar arguments may be applied to frameworks, but here, in addition to load limitation due to yielding, one has to consider cases of buckling as struts. However, experiment shows that the load-compression relation for slender struts is of the same form as the stress-strain relation assumed in Limit Design Theory. The basic theory is therefore still applicable and one concludes that, in the case of a redundant framework under increasing load, successive members yield or buckle until the whole structure becomes determinate and does not fail until a further member reaches its ultimate load. In this case, as previously, continuity of displacement is ensured by the ductility of the material.

These considerations lead to what is the central doctrine of the theory. This states that in the design of a redundant structure the magnitudes of the redundant loads may be chosen by the designer. His choice will be guided only by such considerations as weight saving or economy. There is no need to perform the, often elaborate, calculations demanded by the Theory of Elasticity. Knowing his load distribution the designer then chooses the sizes of the members of his structure so that they will just carry the required loads. The result is a structure which is capable of carrying the loads demanded of it and which will indeed carry those loads in the manner assumed, just prior to failure. At the ultimate load, the distribution of load among the members will be determined by their relative strength, rather than by their stiffness.

Commentary

(*a*) Aircraft designers are required to show that their structures will meet two stressing conditions. They have to demonstrate that no serious permanent deformation will result from the application of a Proof Load, as well as to show that failure will not occur at any load less than a certain Ultimate Load. To ensure satisfaction of the Proof Requirement the appropriate theoretical method would seem to be the Theory of Elasticity, combined with certain allowable stresses which will be the yield or proof stresses for the materials concerned. It is in calculations for the Ultimate Requirement that the methods of Limit Design are appropriate if at all. However, if, as it must be confessed is often the case, the assumption is made that compliance with the Ultimate Condition implies satisfaction of the Proof Condition, then Professor van den Broek's opinion, that the Theory of Elasticity has held its dominant position in engineering practice too long, would seem to be worthy of serious consideration.

Although as yet not formally compelled by Requirements, aircraft engineers are giving serious consideration to failure by repeated loads. Regions of plastic flow undoubtedly play a crucial part in this type of failure, but they may well be quite small in extent, so that the governing stress distribution will be more accurately calculated by Elasticity methods rather than by Limit Design.

(*b*) The method of design which proceeds from a chosen load distribution to a structure capable of carrying these loads, will be recognized by all aircraft stressmen as perhaps the most important part of their stock in trade. The theorem, that a structure is strong enough if there exists a statically correct diffusion of load which does not fracture any component or joint, is the foundation upon which all difficult stressing is based. This is 'pure Limit Design'. The aircraft engineer may well join the civil engineers, who after having a lecture by van den Broek, realized that 'they had known it all the time'.

(*c*) In all fairness it should be stated that the technical foundations used in the Theory of Limit Design have, of course, appeared before in other places under the titles 'Plasticity', 'Stressing Beyond the Elastic Limit', etc. The significance of van den Broek's work may be described as the systematic development of an 'Ultimate Strength of Materials'. The development of solutions to problems involving more than one component of stress would, however, fill what is quite a serious gap in this theory.

(*d*) The Theory of Limit Design stands or falls by its assumption of ductility. This is clearly justified for structures made of mild steel. The important question for aircraft design is, of course, whether it is justified for aluminium and magnesium alloys. Professor van den Broek gives experimental evidence, consisting of tests on beams, to show that his theories are justified for these materials.

There is much discussion these days of the possibility of producing alloys with larger values of Young's Modulus. If this is to be achieved it will probably be at the expense of ductility. An important question for the future of Limit Design is the determination of the amount of ductility (elongation) which is necessary for the theory to work satisfactorily. This merges with the larger question of the significance of ductility in structural design. It has doubtless saved many stressmen's skins, but to date it has never entered quantitatively into design.

Professor van den Broek draws attention to the need for ductility in the attachment of the members of a structure designed by the methods of Limit Design. It is doubtful whether this ductility is present in aircraft riveted joints and it is undoubtedly absent in spot-welded or reduxed joints. The rule that a line of rivets ultimately transmits load uniformly is certainly untrue for a redux joint.

(*e*) The theory, that the ultimate strength of a structure must of necessity be estimated by such methods as Limit Design, is by no means universally valid in aircraft design. An aircraft structure may well fail by flexural instability of its stringers or general instability of all its reinforcing members at stresses below the elastic limit. In this case stress calculations based upon the Theory of Elasticity would seem appropriate.

(*f*) The application of Limit Design to frameworks requires a knowledge of the post-buckled behaviour of struts. This problem presents no difficulty for slender struts, but, as experimental results given by van den Broek show, there is an appreciable drop in load after buckling for struts of medium length. This is a class of problem which previous design methods would not have brought to the forefront. As van den Broek continually emphasizes, it is entirely a matter of 'sense of value'.

Conclusions

The following conclusions would seem to be admissable as to the significance of Limit Design for the aircraft engineer:

(*a*) The Theory of Limit Design is valid for orthodox structures made from mild steel.

(*b*) Although the aircraft designer often makes use of these methods, they are by no means universally valid and may often, when applied to joints, be positively dangerous.

(*c*) It may perhaps be proper for a civil engineer to forget much of his Theory of Elasticity, but the aircraft engineer must continue his studies, since many of his problems fall into that field. The consideration of plastic stress distributions must continue to occupy the attention of the aircraft engineer, but they cannot, as Professor van den Broek advocates, replace his other techniques.

BOOKS RECEIVED

All books received from Publishers are listed under this heading. Extended reviews of a selection are published later. Inclusion in this list, therefore, neither implies nor precludes, in any particular instance, further notice.

Bulletinul Institutului National de Cercetari Tehnologica. Vol. I, Nos. 1-4, 1946. Paper bound, 139 pages, illustrated. [Institut de Recherches Technologiques de Roumanie, Str. Matei Millo, 7, Bucharest. Free.]

Bulletinul Politehnicii Gh. Asachi din Iasi. Tome 2, Fasc 2, July-December 1947. Paper bound, 356 pages, illustrated. [L'Ecole Polytechnique, Jassy, Roumania. Free.]

Standard Valves. [Standard Telephones and Cables Ltd., Connaught House, Aldwych, W.C.2. 15*s.* 6*d.* post free.]

The Workshop Yearbook and Production Engineering Manual. II. H. C. Toun. 549 pages illustrated. [Paul Elek. 35*s.*]

Bulletin de l'Institut National de Rêcherches Technologiques de Roumanie. Vol. II, 1947, Nos. 1-4. Paper bound. 244 pages illustrated. [The Institute, Str. Matei Millo, 7, Bucharest. No price stated.]

Supercharging the Internal Combustion Engine. E. T. Vincent. 314 pages illustrated. [McGraw-Hill. 30*s.*]

Aeronautical Conference, London, September 1947. J. L. Pritchard and J. Bradbrooke. 704 pages illustrated. [Royal Aeronautical Society, 4 Hamilton Place, W.1. Members 52*s.* 6*d.* Non-Members 72*s.* 6*d.*]

The Sealing Mechanism of Flexible Packings. C. M. White and D. F. Denny. Paper bound, 112 pages illustrated. [H.M. Stationery Office. 10*s.* 6*d.*]

Undercarriages for Deck Landing

Special Design Features with Particular Reference to the Vertical Velocity of Descent at Touch-Down

By J. W. Blinkhorn, B.Sc., A.F.R.Ae.S.

1. Introduction

FOR landing on aerodromes, aircraft undercarriages are now designed to give a certain safety factor on strength for specified conditions. These conditions have been determined after considerable investigations and represent the most severe landings that aircraft can reasonably be subjected to, and are defined in terms of the ground reaction applied to the wheels when the aircraft touches down at a specified arbitrary vertical velocity of descent in an airborne landing; i.e. the aircraft weight balanced by the aerodynamic lift on the wings. In a normal landing, of course, the aircraft is seldom 100 per cent airborne, but this assumption is a sufficiently accurate approximation. The vertical component of this ground reaction may be associated with various components of drag and side load, to cover for example the drag loads due to spinning up the wheels on surfaces with various coefficients of friction, ground 'bumps', drift, etc.

When landing on actual carrier decks, however, the main differences so far as the undercarriage is concerned, compared with aerodrome landings, are as follows:

(*i*) The vertical velocity of descent relative to the deck increases. This is apparent even from visual observations.

(*ii*) The landings may have various degrees of 'airborneness' from approximately 100 per cent airborne to completely non-airborne, i.e. zero wing lift—it is actually possible for the wing lift to become negative.

Difference (*i*) is caused mainly by the restricted area available for touch-down, the psychological effect on the pilot, the limitations of view on some aircraft, the pitching of the deck, and the necessity of avoiding the 'wake' of disturbed air behind the round-down.

Difference (*ii*), i.e. non-airborne landings, can be caused in two ways:

(*a*) the arrester hook may pick up the arrester wire before the aircraft touches down so that the forward speed at touch down becomes small and hence the wing lift is correspondingly reduced and may even be slightly negative if the nose pitches downwards;

(*b*) aircraft may bounce after an initial airborne touch-down and be non-airborne at the second touch-down due to the arrester wire reducing the forward speed considerably.

Determination of the vertical velocity at touch down, together with the corresponding degree of 'airborneness', would therefore give the basic information for incorporating the necessary special undercarriage design features peculiar to deck landings. Rough and accurate methods of determining the vertical velocity of the main undercarriage at touch-down are described in paras. 2 and 4 respectively. Paras. 3 and 5 give the results of observations made during deck landings on the basis of the methods of paras. 2 and 4, the vertical velocities, of course, being relative to the deck. Tail wheel units and nose wheel units may be similarly treated. The corresponding degree of 'airborneness' may be obtained by an extension of the cine-camera method or roughly by determining the potential energy absorbed by the undercarriage during the landing. This potential energy can be estimated from a comparison of the measurements made in the deck landing with those of drop tests made on the same undercarriage in the laboratory.

2. Rough method of determining the vertical velocity at touch-down

This method is based on the comparison of the shock absorber travels which occur during (*i*) the deck landing, and (*ii*) drop tests on the same undercarriage in the laboratory. The shock absorber travels are measured by means of a sliding band of cardboard and adhesive tape wrapped fairly tightly round the piston tube so that, when the shock absorber closes, this band is pushed along the piston tube by the fixed outer cylinder of the shock absorber. For undercarriages with shock absorbers having large static closures it is necessary, particularly in light landings, to check that the maximum shock absorber travel recorded is that which occurs at touch-down, and not that corresponding to the aircraft at rest after being arrested. In the latter case, of course, the outer cylinder will still be in contact with the sliding band, whereas in the former case there will be a gap between the outer cylinder and the sliding band. Also if bounce occurs, the maximum shock absorber travel may occur on the second touch-down. In deck landing trials the maximum shock absorber travel is measured quickly after each landing, and as the aircraft is then usually being man-handled with engine(s) running for a further take-off, this method is rather dangerous and not too comfortable.

Having obtained the maximum shock absorber travels in the various deck landings, the main difficulty in the correlation with the results of drop tests in the laboratory is to decide the degree of 'airborneness', when the aircraft touches down on to the deck. It has been found that by visual observation of the type of landing this degree can be sufficiently approximated to enable the vertical velocity at touch-down to be estimated to within about ±10 per cent—this correction includes other possible sources of error such as the differences in the shock absorber friction characteristics between the undercarriage used in deck landing and that tested in the laboratory.

3. Specimen results obtained by the rough method of determining the vertical velocity at touch-down

This method was used for a Seafire Mk.47 and two Mk.IV Fireflies and the following results obtained for the main undercarriages. The wind speed over the deck varied from about 30 to 36 knots and the moderate pitching of the deck gave an estimated maximum vertical velocity of about ±2 ft./sec. at the area of touch-down. All landings were made by experienced pilots in daylight under good weather conditions.

(*i*) *Seafire Mk.47*

Tyre size=26 in. × 7·75—13 in., patterned tread with pressure=90 p.s.i.

Shock absorber pressure=170 p.s.i., and available shock absorber travel=9 in.

Torsion links were fitted to the shock absorber and a sting type of arrester hook projecting behind the rear fuselage was used. Eleven landings were made on one aircraft by two pilots in turn, and all the touch-downs were made approximately in the three point attitude, with no bounce. The maximum shock absorber travels varied from 7·5 in. to 8·75 in. on the port unit and 7 in. to 7·5 in. on the starboard unit. The corresponding touch-down vertical velocities estimated for airborne landings varied from about 10 ft./sec. to 11·5 ft./sec. Tyre failures due to bottoming on to the wheel rim occurred twice, the port tyre at the seventh landing and the starboard tyre at the eleventh landing. These failures were due, of course, to the maximum permissible vertical reaction at the wheels being exceeded.

(*ii*) *Firefly IV*

Tyre size=32 in. × 10—15 in., smooth tread, with pressure=68 p.s.i.

Shock absorber pressure=200 p.s.i. and maximum available shock absorber travel=8·25 in.

Torsion links were fitted to the shock absorber units and an A-frame type of arrester hook was attached under the central part of the fuselage. Sixteen landings were made on separate aircraft, twelve by one pilot on one aircraft and four by a second pilot on the other aircraft. The type of landing was generally similar to those of the Seafire 47. The maximum

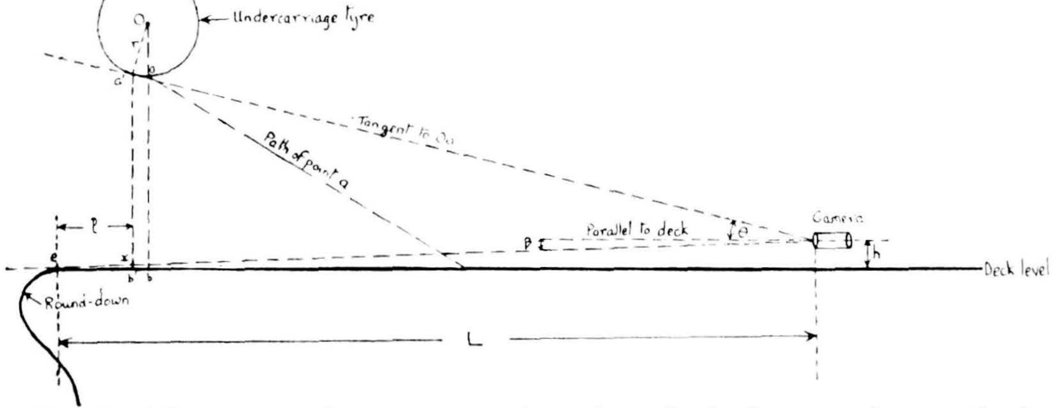


Fig. 1.—Diagrammatic representation of method of measuring vertical velocity by cine-camera, using round-down as datum

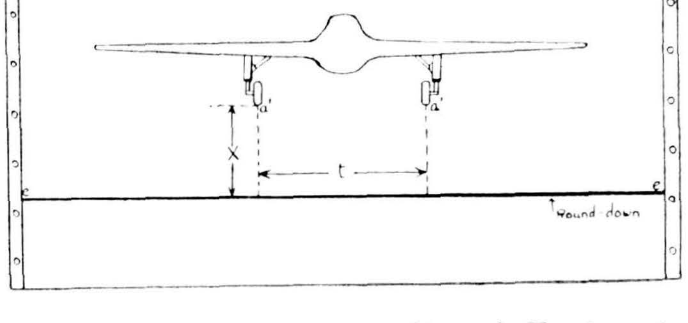


Fig. 2.—Diagrammatic representation of projected frame of cine-camera film

shock absorber travels varied from 5·25 in. to 8·25 in. on the port unit and from 5 in. to 8·25 in. on the starboard unit. The corresponding touch-down vertical velocities estimated for airborne landings varied from about 7 ft./sec. to 12 ft./sec. Tyre failure due to bottoming on to the wheel rim occurred on the port side during the fifth landing of the aircraft which made the most landings.

4. Cine-camera method of determining the vertical velocity of descent at touch-down

This method involves the use of only one cine-camera operating at 24 frames/sec. directed backwards along the deck to obtain pictures of the round-down, the arrester wires and the aircraft for the few seconds up to touch-down. From the films the variation with time of the height of the undercarriage wheels above the deck may be determined and hence the vertical velocity at a touch-down obtained from the plotted Height-Time curve.

The method of analysis of the film at any frame may be seen by considering the diagrammatic representations of the aircraft wheel approaching the deck as shown in FIG. 1 when using the round-down as the height datum. FIG. 2 shows how the aircraft round-down appears on the projected film. From FIG. 1 we have:

H = height of wheel above the deck.

$$\therefore H = ab = a'b' - r(1 - \cos\theta)$$

$$= a'x + \frac{lh}{L} - r\,(1 - \cos\theta)$$

$$\text{i.e. } H = \frac{XT}{t}\cos\alpha + \frac{lh}{L} - r(1 - \cos\theta)\,..(1)$$

where:

H = actual height of the wheel above the deck

T = actual track of main undercarriage

X = apparent height of the wheel above the deck datum

t = apparent track of the main undercarriage

i.e. as measured on the projected film

α = angle of inclination of the axis of the camera lens to the normal to the undercarriage track when the aircraft is landing

l = actual horizontal distance from the deck datum to the lowermost part of the tyre seen on the projected film (positive when the aircraft has passed the deck datum)

h = height of camera lens above the deck

L = distance of camera from the deck datum

$2r$ = actual tyre diameter

θ = angle between the line joining the camera to the apparent lowermost point of the tyre shown on the projected film and a line parallel to the deck, both lines lying in the same vertical plane.

The angles α and θ, of course, vary as the aircraft approaches touch-down. Similarly, when an arrester wire is used as the deck datum, as shown in FIG. 2, we get:

$$H = \frac{XT}{t}\cos + \frac{l}{L}(h - d) - r(1 - \cos\theta) + d\,\ldots.(2)$$

where d = actual height of arrester wire datum above the deck.

Equation (2) is identical to equation (1) except that h has been replaced by $(h - d)$ and the constant d added. The term $r\,(1 - \cos\theta)$ is practically negligible—omitting it from equations (1) and (2) will cause an error of less than 0·1 per cent in the estimated vertical velocities of the magnitude which occur.

Equations (1) and (2) may therefore be written:

$$H = \frac{XT}{t}\cos\alpha + \frac{lh}{L}\,\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

$$\text{and } H = \frac{XT}{t}\cos\alpha + \frac{l}{L}(h - d) + d\,\ldots\ldots\ldots(4)$$

X, T and t are known exactly as are h and d, but α, l, and L can only be roughly estimated. However, by mounting the camera as far forward on the deck as practicably possible—for safety in operation it must be stationed on one side of the deck—e.g. between the last arrester wire and the first crash barrier, cos will only vary from about 1·0 to 0·98 during the two seconds or so up to touch-down, the value decreasing within this range as the aircraft approaches touch-down according to the position and yaw of the aircraft. The camera was stationed so that the value of h in equation (3) and $(h - d)$ in equation (4) was so small that $\frac{lh}{L}$ in equation (3) or $\frac{l}{L}(h - d)$ in equation (4) was negligibly small compared with $\frac{XT}{t}$

As d is constant it will, therefore, be seen that the vertical velocity obtained by assuming

$$H = \frac{XT}{t}\,\ldots\ldots\ldots\ldots\ldots(5)$$

for the last second or so up to touch-down will have a maximum error of only about +1 per cent.

5. Specimen results obtained by cine-camera method of determining the vertical velocity at touch-down

On the basis of equation (5), the vertical velocities occurring on the touch-down of various aircraft during deck trials have been determined.

The prevailing conditions for these deck trials were similar to those described in paragraph 3; i.e. experienced pilots in daylight under good weather conditions with a wind speed over the moderately pitching deck varying from about 30 to 36 knots, except for the Attacker when this speed varied from 39 to 43 knots.

It was found that the variation of the height H with time was approximately linear for at least the last two seconds or so up to touch-down, i.e. the readings taken at every one-twenty-fourth of a second interval indicated no flattening out in the approach path immediately before touch-down. Examples of the Height-Time curve obtained for various aircraft in airborne landings are shown in FIG. 3 and TABLE I gives a detailed list of the vertical velocities determined from such curves. The landings recorded were all made by only one or two aircraft of each type. It will be noted that the Attacker is the only jet-propelled aircraft recorded and that all the aircraft were fitted with tail wheel type landing gear.

Table I
DECK LANDINGS
VERTICAL VELOCITY AT TOUCH-DOWN

Aircraft	Vertical Velocity (ft./sec.)			
	Individual Landings (in chronological order for each aircraft type)	Minimum	Maximum	Mean
Seafire 47	7·6, 8·4, 7·4, 7·4, 7·8, 5·6, 6·2, 7·0, 8·4, 10·6, 7·4, 8·4, 10·8, 7·0, 10·0, 7·4, 13·0, 8·8, 9·8, 8·4, 8·2, 8·3, 6·7, 6·0, 10·7	6·0	13·0	8·3
Sea Fury	7·0, 11·6, 9·0, 12·5, 10·6, 7·6, 7·8, 8·8, 9·4, 9·8, 10·0, 11·8, 10·2, 8·8, 10·0, 10·2, 6·2, 10·5, 11·4, 7·0, 8·1	6·2	12·5	9·5
Barracuda V	4·4, 7·2, 4·1, 6·9, 8·3, 8·7, 6·9, 9·1, 8·4, 8·0, 8·4, 7·5, 7·5, 7·1, 11·0, 8·9, 7·1	4·1	11·0	7·7
Sturgeon	7·6, 7·0 7·6, 8·1, 6·1, 8·4, 10·4, 9·5, 9·6, 9·6, 9·2, 10·4	6·1	10·4	8·6
Seafang	7·3, 6·8, 4·8, 6·7, 11·6, 8·7, 9·1, 9·1	4·8	11·6	8·5
Firefly I	6·7 11·4, 9·3			
Avenger	12·2, 9·1, 7·1, 5·6			
Attacker	12·7, 13·3, 12·0, 12·7, 14·0, 9·6	9·6	14·0	12·4
	Average of all types =	4·1	14·0	8·8

6. Discussion of results

The vertical velocities measured by the cine-camera method appear to confirm the order of the velocities obtained by measuring shock absorber travels. This discussion deals only with the cine-camera results.

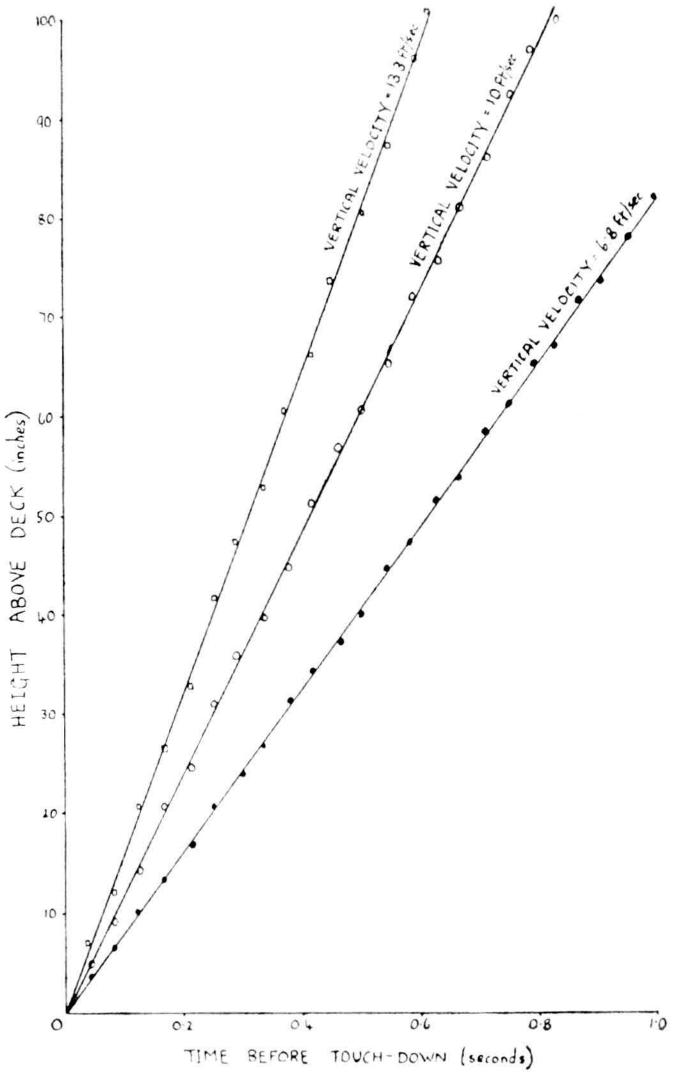


Fig. 3.—**Flight path of undercarriage in relation to deck**

TABLE I records 96 landings of various types of aircraft, the vertical velocity varying from 4·1 ft./sec. to 14·0 ft./sec. with an average of 8·8 ft./sec.; all landings being almost fully airborne. As can be expected, the Attacker, i.e. a high speed jet type, touches down at a greater vertical velocity than the other types. It must be noted, of course, that only six landings were recorded for the Attacker—but on the other hand the recorded vertical velocities have comparatively less scatter than those of the other types.

For the purpose of designing the landing gear then, a compromise is required between (i) the minimum desirable 'life' of the undercarriage measured, for example, by the number of landings per accident, serviceability, maintenance, etc., and (ii) the vertical velocities of the order given in TABLE I increased to allow for actual service conditions, e.g. less skilled pilots, night landings, bad visibility and deck pitching. The undercarriage should be designed to a vertical velocity which will only occur infrequently under actual service conditions—say once every 500 or 1,000 landings, because only a small strength safety factor is obtained on the loads which occur at this specified velocity. The acceptable accident rate, of course, is connected with the compromise mentioned previously.

The vertical velocities occurring in non-airborne landings are beyond the scope of this article but in general it is true to record that these are usually less than those achieved during airborne landings.

AEROMATIC PROPELLERS

A licence agreement has been reached between Hordern-Richmond Ltd., of Hydulignum Works, Haddenham, Bucks, and the Everel Propeller Corporation of Baltimore, Maryland, U.S.A., whereby the world manufacturing and selling rights (outside North and South America) of Aeromatic propellers have been acquired by the English company. A complete propeller assembly was shown on Stand 113 at the S.B.A.C. Display at Farnborough.

An Analysis of Range for Aircraft Project Design

A Rapid Method for the Estimation of Still Air Range When Operating on Constant Power

By A. H. Stratford, B.Sc. (Eng.), A.F.R.Ae.S.

Summary

THE various flight procedures for medium and long range operation of transport aircraft are described, and the constant power basis is shown to be advantageous for airscrew-driving power units when comparisons are required in the design study stage. To avoid the approximation involved in assuming a cruising speed which is a mean of the initial and final speeds and likely to introduce errors when the fuel load is an appreciable percentage of all-up weight, a method is presented which by means of a chart enables the true Still Air Range to be evaluated.

The method employs the conception of speed ratios based on the true speed for minimum drag at the selected cruising altitude at the instantaneous all-up weight of the aircraft, and enables a rapid solution to be obtained once the basic aircraft characteristics and the design and operational parameters are known or evaluated.

Notation

A_e	Effective Aspect Ratio.
B	Cruising Speed Constant (Eqn. 16).
c	Specific Fuel Consumption (lb. per effective shaft-horsepower per hour).
C_{DO}	Total aircraft profile drag coefficient.
D	Aircraft drag (lb.).
E	Maximum Lift/Drag Ratio.
m	A function of the Speed Ratio n. (See FIG. 1.)
N	Number of operating engines.
n	Speed Ratio: V/u.
P_e	Effective shaft-horsepower (including Jet Thrust Allowance).
R	Still Air Range (miles).
r_c	Rate of climb (ft./min.).
S	Wing Area (sq. ft.).
u	True speed for minimum drag (m.p.h.).
V	True cruising speed (m.p.h.).
W	All-up Weight of aircraft (lb.).
w	Wing Loading (lb. per sq. ft.).
Z	Thrust index ($=m.W.$).
Δ	Range Factor.
η	Airscrew efficiency.
ρ	Air density (slugs/cu. ft.) at altitude.
ρ_0	Sea level air density.
σ	Air density ratio at altitude.

Subscript 1 denotes initial cruising condition at the selected altitude after consumption of run-up and climb fuel.

Subscript 2 denotes final cruising condition at selected altitude after all cruise fuel is consumed.

Introduction

In the early stages of aircraft design, a generalized performance analysis of various power plant and airframe layouts is frequently required. Recent investigations into new types of engine of widely different specific consumptions and specific weights, installed in aircraft designed for medium and long range, have made it necessary to find methods that would minimize the work involved in design study and increase the results available to the project engineer in a given time. The calculation of range, in particular, may prove difficult particularly where constant power operation is considered advantageous for comparative purposes.

For this reason there was evolved the method which is introduced below for the calculation of Still Air Range with propeller-driving turbine, piston or compound engines, when operating on constant power.

The Flight Procedure

The three basic flight procedures for ideal operation at constant altitude are well known to be:

(*a*) Constant L/D ratio.
(*b*) Constant Cruising Speed.
(*c*) Constant Effective Power.

In these three cases respectively the cruising speed decreases, remains constant, and increases as flight proceeds.

The well-known Bréguet formula for range deals conclusively with flight at constant L/D, assuming a constant airscrew efficiency and specific consumption which may be justifiable with constant speed airscrews and when a flight engineer is available to supervise power control. However, flight at constant L/D is usually rejected on the grounds of difficulty in airspeed control, and because the effect of the speed and power falling as fuel is consumed, is to penalize the gas turbine whether driving a propeller or producing a jet.

The second procedure, constant speed and altitude, is also open to serious criticism for comparative study purposes. This is chiefly because on most projected types of turbine engine high forward speed is a major factor in thermal efficiency, which maintains its best values over a narrower range of output than with the older power plants.

Constant speed operation presupposes a reduced thrust (or power) as flight proceeds because of fuel consumption, and when fuel load becomes an appreciable proportion of take-off weight the ratio of final/initial thrust (or power), may be low enough for an adverse effect to be felt in specific consumption.

Owing to the higher flight speed, medium-long range operation may be justified with jet units operating at constant true air speed, but at all altitudes as fuel is consumed aircraft with propeller-driving turbines will be required to pay a premium in increased specific consumption which must be offset against their reduced power requirements if operated at constant cruising speed.

The method suggested by R. M. Willcock (R.A.E. Report No. Eng. 4131) for the calculation of range at constant mean speed is of considerable value and may be used where these conditions of flight are more realistic, e.g. on short range.

The calculation of range at constant true speed has also been developed on the assumption of a variable altitude so that if height is gradually increased to give an air density proportional to all-up weight, the power required is directly proportional to the instantaneous weight of the aircraft, and L/D remains constant.

If altitude and weight are alone variable then power required may be written as:

$$a_1\cdot\sigma+a_2\cdot\frac{W^2}{\sigma}+a_3\cdot r_c\cdot W \quad \ldots\ldots\ldots\ldots\ldots(1)$$

where r_c is rate of climb (f.p.m.) (assumed constant and small)
W is all-up weight of aircraft (lb.)
σ is relative air density
and the a's are constant.

If now we increase altitude at such a rate that $\sigma \propto W$ (say $\sigma=k.W$) and assume that V and η remain constant,

then $P_e=a_1\cdot k\cdot W+a_2W/k+a_3\cdot r_c\cdot W$

i.e. $P_e=a_4\cdot W$ where $a_1=\frac{V}{375}\eta\cdot L/D$ and L/D and incidence are constant throughout.

Integration leads us back to the Breguet equation for range at constant L/D:

$$R=375(L/D)\,(\eta/c)\,\log_e W_1/W_2 \quad \ldots\ldots(2)$$

where c would require to be a carefully selected mean with gas turbine engines.

This relation lends itself conveniently to integration but the underlying assumptions are not sufficiently realistic. The range of altitudes for a fuel load of $33\frac{1}{3}$ per cent of take-off weight could be typically 20,000 ft. initially increasing to 31,500 ft. at the conclusion of the flight.

The third ideal procedure, constant power at constant altitude, is the one assumed for the method described below. Constant power analysis for medium and long range normally involves a tricky integration since flight speed continually increases as fuel is consumed: the solution of this problem is the object of the present analysis.

Some assumptions are implicit in the use of constant mean values of airscrew efficiency, aircraft profile drag coefficient, and specific fuel consumption, but these are considered to be justifiable and are standard practice in preliminary design work; however, the use of a constant mean speed of flight when flying at constant power was not held to be sufficiently accurate for adoption except on short ranges.

Range Calculation with Airscrew Propulsion

In the calculation of Still Air Range with propeller-driving engines operating on constant power, it is found useful to introduce non-dimensional parameters. In the present method the well-known ratio n (true speed of flight, V, ÷ true speed for minimum drag, u, at the given altitude) and m, a function of n are employed, to give a final non-dimensional range function Δ.

$m=(n^3+n^{-1})^{\frac{1}{3}}$ is plotted in FIG. 1 for rapidity of reference. If we write drag, D, at speed, V, in terms of the true speed of minimum drag, u, and optimum L/D ($=E$), at constant altitude,

then $D=W/2E[(V/u)^2+(u/V)^2]$ ....(3)

and $E=[\pi/4\cdot A_e/C_{DO}]^{\frac{1}{2}}$ ....(4)

where W is the instantaneous weight of the aircraft (lb.)
A_e is the effective aspect ratio (including an induced drag correction)
and C_{DO} is the total aircraft profile drag coefficient.

C_{DO} is usually calculated for a limited range of aircraft size, cruising speed and altitude, and mean values may be chosen to make E sensibly constant over selected groups of conditions.

The power required at speed V, is:

$$W\cdot n\cdot u/750E\,(n^2+n^{-2}) \quad \ldots\ldots\ldots\ldots(5)$$

If now
P_e is the effective cruising shaft-power per engine,
N is the number of operating engines,
and η is the mean airscrew efficiency for cruising flight, then

$$P_e\cdot N\cdot\eta=W\cdot u/750E\,(n^3+n^{-1}) \quad \ldots\ldots\ldots(6)$$

Utilizing the expression for minimum drag speed at height, h, we may re-write this equation as:

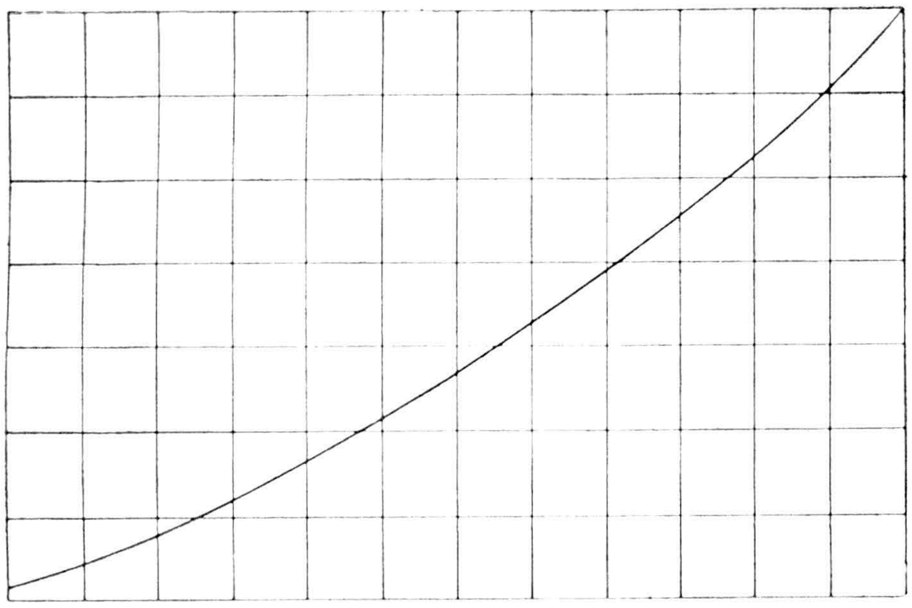


Fig. 1.—Relationship between m and speed ratio n

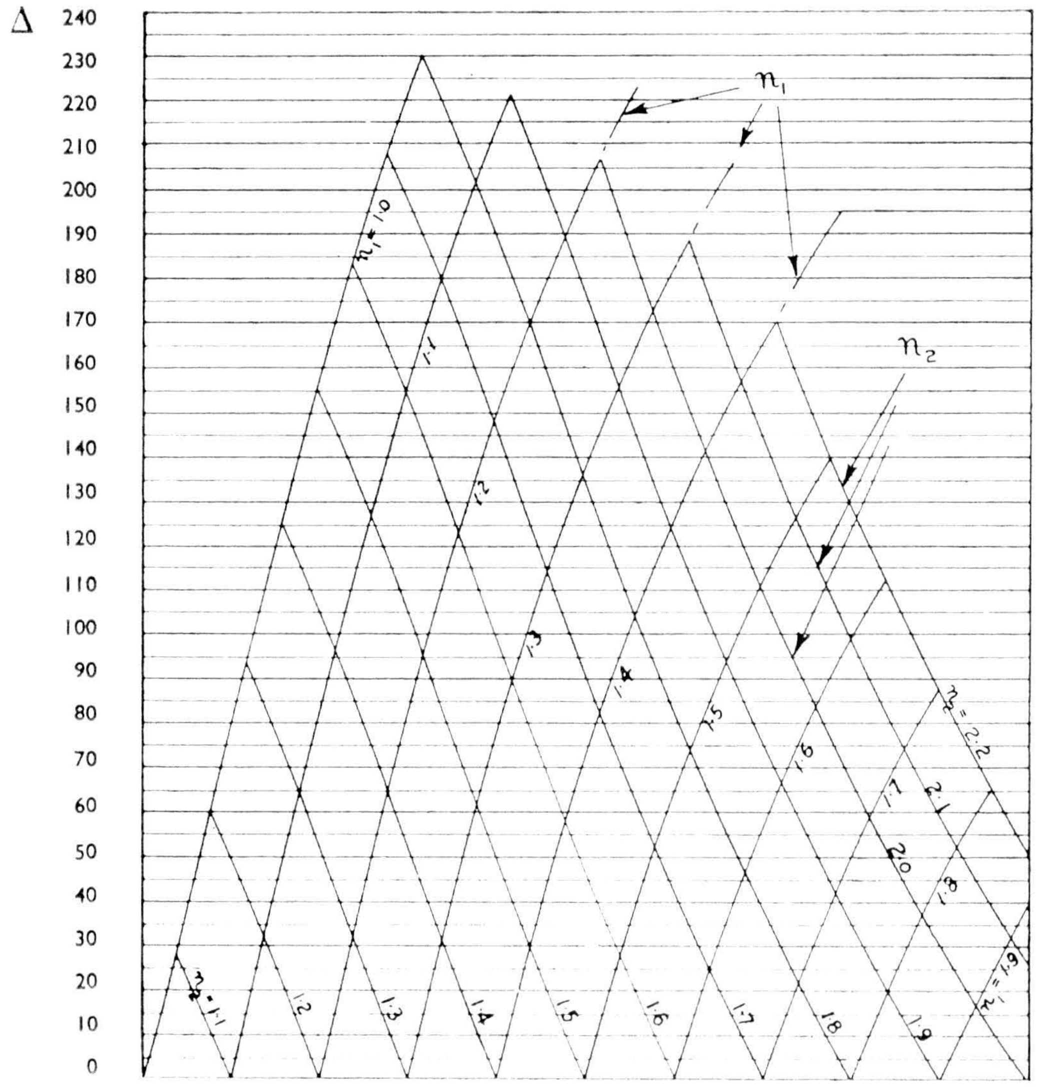


Fig. 2.—Variation of range factor, M, with speed ratios, n_1 and n_2

$$(n^3+n^{-1})^{\frac{2}{3}}=13\cdot65(E\cdot\eta\cdot P_e\cdot N)^{\frac{2}{3}}(S\cdot\sigma)^{\frac{1}{3}}(C_{DO}\cdot A_e)^{\frac{1}{3}}/W \quad \dots\dots\dots\dots(7)$$

Substituting m and Z/W for the left and right hand sides of the above equation we may write (7) again as

$$m=Z/W \quad \dots\dots\dots\dots\dots\dots(8)$$

First of all we require to calculate Z which may be regarded as a thrust index (with dimensions of force before the elimination of sea level air density, ρ_0).

From the previous equations:

$$Z=13\cdot65(E\cdot\eta\cdot P_e\cdot N)^{\frac{2}{3}}(S\cdot\sigma)^{\frac{1}{3}}(C_{DO}\cdot A_e)^{\frac{1}{3}} \quad \dots\dots\dots\dots(9)$$

which is constant for the particular operating condition (geometric form, power and altitude) under consideration, and we then employ two pairs of corresponding values of W and m (for take-off and landing).

If these are written W_1 m_1 (take-off condition)
W_2 m_2 (landing condition)

(For full definitions of subscripts see Index of symbols.)

then for known initial and final all-up weights we may calculate the two values of m (Z/W_1, Z/W_2.) and from FIG. 1 read n_1 and n_2 corresponding to them.

W_1 will naturally be corrected for fuel consumed during run up, take-off and climb according to some requirement such as A.D.M.514.

Defining Still Air Range, R miles, by the equation:

$$R=1/c\cdot P_e\cdot N\int_{W_2}^{W_1}V\cdot dW.. \quad \dots\dots\dots(10)$$

where c is the specific fuel consumption in lb. per effective shaft horsepower per hour, and the other symbols have their previous significance,

$$\text{then } R=1/c\cdot P_e\cdot N\int_{W_2}^{W_1}u\cdot n\cdot dW\dots\dots(11)$$

Since we can also write u and W in terms of n only, the above equation may be transformed.

The solution is:

$$R=250E\cdot\eta/c\Big[\tan^{-1}n^2-\sin(2\tan^{-1}n^2)\Big]_{n_2}^{n_1} \quad \dots\dots\dots\dots(12)$$

This equation may be symbolized in the form:

$$R=E\cdot\eta/c\cdot\Delta \quad \dots\dots\dots\dots\dots\dots(13)$$

$$\text{where } \Delta=250\Big[\tan^{-1}n^2-\sin(2\tan^{-1}n^2)\Big]_{n_2}^{n_1} \quad \dots\dots\dots\dots\dots(14)$$

A plotting of Δ on a carpet of n_1 and n_2 is shown in FIG. 2 for values of n_1 between 1·0 and 1·9 and n_2 between 1·0 and 2·2.

Since Still Air Range is directly proportional to $E\cdot\eta/c$ (L-dimensional) the final result may be rapidly modified for variation in the above product.

TABLE I

VALUES OF $m=(n^3+n^{-1})^{\frac{2}{3}}$

n	m	n	m
1·0	1·587	1·6	2·814
1·05	1·645	1·65	2·962
1·1	1·712	1·7	3·117
1·15	1·788	1·75	3·277
1·2	1·870	1·8	3·442
1·25	1·965	1·85	3·615
1·3	2·064	1·9	3·792
1·35	2·172	1·95	3·976
1·4	2·287	2·0	4·165
1·45	2·408	2·05	4·359
1·5	2·537	2·1	4·560
1·55	2·672	2·15	4·766
		2·2	4·977

TABLE II

VALUES OF $A=250\,[\tan^{-1}n^2-\sin(2\tan^{-1}n^2)]$

n	A	n	A
1·0	−53·650	1·7	154·938
1·1	−25·508	1·8	176·930
1·2	6·705	1·9	196·505
1·3	39·995	2·0	213·845
1·4	72·367	2·1	229·125
1·5	102·550	2·2	242·673
1·6	130·165		

FIGS. 1 and 2 as shown are not of sufficient scale to be directly employed and for that reason the values from which they were drawn are tabulated below in TABLES I and II. For a maximum accuracy the values of Δ should be replotted with interpolations on a large-scale chart.

Clearly the calculation of range by a method allowing for speed variation with all-up weight is justifiable only when the speed ratios (n_1 and n_2) are measurably distinct. Ultra-short range operation may be taken as that defined by $n_2-n_1<$ approx. 0·3 within which domain the simpler and more obvious method of using a mean speed of flight is to be preferred.

Standard Method of Range Calculation

In the most usual approach to a range investigation both take-off and landing all-up weight for the aircraft are known, as well as the mean C_{DO}, airscrew efficiency, cruising power, specific consumption and the geometric characteristics of the aircraft. From this data the Still Air Range is required.

In this case first of all calculate E from equation (4) and Z from equation (9). This enables us to find m_1 and m_2 from equation (8), and the corresponding values, n_1 and n_2 which may be read from FIG. 1.

Using now FIG. 2 we can immediately obtain Δ from the intersection of the actual values of n_1 and n_2, which gives the Still Air Range from the product,

$$R=E\cdot\eta/c\cdot\Delta.$$

A preliminary estimate of mean cruising speed may be necessary to obtain the jet thrust contribution to effective shaft power, and for a final evaluation of specific consumption and airscrew efficiency accurate initial and final cruising speeds are obtained as follows:

Since $V=n\cdot u$

$$=\frac{n\cdot W^{\frac{1}{2}}}{(\rho_0\cdot\sigma\cdot S)^{\frac{1}{2}}}\left(\frac{4}{\pi\cdot C_{DO}\cdot A_e}\right)^{\frac{1}{4}} \quad \dots\dots\dots(15)$$

using symbols previously identified, we may write,

$$V_1=n_1\cdot w_1^{\frac{1}{2}}\cdot B$$
$$V_2=n_2\cdot w_2^{\frac{1}{2}}\cdot B \quad \dots\dots\dots\dots\dots(16)$$
$$\text{where } B=\frac{14\cdot86}{\sigma^{\frac{1}{2}}[C_{DO}\cdot A_e]^{\frac{1}{4}}}.$$

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A Russian Notebook

Some General Observations on the Form and Organization of the Aircraft Industry of the U.S.S.R.

By Charles W. Cain*

For some years the writer of this article has carefully studied the scanty and conflicting information available on the aircraft of the U.S.S.R. and the organization of both military and civil aeronautics. It has been our policy to publish, whenever possible, articles giving accurate—if of necessity limited—details of Russian developments. In this respect we would point out to readers that the contents of this present article may appear somewhat conservative, because only undoubted facts have been presented and, as such, it offers a commentary upon the mixture of fanciful propaganda and restricted information available—a fact which we have had to mention on each previous occasion that we have published a similar article.— EDITOR

Previous articles on Russian aviation that have appeared in AIRCRAFT ENGINEERING, **including those translated from wartime enemy reports, are as follows:**

Design Progress in the U.S.S.R.: A. I. Nekrasov. Vol. VII, Jan. 1935, pp. 3-6.

Types of the Red Air Fleet: J. H. Stevens. Vol. XI, Nov. 1939, pp. 411-414.

Radiator Research in the U.S.S.R. Vol. XII, May 1940, pp. 133-136.

Soviet Military Aeroplanes: J. H. Stevens. Vol. XIV, June 1942, pp. 152-159.

A New Russian Bomber (TB-7). Vol. XIV, July 1942, p. 197.

The YAK-1 in Production (photographs). Vol. XIV, Dec. 1942, pp. 363-364.

Woods Used in Russian Aeroplanes: J. Theiner. Vol. XV, Oct. 1943, p. 288.

The LAGG-3 Russian Fighter: Nils Hulten. Vol. XV, Oct. 1943, pp. 289-292.

The PE-2 Russian Light Bomber. Vol. XVI, May 1944, pp. 124-127.

The Utilization of Exhaust Thrust: N. Ya. Litvinov. July 1944, pp. 188-189.

A Russian Aero-Engine (AM-34): Lionel Mote. Vol. XVII, June 1945, pp. 159-165.

Fig. 1.—The ANT 35 is a Russian design of 1936 and is shown here as an example of their most advanced pre-war thoughts. It was widely used on the shorter routes, including from Moscow—Leningrad—Stockholm

The so-called 'Iron Curtain' is a very real problem and, unfortunately, it is not entirely the responsibility of Russia herself. Recently an outraged Central-European Communist spokesman complained that 'the Iron Curtain was invented in the newspaper offices of Fleet Street'. The half-truth of this statement is that for many years before the Second World War Russia was left to her own devices and few seriously-minded people, technicians and observers alike, ever entered Russia—so reports were scanty, often highly-coloured and usually inaccurate. Tracing this state of affairs down to Russia's aircraft industry brings out one striking fact, that we of the English-speaking nations know only about ten per cent of what is going on in the Soviet design bureaus, technical offices and workshops. Now the opportunity for investigation at first hand no longer exists. Russia is as suspicious of the Western Powers as they are of the Soviet Union. Few aviation publications are allowed to leave the U.S.S.R., no Russian aviation technicians are allowed to leave the Union and converse freely with fellow workers, and even the most skilled and determined writer, a student of Russian aeronautics, must spend many hours chasing up minute facts to fit into the jig-saw puzzle.

Today there is no comprehensive survey of Soviet aviation, no steady break-down of design technique. Yet to everyone must come the realization that if Russia can build aircraft which fit into every known foreign category then there must be something we can learn from Soviet aviation. The galling feature of the problem is that while few people ever get an opportunity to examine Russian aircraft, Soviet military attachés and their enormous staffs are free to wander abroad, and examine, photograph, measure and evaluate just about every British-built aeroplane there is.

It is because so much nonsense has been published in recent months, even years, about Russian aviation that I welcome this opportunity of expounding my own point of view as any independent observer of the U.S.S.R. and her aeronautical endeavours. But, as one sage once put it, 'the more you know about a subject the less inclined are you to commit yourself to paper', so I would like to make it clear that this is not an attempt at a complete survey of contemporary Russian aviation but simply a series of notes and observations made after some years' close study of the scanty material to be gleaned from various sources and recently crystallized when preparing the Russian section of the 1948 edition of Jane's *All the World's Aircraft*.

The Air Power of the U.S.S.R.

With the hundred per cent backing of Stalin, the Soviet aircraft industry has prospered under the series of Five-Year Plans. The first post-war Five-Year Plan was started in 1946 and although no accurate figures are available Lieut-General of Aviation Alexander Osipenko claims, in an article appearing in the London-published *Soviet Weekly* for July 22, 1948, that by 1950 passenger conveyance will have increased by fourteen times the figure of 1940. Another writer, F. Zakharov, of the Central Civil Air Fleet Administration in *Soviet News* (published by the Press Department of the Soviet Embassy in London) for July 8,

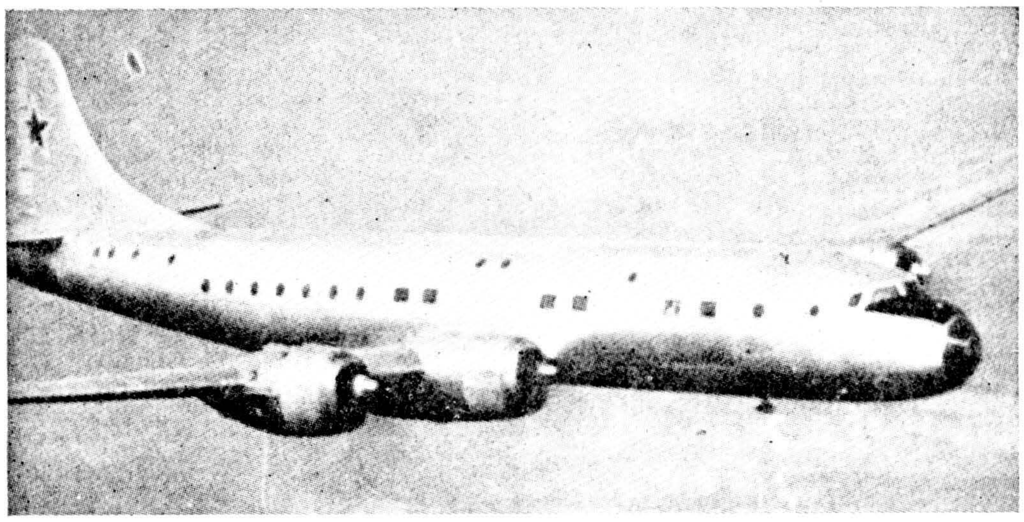
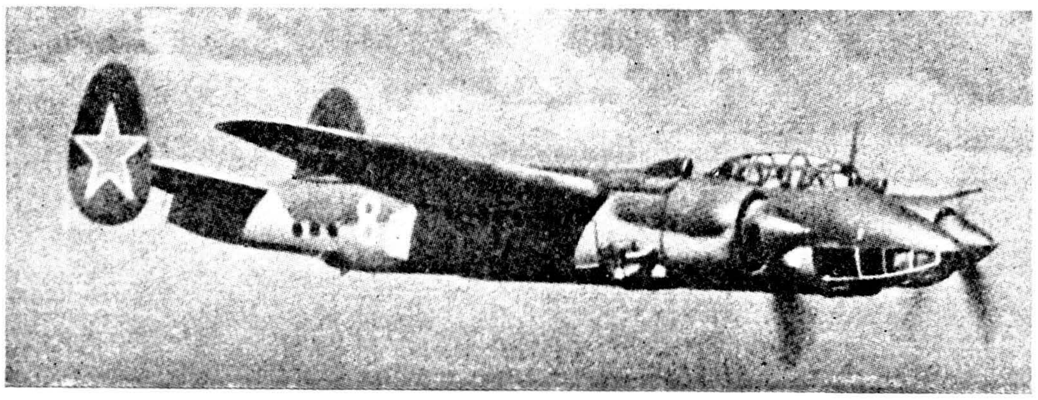


Fig. 3 (above).—The Tu-70 is a curious development from the Boeing B-29s that force landed in Russia in 1945. There is no apparent difference in the wing flaps, engine nacelles, undercarriage and tail unit. Such small points as the retractable tail skid, the turbo supercharger mounting and the smallest details of the undercarriage are identical. Although the fuselage has been enlarged to give passenger accommodation, the bomb-aimer's window in the nose is identical with that on the B-29. In view of this direct copying as regards appearance, there is little doubt that the structure too follows the B-29 closely, while the ASH-90 engines quoted will probably be based on the Wright Duplex Cyclone. Available data are: span 43 m. (141 ft.); length 36.27 m. (119 ft.); height 8.64 m. (27 ft. 9 in.) wing area 170 sq. m. (1,720 sq. ft.)

Fig. 2 (below).—The Tu-2, which looks like a radial-engined version of the Pe-2 is actually its replacement designed by A. N. Tupolev. The structure is of metal, with a conventional tail-wheel undercarriage and ASH-82 FNV engines of 1,850 h.p. Armament consists of two 20 mm. cannon in the wing roots, with 200 r.p.g., two upper and one lower 12.7 mm. rear guns (each with 250 r.p.g.); with a max. bomb load of 2,370 kg. (5,000 lb.). General data are: span 18.86 m. (62 ft. 0 in.); length 13.8 m. (45 ft. 3 in.) and max. gross weight 12,800 kg. (28,224 lb.); max. speed 560 km.p.h. (345 m.p.h.) at 5,800 m. (19,000 ft.); ceiling 10,000 m. (33,000 ft.); range with 1,500 kg. (3,300 lb.) bombs, 2,500 km. (1,550 miles), with 2,270 kg. (5,000 lb.) bombs, 1,400 km. (880 miles)



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* Lately Editor of 'The Aeroplane Spotter'.

Fig. 4.—These two views of the interior of the Tu-70, seventy-two passenger air liner show that it is genuinely fitted out as such. The rather Victorian decor, with antimacassars and mirrors, and the severe square seats make a striking contrast with current Western ideas of air line equipment

1948, claims that whereas in 1940 the total air route mileage of the Civil Air Fleet was 85,000 miles, by 1950 the total would be increased to 110,000 miles. Zakharov further claims that the present air route mileage in the Soviet Union is greater than the contemporary domestic mileage of the United States. He also claims that the longest air route, that of 'well over' 4,000 miles, Moscow to Khabarovsk, can be completed in a day. Unless this route is being operated by the 72-75 passenger Tupolev Tu-70 (a curious copy of the Boeing B-29 Superfortress) or the four-engined 65-66 passenger Ilyushin Il-18, this claim seems a trifle optimistic, since the standard 27 passenger, twin-engined Ilyushin Il-12 has a range of 1,240 miles at a cruising speed of 217 m.p.h. at 8,500 ft. At least three, if not four changes must be involved and a total flying time of over 19 hours. But with no Russian authority with whom to check or corroborate these statements we have to read 'between the lines'.

On the purely military side the situation is even worse, for if it is frowned upon to deliberate on civil aeronautical endeavour, it is a heavily punishable offence to expound on military aviation—and for the Russian the Soviet Secrets Act is both all-embracing and all-powerful. Alexander Osipenko in his *Soviet Weekly* article (July 22) entitled 'Aviation Day in the U.S.S.R.', gives a few illuminating figures on the Soviet Air Fleet (military) strength at the end of the war. During 1943 and 1944, the Russian aircraft factories turned out nearly 40,000 front-line aircraft (as against the reported German total of 25,527 aircraft), and from 1941-1945, the Air Fleet made about 3,000,000 sorties. For instance, during the Battle of Berlin, over 8,400 fighters, bombers, reconnaissance and assault aircraft took part, and over 700 Luftwaffe fighters were destroyed. Even allowing for optimism, these figures are impressive, for it must be remembered that during the war the Red Air Force (as it was then called) acted as an offensive and defensive weapon of the Red Army. Equally significant is the fact that now there is a strong move to make the Soviet Air Fleet an independent battle force, more on the lines of the Royal Air Force than the war-time United States Army Air Forces. The usually well-informed American *Newsweek*, in a survey article, 'U.S.A.—U.S.S.R. Air Power' (May 17, 1948), estimates that from the 1944 total output of 40,000 aircraft, Soviet production has fallen to 18,000 annually, as against the United States colossal figure of 96,000 which dropped down to 1,500 aircraft in 1947, but is now being raised to deal with the U.S. Congress vote for a 70 group Air Force (20,000 aircraft). But with all the juggling with figures, percentages, estimates (and guesses), the real test is in design skill, suitability for mass production, quality of materials and handling by both air and ground crews.

The Designers and their Teams

At a discussion organized by the Aircraft Recognition Society, London, in April, 1948, Mr H. R. Gillman, of the British Air Lines Pilots Association (B.A.L.P.A.), was asked if he thought Russian aircraft design and application was on a par with current British and American standards. Mr Gillman, it will be recalled, was one of the members of a mission comprised of members and officials of the S.B.A.C. who were invited to Moscow to examine the Soviet aircraft industry. After the usual Russian 'delay and confusion' tactics, the mission was taken to the headquarters of Ts.A.G.I. (the Central Aero-Hydrodynamics Institute), Moscow, and shown some aircraft and introduced to a few of the leading lights. Mr Gillman's own theory is that in those days, at any rate, the designers were just as sound as their Western counterparts and that scientific advancements were good but application bad. He likened the comparison to two pyramids. The Russian pyramid was equally as tall as the Western Powers, but had a smaller base. In other words the scientific and technical quality did not percolate through to the men who used the aircraft. That may have been true before the Second World War, but what about now, nearly a decade later? One must remember that the Russians are a persevering and hard-working race, quite adaptable to the drawing board or the machine-shop. If any nation could build 40,000 aircraft in a year, four years ago, then they are probably capable of even bigger things today, using the combined knowledge of the technicians of defeated Germany and the priceless information readily available in all the leading Western aviation centres.

Never must it be overlooked that modern Russia is a new nation and that as such it looks for heroes on which to build up tradition. Perhaps

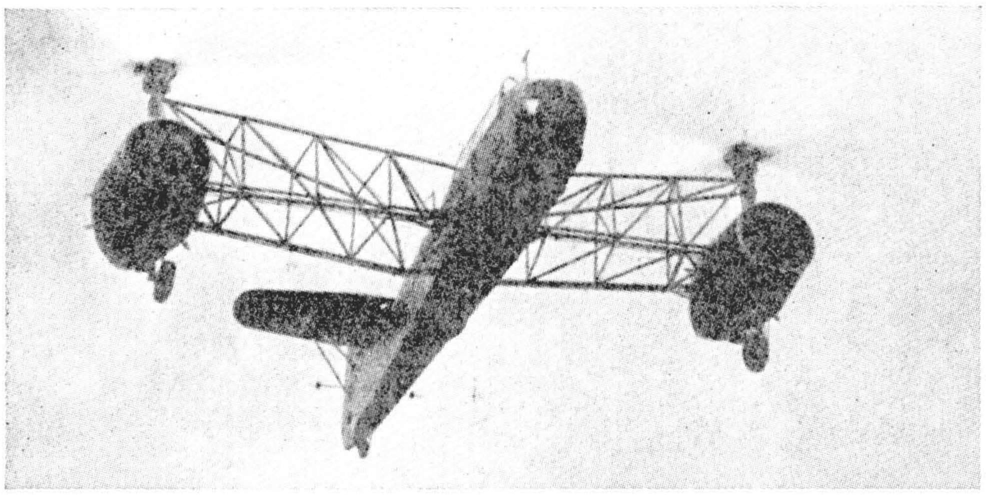


Fig. 5.—The Omega twin-engined helicopter that was first exhibited at Tushino on August 18, 1946. The engines are 145 h.p. M-11F, five cylinder, air-cooled radials. Accommodation is for two in tandem seats. A forward speed of 180 km.p.h. (112 m.p.h.) and a vertical climb of 6 m./sec. (20 ft./sec.) are claimed

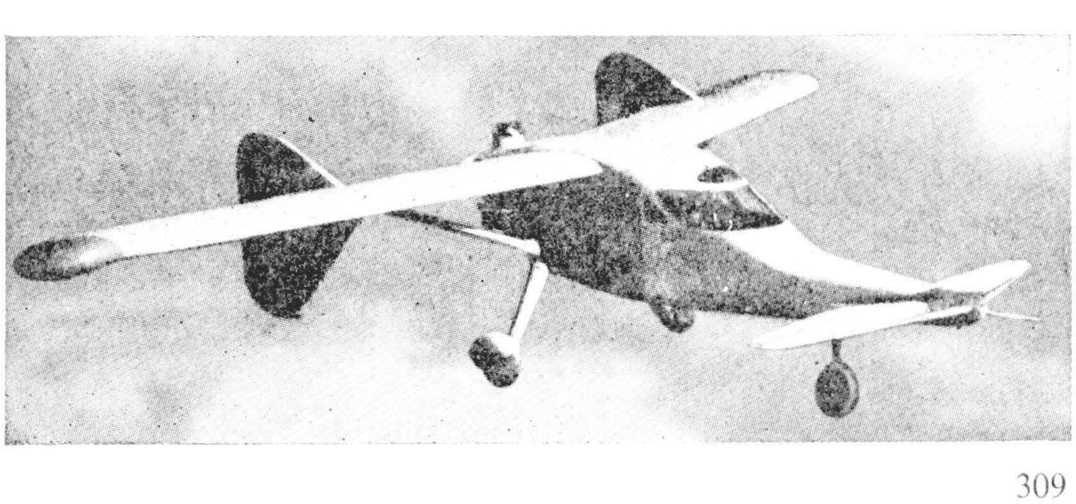
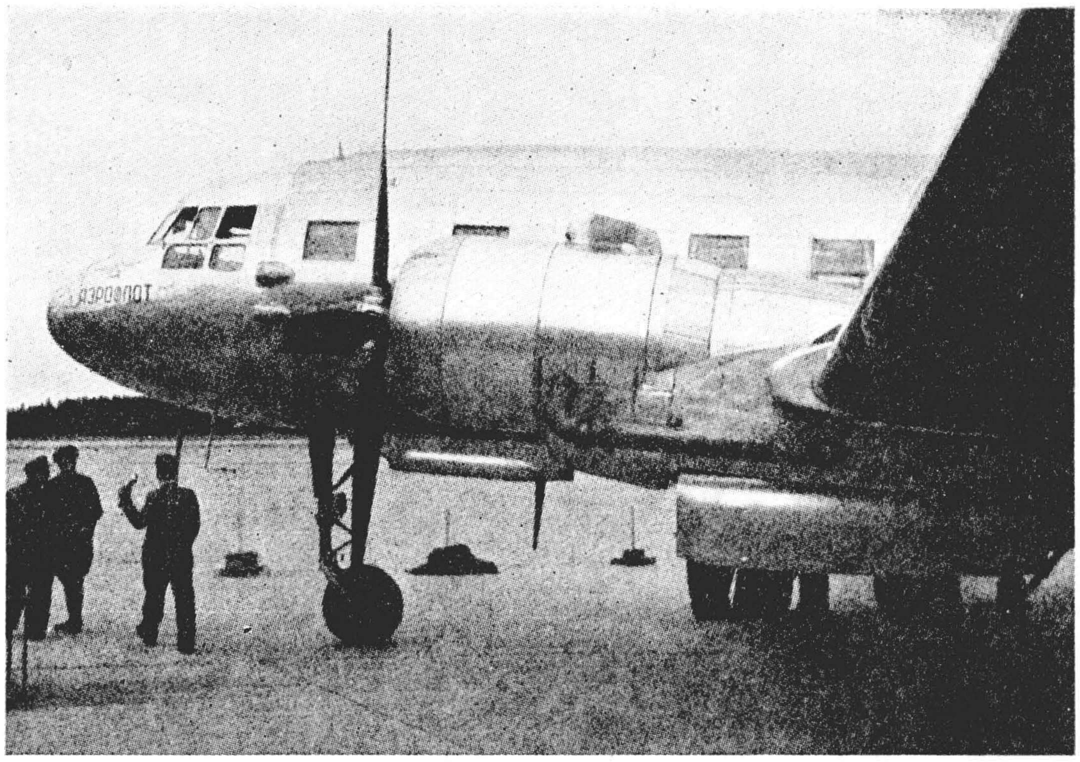


Fig. 6.—This unconventional canard, the MIG Utka (Duck), is reported to be in production as a replacement of the old Po-2 biplane. A unique feature is that when fitted with skis, the wings can be removed and the machine used as a motor sledge. Although not certain, the structure is probably mainly of wood. A version of the ubiquitous M-11 five-cylinder air-cooled engine giving 110 h.p. is installed. Unconfirmed data are: span 10 m. (32 ft. 10 in.), length 5 m. (16 ft. 5 in.); max speed 200 km.p.h. (125 m.p.h.); duration 5 hours



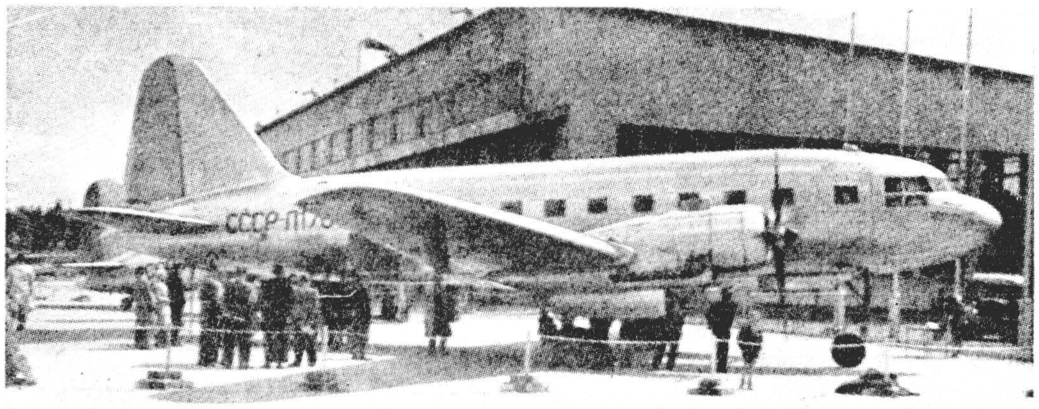


Fig. 7.—New photographs of the standard Il-12 medium range air liner and troop transport, which has a crew of 5 and 27 to 32 passengers. The engines are ASH-82 fourteen cylinder two-row radials with two-speed superchargers giving 1,700 h.p. Span 31.7 m. (104 ft.); length 21.3 m. (70 ft.); height 6.25 m. (20 ft. 6 in.); gross weight 17,250 kg. (38,000 lb.); pay load 3,000 kg. (6,600 lb.) max.; max. speed 407 km.p.h. (253 m.p.h.) at 2,600 m. (8,530 ft.); cruising speeds 320 km.p.h. (200 m.p.h.) at sea level, 350 km.p.h. (217 m.p.h.) at 2,600 m (8,350 ft.): range 1,250 km–4,000 km. (775 miles–2,480 miles). A freighter version is said to have been built with a maximum load capacity of 4,000 kg. (8,820 lb.)

this is one reason why so many people tend to forget that behind the dozen or so leading and well-publicized (in the Soviet Union, of course) designers, there are hundreds of junior designers and literally thousands of technicians. These men work in conjunction with many of the finest German technicians who have been brought to Russia to build up the technical standards to even higher levels. All aeronautical projects have the personal backing of Stalin and as such have the highest priority. Moscow is the fount of knowledge and it is at their great experimental centre, Romanskya, some 24 miles from the centre of Moscow, that these technicians work together and close by is the aerodrome where the experimental aircraft, mainly jets, are tested. British designers would object to having a political leader in charge of them, but to the Bolshevik Party Russian this comes as a matter of course and duty. Politics and aerodynamics must go hand in hand. In this case the M.V.D. (political police) under Marshal L. P. Beria look after the interests of the State for both Russians and Germans.

A key to the present increased industry of the Soviet experimental centres is the dictum issued by Stalin on the occasion of the annual Soviet Aviation Day celebrations on Sunday, August 3, 1947, when designers and technicians were exhorted to produce the finest aircraft in the world which would in fact, to quote the stirring phrase, 'Fly Higher, Faster and Farther'. To assist the designers, if not the design teams, practical encouragement is given in the form of so many thousands of roubles (Stalin prizes) for outstanding achievements in the scientific and experimental field. For instance, 573 Stalin Prizes of varying monetary amounts were awarded this year, and out of the ten premier awards five went to senior aircraft designers, M. I. Gurevich, S. A. Lavochkin, A. I. Mikoyan, A. N. Tupolev and A. S. Yakovlev. Their works range from multi-engined long-range transports to advanced single-seater research jet aircraft.

The leading aircraft designer and incidently co-founder of the Soviet aircraft industry, is Lieut-General of the Aviation Engineering Corps **Andrei Nikolaevitch Tupolev.** At 60 years of age A. N. Tupolev is head of Ts.A.G.I. (and has been for the past sixteen years), and is responsible for many of the more successful designs since he started in 1922. Over 25 designs stand to his credit apart from work on such non-aeronautical projects as motor torpedo-boats. To Tupolev must go the credit of redesigning the Boeing B-29 Superfortress in 1945, which is now hailed as Russia's leading multi-engined civil transport, the Tu-70. At present his only known original designs are the successful Tu-2 twin-engined attack-bomber and a twin-jet development which was shown for the first time on August 3, 1947, at Tushino aerodrome, spiritual home of the Moscow Soviet Aviation Day celebrations.

Little is known about the background of Soviet glider and sailplane designers or their recent works, and the helicopter designer also falls into this category. **Professor Ivan P. Bratukhin** is the most easily identifiable rotating-wing engineer, having been associated with helicopter-pioneer Professor Boris N. Yuriev for many years. The most notable post-war design is the two-seat twin-engined helicopter, the Omega, which first appeared at the 1946 Soviet Aviation Day on August 18. He is known to be working on a larger design but no evidence of its advancement is available at this time.

Co-designers **Artem I. Mikoyan** and **Mikhail I. Gurevich** were working together before the start of the Russo-German War (the Great Patriotic War) in 1941. Their joint efforts (and incidentally joint initials—MIG) culminated in the MIG-1 single-seater, single-engined fighter which was available at the time of the German invasion in June, 1941. Then followed the MIG-3 and a radial-engined version of which little is known

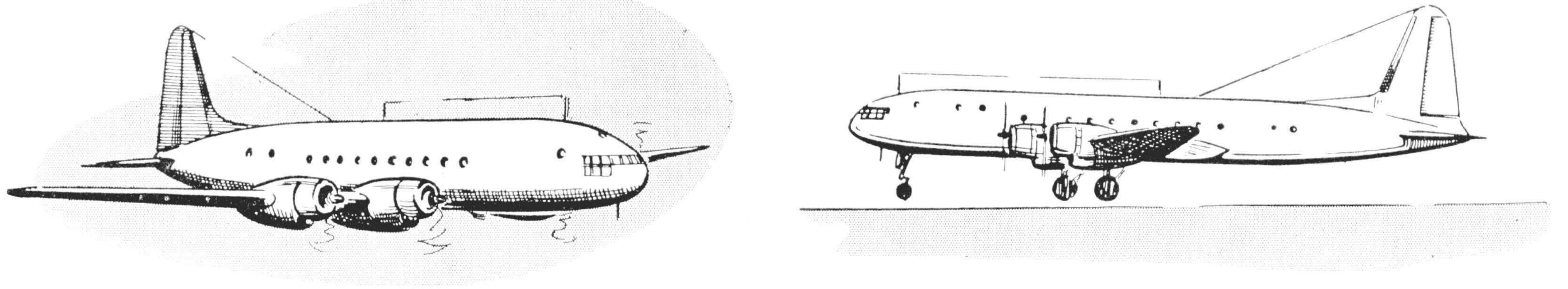
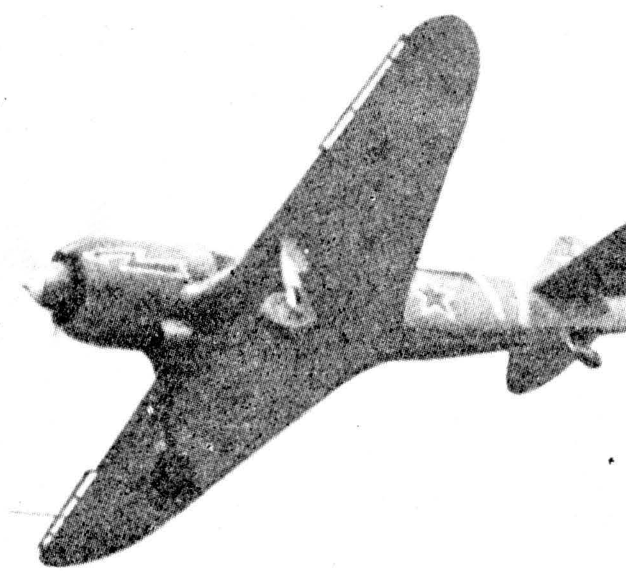


Fig. 8.—These two sketches of the Il-18 four-engined monoplane are based on the only authentic photographs at present known. The form of the wing, tail and engine nacelles follows that of the Il-12. The shape of the fuselage suggests pressurization. Note the rubber de-icing boot on the fin and other surfaces. A crew of six and sixty-five passengers are quoted. The following data for the machine, with four ASH-82 engines, has been given: span 39.35 m. (131 ft. 0 in.); length 30.5 m. (100 ft. 0 in.); max. speed 485 km.p.h. (290 m.p.h.); economical cruising speed 270 km.p.h. (612 m.p.h.); range 2,500 km. (1,500 miles)



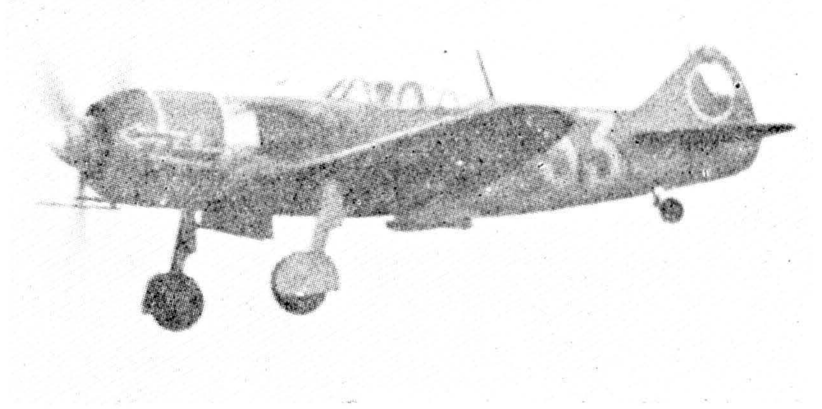


Fig. 9.—One of the standard wooden fighters, the La-5 (left). In order to overcome the shortage of metal, most fighter aircraft were built largely or wholely of wood. Resin-bonded plywood and a special varnish liberally applied internally has overcome the exigencies of the Russian climate. 1,540 h.p. ASH-82F or 1,825 h.p. ASH-82FNV air-cooled radial engine installed in a cowling similar to that on the Fw-190. The familiar Hucks starter dog is retained on the propeller shaft. Armament is two 20 mm. cannon, with 170 r.p.g., in the top of the fuselage, with bombs or rockets under the wing. Span 9.8 m. (32 ft. 3 in.); length 8.5 m. (28 ft. 5 in.); wing area 17.4 sq. m. (188 sq. ft.); tare weight 2,760 kg. (7,072 lb.); gross weight 3,357 kg. (7,385 lb.); max. speed 520 km.p.h. (324 m.p.h.) at sea level, 549 km.p.h. (341 m.p.h.) at 2,400 m. (7,500 ft.); cruising speed 400 km.p.h. (250 m.p.h.); range 640 km. (400 miles). The La-7 (right) is similar to the La-5, but refinements and an improved engine installation give it a top speed of 373 m.p.h.

except that it did go into limited squadron service in 1943. After the war came a surprise. This team entered the light aircraft field and brought out the novel three-seat 'canard' high-wing monoplane, the MIG Utka ('duck') which was first shown at Tushino aerodrome (Soviet Aviation Day) on August 18, 1946, although details of the design were quoted by Moscow radio as early as December, 1945. About the same time, 1945 that is, the MIG team developed a rocket-assisted fighter research monoplane, the auxiliary rocket-booster being situated in the fuselage under the large area fin and rudder. Main power unit is a tractor two-row radial engine, possibly an ASH-82 FNU air-cooled 14-cylinder power unit. It is possible that this team has now parted and that Mikoyan and Gurevich are working on separate themes. They have been credited with at least one twin-jet single-seater fighter which is in full squadron service. *Inter-Avia* quotes this as the MIG-9.

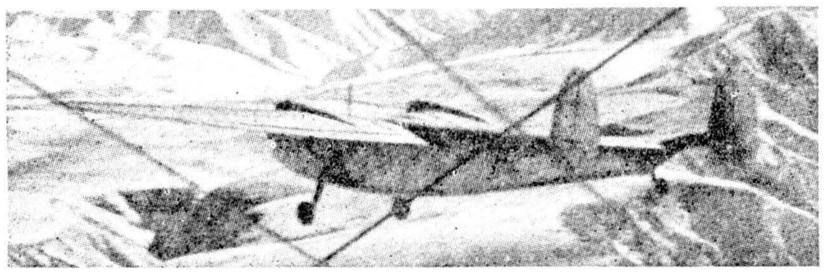
Like most leading Russian designers of today, **Sergei Ilyushin** started his engineering career the hard way. He was born in 1894 of peasant stock and went to Moscow when he was fifteen to find work. Attracted by all things mechanical he advanced from an aerodrome labourer and mechanic's assistant to become chief flight mechanic in the Russian Air Force of the Four Year's War. After the Revolution he entered the Zhukovsky Air Academy at Moscow and eventually succeeded in gaining employment at Ts.A.G.I. where he prospered and was appointed a director and chief designer of one of Moscow's aircraft factories. Ilyushin's first notable contribution to the aeronautical field was the long-distance record-breaking Ts.K.B.-26 twin-engined bomber of 1934, which was modelled after the American Douglas DC-1 and DC-2 series of transports. This experimental bomber was later developed into the DB-3 and Il-4 series and gives a clue to the origin of his post-war replacement for the DC-3, the Il-12, which is now in full-scale production as a 27-32 seater medium-range passenger and troop transport. Ilyushin can claim to be the first Russian designer to build an original post-war four-engined transport, the Il-18, which carries 65-66 passengers and is reported by the Tass Agency to be in production. Another of Ilyushin's machines, a four-jet medium bomber, surprised military observers at Tushino in 1947; but perhaps his best-known type was the heavily-armoured, rocket-firing single-engined Il-2 series, the 'Stormovik'. The latter became the main spearhead of Russian Army attacks and advances from 1943 onwards. From a single-seater, the Il-2 was developed into a two-seater, and in 1945 was completely re-designed, with new wing shape, refined undercarriage detail and a more powerful liquid-cooled in-line engine. This is the Il-10, which is in full squadron service as an assault-bomber and in some cases as a ground-attack advanced trainer.

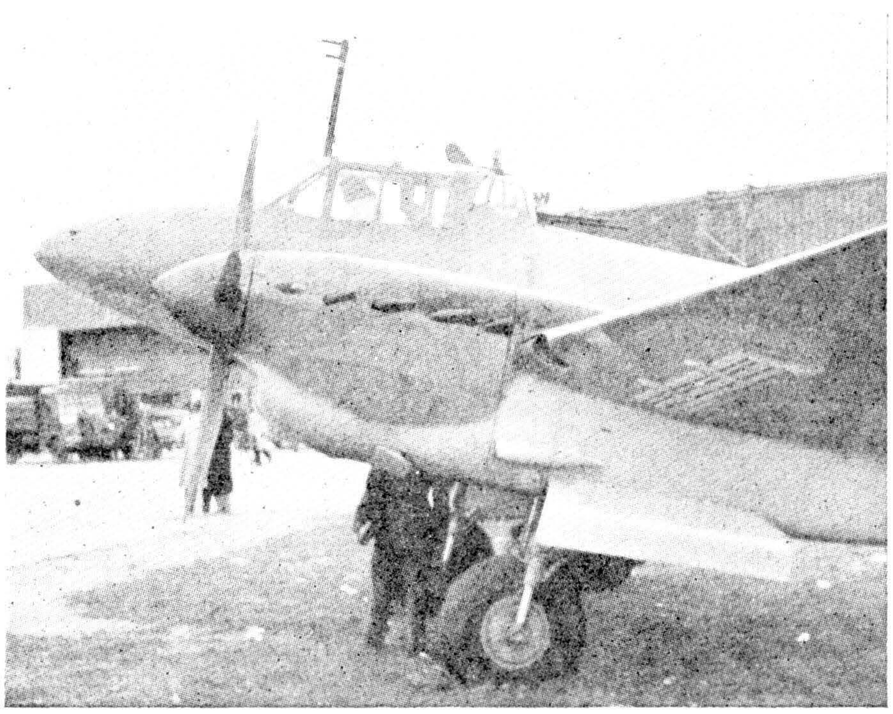
Semyon A. Lavochkin, although born in 1900, did not make his mark in Russian aviation until just before the war, when, in conjunction with Gorbunov and Gudkov, he designed the LAGG-1, a single-seater fighter which came into service at the time of the 1941 invasion. Then came the LAGG-3, an improved version, followed by the large-scale production radial-engined La-5, which appears to be his first solo effort. This successful wooden fighter first appeared in the spring of 1943 and was further developed into the front-line La-7 in 1944. Not until after the war in 1945 did the next version appear, namely the La-9, which is believed to be an all-metal development which has the look of the German Focke-Wulf Fw190. The La-9 is in full squadron service and during the 'trouble' in Berlin in July of this year was often to be seen in numbers over the Royal Air Force aerodrome at Gatow. The La-9 has been shown at Tushino (Soviet Aviation Day) in 1947, with a jettisonable rocket-unit under each wing. Another variant was also displayed with two Argus-type impulse ducts similarly mounted. Strangely enough the Russians seemed to favour this idea, for more than one example appeared over the aerodrome. Lavochkin also produced a La-7 two-seater, a clean affair which, it is reported from an eye-witness, 'vibrates like mad' when the engine is being warmed up.

Although both **Vladimir Petlyakov** and **Nikolai N. Polikarpov** are now dead, Petlyakov in an air accident in 1944 and Polikarpov in July of that year through natural causes, both will long be remembered for their contribution to the Soviet science of aircraft design. Vladimir Petlyakov was the designer of the solitary four-engined Russian heavy-bomber to appear during the war, the Pe-8 (TB-7). Until the system of aircraft designation was changed in 1940, from design duty to designer's initials, the Pe-8 was known as the TB-7 (TB standing for heavy-bomber). The TB-7 was seen in this country in 1943, but was little used operationally. As a heavy bomber the Pe-8 seemed to have little to commend itself and is reported to be used as a freight transport. Both in-line and radial-engined versions were built. Petlyakov's most important contribution was the Pe-2 series of small, twin-engined attack-dive bombers. The Pe-2 was built in large numbers and from its inception in 1940 was variously

Fig. 10 (right).—The Pe-2 has already been fully described and illustrated (with three view drawings), but this photograph is of interest because it shows the latest version, which is in general use with the Soviet and satellite air forces. The engine cowling, small power-operated turret and Junkers-type dive brakes should be noted. The engines are the VK-105R (M-105) which give 1,100 h.p. at 2,000 m. (6,560 ft.) or 1.050 h.p. at 4,000 m. (13,120 ft.)

Fig. 11 (below).—The Shche-2 twin-engined monoplane is largely used for general communications and ambulance work. It is of light wooden construction based on sailplane practice. The machine was used for supplying partisans toward the end of the war and is specially designed for operating from restricted spaces. The engines are said to be the M-11F of only 145 h.p. Span 21.95 m. (75 ft.); length 15.24 m. (50 ft.); range 640 km. (400 miles)





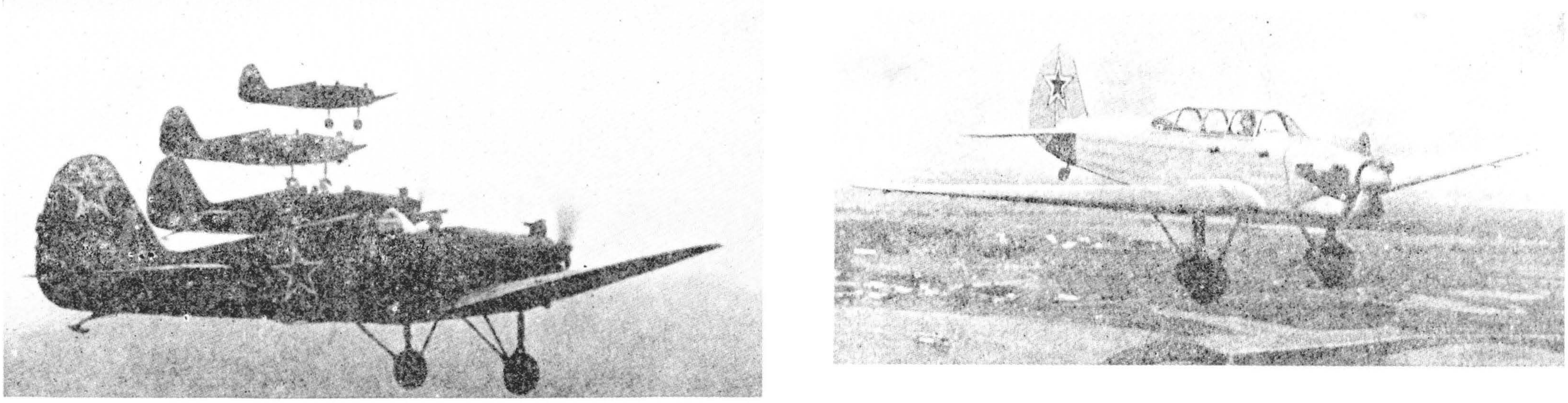


Fig. 12.-Yakovlev's Ut-2 trainer is another example of the Russian predilection for development of a theme. Originally designed as a simple low-wing monoplane, rather like the first Miles Hawk in layout, it has undergone progressive refinement since 1935. It was obviously intended as a replacement for the Po-2 as a general elementary trainer, both for the Air Force and the clubs. In its original form the cylinders of the engine were uncowled, the cockpits open and the undercarriage fixed—then it was 'cleaned up' with enclosed cockpits, more powerful versions of the M-11 and, eventually, a retractable undercarriage. Data for the Ut-2 are: span 10·21 m. (33 ft. 8 in.); length 7·16 m. (23 ft. 6 in.); wing area 17·2 sq. m. (185 sq. ft.); tare weight 625 kg. (1,375 lb.); gross weight 940 kg. (2,075 lb.); max speed 195 km.p.h. (122 m.p.h.); cruising speed 160 km.p.h. (100 m.p.h.); max. rate of climb 4·2 m. sec. (820 ft. min.); service ceiling 4,700 m. (15,400 ft.); range 750 km. (450 miles)

modified to incorporate new gunner's positions, including a rear turret, and revised and more powerful engines. At least one version is used by the Polish Air Force as a gunnery trainer, having the pilot's cockpit faired down at the rear and replacing the normal cramped turret is a large turret, presumably power-operated—the whole being reminiscent of the Fairey Battle gunnery trainer of 1942. The Pe-2 series is largely replaced by the more powerful Tu-2 of similar general form, although it does form the front-line bomber strength of such smaller air forces as Poland and Czechoslovakia. Polikarpov will be remembered chiefly for his ubiquitous 'work-horse', the Po-2 biplane, which has been and still is used for every purpose imaginable from elementary training and glider towing to ambulance and crop-dusting work. Thousands have been built and at least 14 versions are known to have existed since it was first exhibited at the 1928 Berlin Aero Show. Polikarpov was also responsible for many of the pre-war single-seater fighters, both biplanes and monoplanes.

A little-known designer is **S. O. Shchebakov**, who concentrated on glider and sailplane design before the war. His most notable military contribution was the twin-engined powered-glider freight and troop transport Shche-2. Now the Shche-2 is used as a 10-seater short-range feeder-liner on the Aeroflot internal routes. The Shche-2 was also used for dropping supplies to the partisans in 1944-45, and for taking out the sick and wounded from small, moderately inaccessible air-strips. Poland uses a few of these aircraft as eight-seater parachute transport trainers.

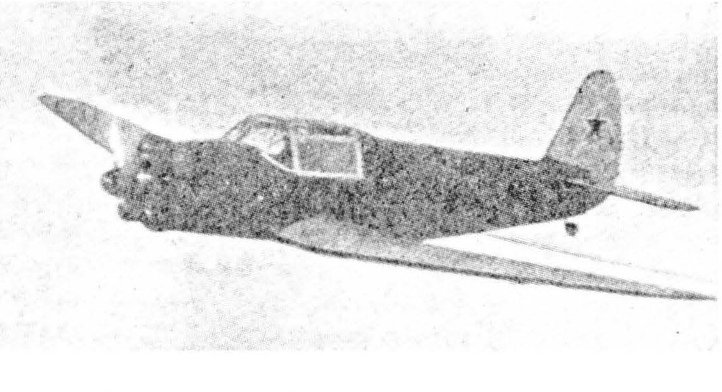


Fig. 13.—The Yak-12 appears to have been a prototype only, probably built to decide whether a high or low wing was preferable for a communication machine—the Yak-14 being chosen. The standard 145 h.p. M-11F is fitted and the only data are, span 10·5 m. (35 ft.); length 7·5 m. (25 ft. 0 in.)

Of all the well-known contemporary designers, **Alexander Sergeiovich Yakovlev** is the most prolific, versatile and, incidentally, the youngest. Born in Moscow on March 19, 1906, Yakovlev entered the Zhukovsky Air Academy in 1924 and graduating from the aero-engine division, entered the aircraft field and designed a single-seater sporting biplane. In rapid succession he produced the AIR-series of sporting and light transports. Even with regard for the Russian enthusiasm for awards and decorations, Yakovlev is highly placed, for during the past eight years he has been awarded the following: Doctor of Technical Sciences (1940), Member of the Academy of Sciences of the U.S.S.R. (1944), Lieutenant-Generalship of the Aviation Engineering Corps, Hero of Socialist Labour, and, most important of all, People's Vice-Commissar for Aircraft Production. Besides numerous Orders, Yakovlev has been awarded four Stalin Prizes, 1941-42-43 and 1947. Despite this success in the semi-political field it must be admitted that Yakovlev has more different types in service at this present time than any other Russian designer. In 1941, Yakovlev designed the I-26 (Yak-1) which was the precursor of the famous series, Yak-3, 7, 7B and 9, of which 10,000 were built from 1941 to 1945. Yakovlev decided that the combination of a powerful in-line engine, small fire-power, a lightly constructed airframe and small wing area would bring about a highly manoeuvrable 'dog-fighter'. What the Yak-3 loses in speed, it gains

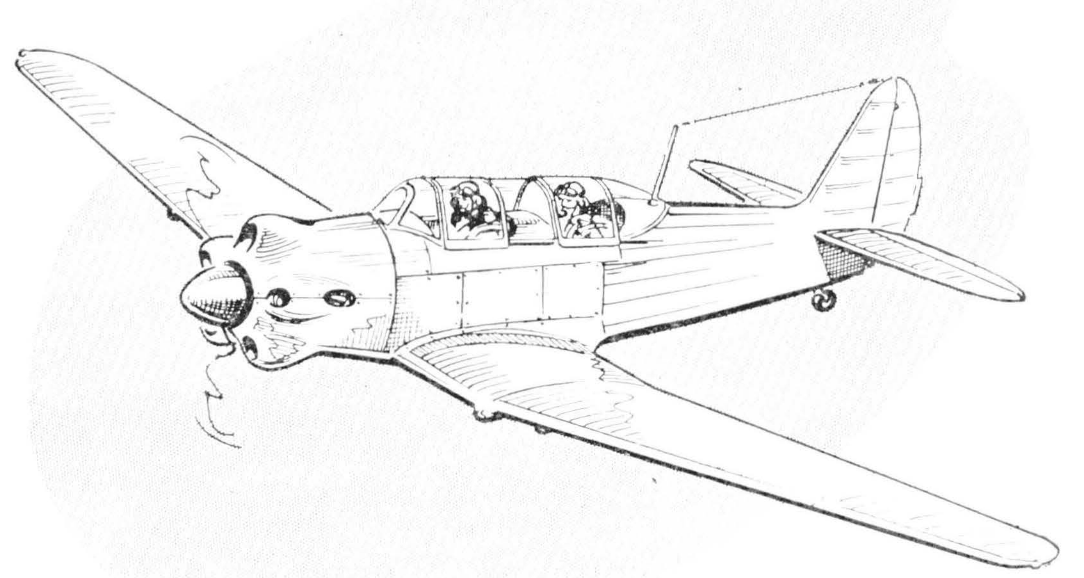
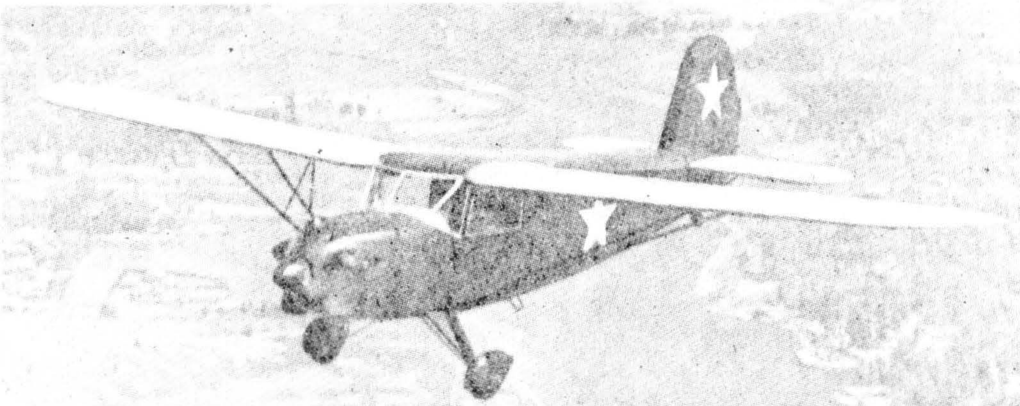


Fig. 14 (left).—There is, again, some confusion in the identification of the Yakovlev trainers, but the machine shown here is the Yak-18. It is generally very like the later versions of the Ut-2, although it is slightly larger, and one guesses that many of the parts are interchangeable. The structure is said to be of metal with fabric covering and it obviously departs from the earlier layout in having a centre section. Full night-flying equipment and radio are fitted and from the form of the windscreen it would appear to be fitted for gunnery training also. It has a 160 h.p. M-11FR engine and a 6 ft. 6 in. dia. c.p. metal propeller is fitted. Characteristics given when the Yak-16 was exhibited in Poland were as follows: span 10·6 m. (34 ft. 9 in.); length 8·03 m. (26 ft. 4 in.); height 3·15 m. (10 ft. 4 in.); wing area 17 sq. m. (183 sq. ft.); tare weight 755 kg. (1,665 lb.); gross weight 1,070 kg. (2,360 lb.); max. speed 257 km.p.h. (159 m.p.h.); cruising speed (53 m.p.h.); service ceiling 5,000 m. (16,400 ft.); range 900 km. (560 miles)

Fig. 15 (below).—Built in 1945, the Yak-14 is a little known communications monoplane in service both as a land, sea and ski plane. 145 h.p. M-11 engine in a helmet cowling. Span 12 m. (39 ft. 6 in.); length 8·45 m. (27 ft. 8 in.); wing area 22 sq. m. (237 sq. ft.); tare weight 770 kg. (1,700 lb.); gross weight 1,200 kg. (2,650 lb.); max. speed 200 km.p.h. (124 m.p.h.); cruising speed 160 km.p.h. (100 m.p.h.); landing speed 70 km.p.h. (43 m.p.h.); initial rate of climb 3·3m. sec. (650 ft. min.); ceiling 4,000 m. (13,700 ft.); range 1,000 km. (620 miles)



PERFORMANCE

A superior eel is the conger,
The same shape but 'intenser' and stronger,

He wins every tussle
By sheer mass of muscle—

Because his 'performance' lasts longer.

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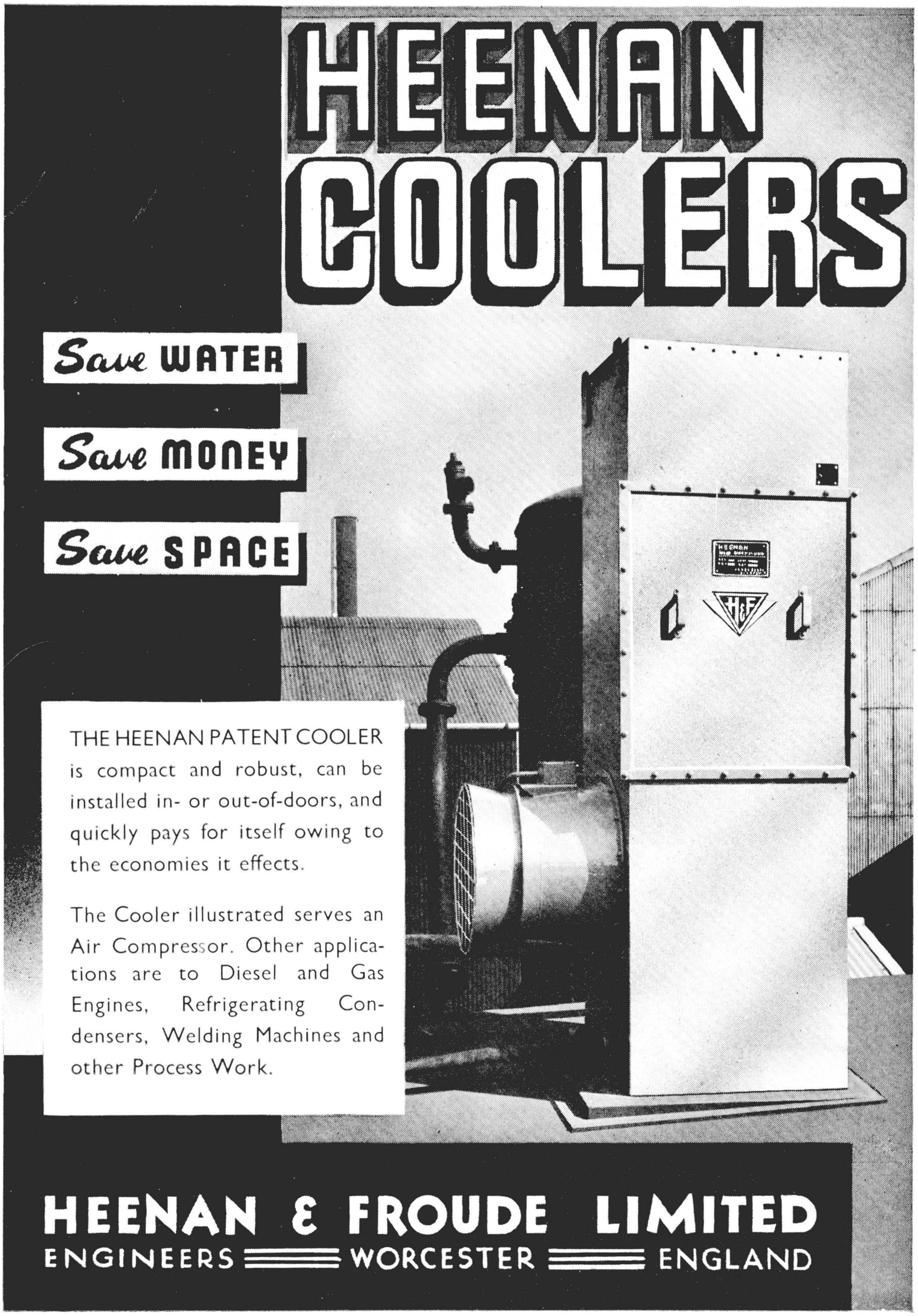
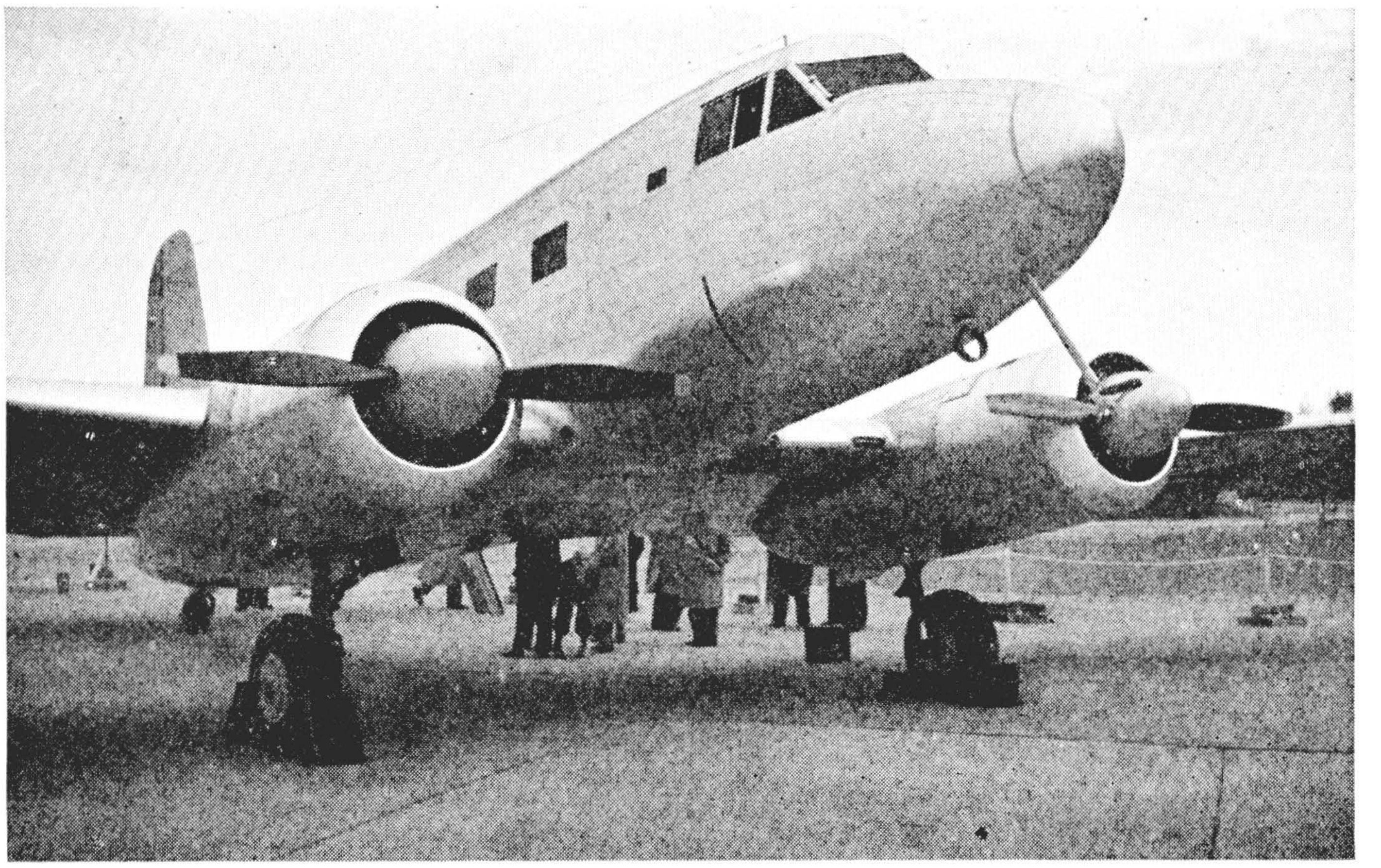


in great manoeuvrability and a high rate of climb. As a front-line stand-by the Yak-3 is in full squadron service in Germany today, along with the La-7 and La-9. From the Yak-3 has been developed one of the single-jet aircraft of pure Russian design. This is the tail-wheel undercarriage Yak-15 (the nomenclature is quoted from *Inter Avia*), which is one of the smallest jet fighters yet built. It is in full squadron service. Something of a mystery is the Yak-4 which first appeared in 1942 as a single- or two-seater twin-engined fighter. Although it may have been proved a success it never appeared in quantity.

During the war Yakovlev found time to devote his attention to the light transport field and in 1943-44, the twin-engined Yak-6 light bomber, radio and navigational 'maid-of-all-work' appeared. Carrying a crew of two and six passengers the Yak-6 can be described as the Russian Anson, counterpart of the commercial Yak-8. Fitted with a larger fuselage, the Yak-8 can carry eight passengers. Latest in the line, and a break-away from the earlier all-wood light transports is the Yak-16, a ten-seater, twin-engined, all-metal feeder liner, which is reported to be in service on Aeroflot routes. Until the Yak-16 was displayed at the Poznan (Poland) International Fair in April of this year, few people outside Russia had ever heard of it.



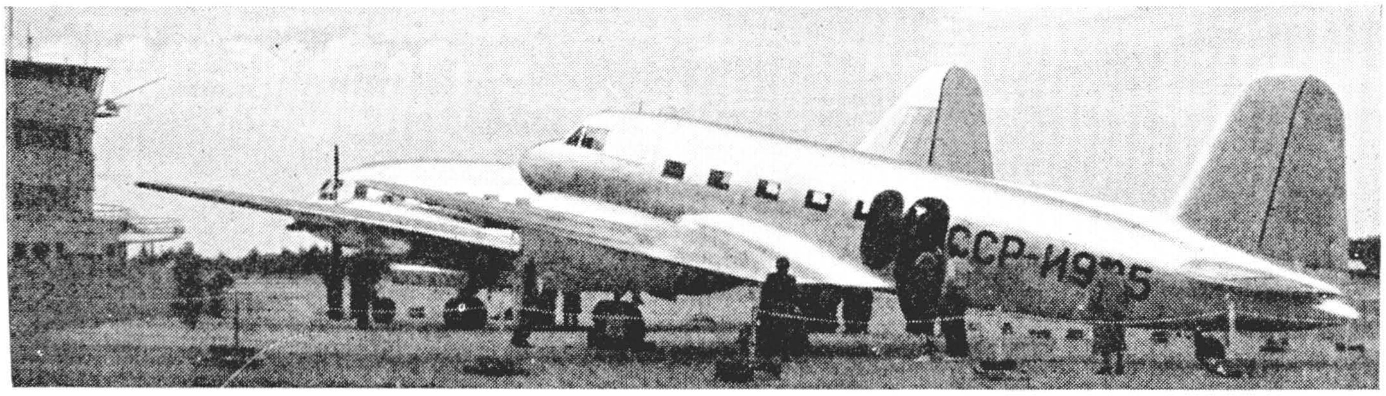
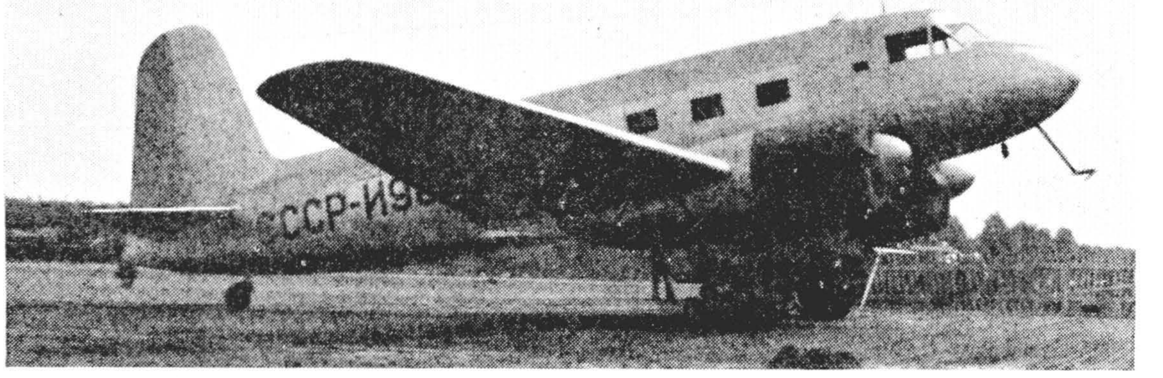


Fig. 16.—Although the Yak-16 all metal feeder liner was exhibited this year at the Polish Air Show, information about it is still conflicting. Inspection of photographs shows it to be of conventional construction and apparently good workmanship—but the exteriors of Russian aircraft are generally better finished than the unseen parts. Statements on accommodation vary and it is not clear whether a total capacity of fourteen is available or that there are ten passenger seats with a crew of two or four. The engines are the ASH-21, a nine-cylinder air-cooled radial, giving 760 h.p. for take-off and rated at 630 h.p.; with two-bladed Visch c.p. propellers. Data, which we give with reserve, are as follows: span 17 m. (56 ft.); length 11 m. (36 ft.); height 3·6 m. (12 ft.); max. speed 310 km.p.h. (190 m.p.h.); cruising speed at 1,700 m. (5,600 ft.) 290 km.p.h. (177 m.p.h.); landing speed 90 km.p.h. (50 m.p.h.); service ceiling 5,000 m. (16,400 ft.); range 1,000 km. (620 miles)

In the elementary trainer field Yakovlev has designed many successful types: following on from the standard two-seater low-wing elementary trainer, the Ut-2 comes the present Yak-18, a larger, intermediate trainer which has a smooth cowled radial engine, enclosed, tandem cockpits, retractable undercarriage, and a fabric-covered rear fuselage. The Yak-18 also has one of the typical Russian all-weather 'helmeted' engine cow-



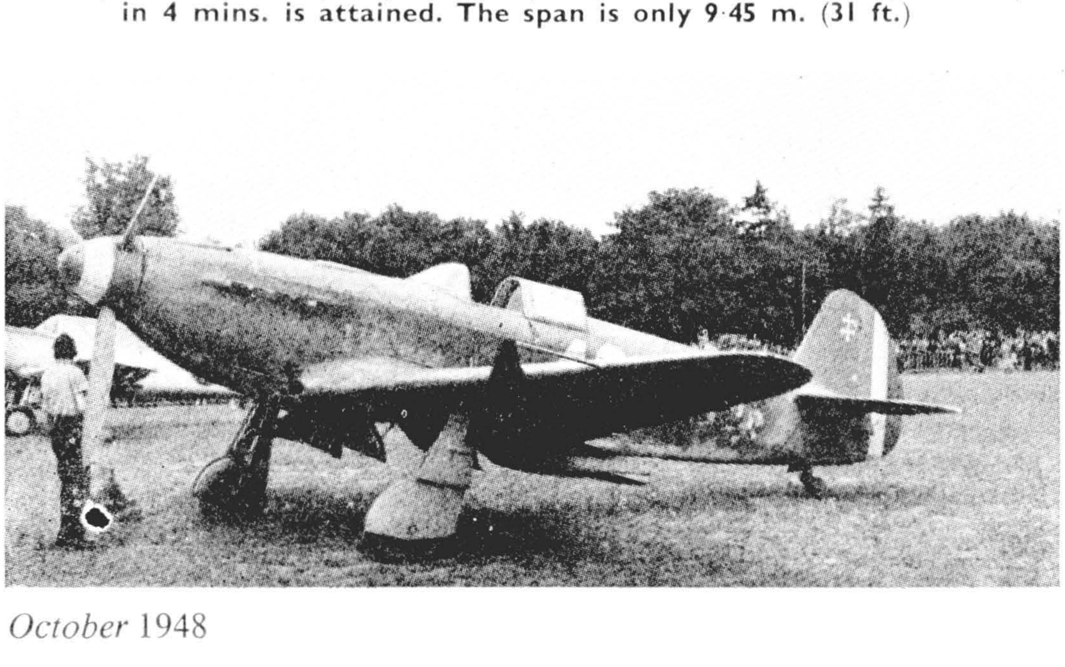


Fig. 17.—This example of the Yak-3 was 'exported' as part of the Normandie-Niémen escadrille of the Armée de l'Air. This is an outstanding example of the Russian designers' ability to concentrate on essentials. Lacking a high-powered engine the machine was made small, light and, consequently highly manoeuvrable, with only one 20 mm. cannon and two 12·7 mm. guns. The structure (welded tubular fuselage with wooden covering and wooden wing and tail) is well-finished externally and very rough inside. The obvious idea was to make the machine quickly with available labour and both the woodwork and welding are astonishingly crude, but that control was maintained is evidenced by inspection stamps on all parts. With a Hispano-Suiza type (VK-107) engine of 1,310 h.p. a max. speed of 552 km.p.h. (343 m.p.h.) and a climb to 5,000 m. (16,400 ft.) in 4 mins. is attained. The span is only 9·45 m. (31 ft.)

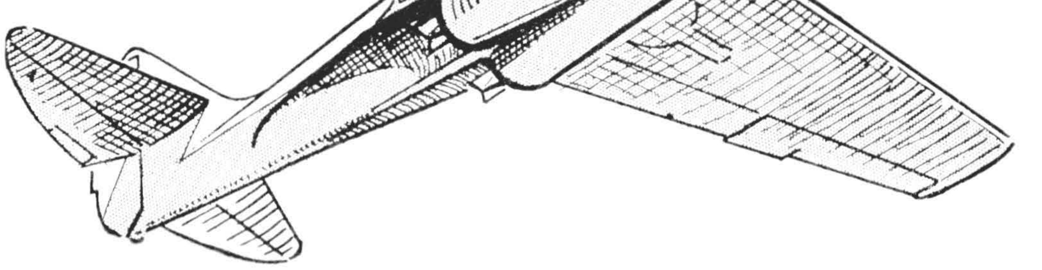


Fig. 18.—This sketch of the MIG-9 twin-jet fighter has been made from a photograph that was not clear enough for reproduction and it shows only those details not open to contradiction. The engines, two axial-flow units of the B.M.W. type, are mounted in the fuselage under the wing and there is a 'keel' between them that divides the thrust. Armament, in the nose, consists of one 37 mm., or larger, cannon and two 12.7 machine guns

lings. Less well-known is the remaining low-wing monoplane, the Yak-12, which has side-by-side seating and a retractable main undercarriage. There is also the strut-braced high-wing monoplane, the four-seater Yak-10 (which can also be fitted with floats) and the Yak-14. Little is known of the Yak-10, except that the Russian Air Fleet uses it in small numbers. There seems every likelihood that when A. N. Tupolev retires, or dies, Yakovlev will step into the position of Director of Ts.A.G.I.

Some Current Design Trends

With money no object and labour unlimited, the Soviet aircraft industry is indeed in a happy position, but, as has been stated previously in this article, it appears as if the designer has to take his ideals and then work them out to fit in with the lowest common denominator. In many ways this is an excellent plan to follow, but how well it works in practice only the Russians can tell. The Soviet Union covers a vast territory, one-sixth of the total land area of the world and, as such, experiences nearly every known climatic condition. Every important aeroplane has therefore to be designed to meet these conditions. An example of this is the Ilyushin Il-12 passenger transport which meets temperatures of −62 deg. C. at Yakutsk in the North to +60 deg. C. at Tashkent. The Russians claim a constant cabin temperature of +25 deg. C. with an outside temperature of −50 deg. C. To overcome the extreme cold, many aircraft are fitted with the familiar fan-shaped shutters over the air inlets of their radial engine. When warming up or on the ground the sliding shutters are kept in the fully closed position, and when sufficiently warm they are opened mechanically to allow the air to flow over the cylinders. A very noticeable feature of most Russian aircraft is their ability to be started almost immediately. Once when an R.A.F. aircrew went to Vnukovo (Moscow airport) soon after the war, in midwinter, they were amazed at this speed of operation, whereas they lost much time, in comparison, in starting the Rolls-Royce Merlins which powered their Avro Yorks.

Going to the opposite extreme it appears that American radio installations are preferred to the Soviet designed sets, as witness the Ilyushin Il-12.

Although machine-guns and especially 'heavy' cannon (23 mm. and 37 mm.) are rated high for efficiency there seems to have been little attempt to deal with the problems of power-operated turrets—probably because the close army co-operation work required led to the design of few aeroplanes suited to turret armament. Now, with the appearance of the Ilyushin 4-jet bomber and the Tu-70 version of the Superfortress, it is logical to assume that development work is well in hand on the Boeing type of barbette.

The tricycle undercarriage is becoming more popular with Soviet designers, as witness the Ilyushin Il-12, Il-18, Tu-70 (and its bomber counterpart) the MIG Utka, not forgetting, of course, the numerous new jet fighters, bombers and reconnaissance aircraft. This concept brings its own troubles, not least the question of runway length. A curious feature of some Russian airport-type runways is that the concrete is built into hexagonal units, presumably to allow for severe expansion and contraction.

On the aero-engine and accessory side it is difficult to differentiate between genuine domestic design and foreign adaptations. We know, for instance, that certain foreign accessories are used on modern Soviet aircraft and we have the classic example of Russia building a complete heavy bomber (the B-29 Superfortress) with neither licence nor authority from the parent company. Although the Russians credit their own designers with certain power units, it is a fact that basically they are the same as their original foreign counterparts.

Most interesting of all, and of which least is known, is Russia's progress in the jet field. So little can be said at the present time that any specific appraisal would be superfluous. Nevertheless, when more reliable information has become available an article on this subject will appear.

FLOW IN NOZZLES

(Concluded from 296)

and 11) so that the difference in the ordinates between (d) and (d') is log S'_c/S_c. The origin 0 of the transparent sheet is displaced on (γ); it coincides with P. Then (d') cuts (γ) at P'. The shock wave is produced at PP' if the ordinates of these two points are of opposite sign. The determination of PP' is simple if the precaution is taken of tracing the (γ) curve symmetrically about the α axis (FIG. 11).

3–1–3–2–2–2 *The Second Approximation*

The first determination of PP' makes it possible to calculate p and p'. The curve in FIG. 10 gives a new value of P'_c/Pc, and therefore of $p'c$ from which a second and more accurate construction may be made.

3–2 Calculation of the Pressure Upstream when the Downstream Pressure is known

The known values are:

the shape of the nozzle
the downstream pressure p_e
the discharge D
the upstream temperature T_0 (or the sonic velocity a_0).

The problem presents two different aspects according to whether the nozzle has a critical section or not.

3–2–1 *Sonic or Supersonic Conditions*

The critical section S_c is the minimum cross section of the nozzle: since S_0 is given, we know

$$\sigma_0 = S_0/S_c$$

which fixes the position of the point P_0 on the (γ) curve (FIGS. 4 and 12). Construction as in paragraph 2–5).

The Mach number M_0 at P_0 is known (FIGS. 3 and 12. Construction as in paragraph 2–4) from which

$$v_0 = a_0 M_0$$
$$\text{and } \rho_0 = D/S_0 v_0.$$

The Gay-Lussac law gives:

$$P_0 = \rho_0 R T_0.$$

3–2–2 *Subsonic Conditions*

The simple construction of paragraph 3–2–1 cannot be used as the critical section is not known. It is therefore necessary to proceed by approximation.

Given an approximate value of p_0 we deduce

$$\rho_0 = p_0/RT_0$$
$$\text{and } v_0 = D/\rho_0 S_0.$$

The initial conditions being known we may calculate p_1 by the construction in paragraph 3–1–1.

According to whether $p_1 > p_e$ or $p_1 < p_e$ the construction is made with a smaller or greater value of p_0 and the exact value of p_0 is determined by interpolation.

4. CONCLUSION

The method described permits a graphical solution to be made of a large number of problems concerning nozzles. It requires no calculation and, owing to the use of the transparent paper, avoids interpolation, so that very accurate readings may be made.

CLOSED CYLINDRICAL VESSELS

(Concluded from 297)

$k = t/T$. It will be observed that, when the thicknesses of the shell and hemispherical end are equal ($k = 1$), the bending moment at the junction vanishes and the shearing force Q per unit length is $-\dfrac{p}{8m}$.

Example. A circular cylinder of mean diameter 20 in. and wall thickness 1 in. is closed at both ends by hemispherical shells 2 in. thick. Calculate the maximum bending moment and shearing force set up by an internal pressure of 100 lb. per sq. inch (gauge)

$$\alpha = \frac{a}{t} = 10$$

$$k = \frac{t}{T} = \tfrac{1}{2}$$

From FIG. 3: $\dfrac{M}{pt^2} = \gamma = 0{\cdot}583$

$$M = 0{\cdot}583 \times 100 = 58{\cdot}3 \text{ lb. in./in.}$$

From FIG. 4: $-\dfrac{Q}{pt} = \xi = 0{\cdot}745$

$$Q = -0{\cdot}745 \times 100 = -74{\cdot}5 \text{ lb./in.}$$

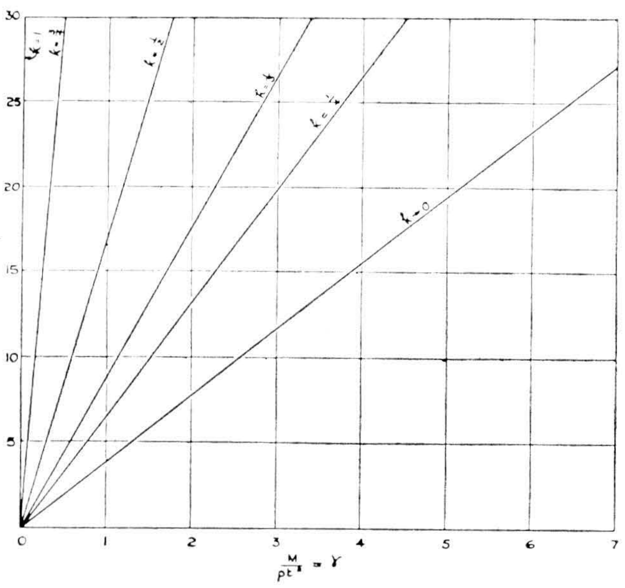


Fig. 3

It will be observed that these values are very much smaller than those obtained for a cylinder closed by flat plates.

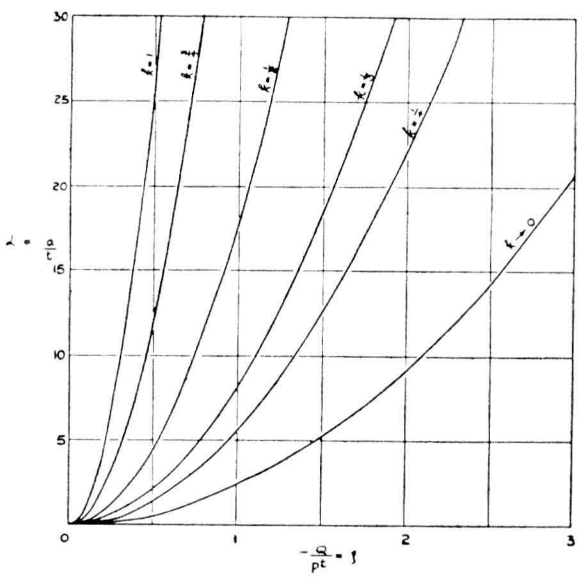


Fig. 4

Spun Glass Blankets for Press Stretching

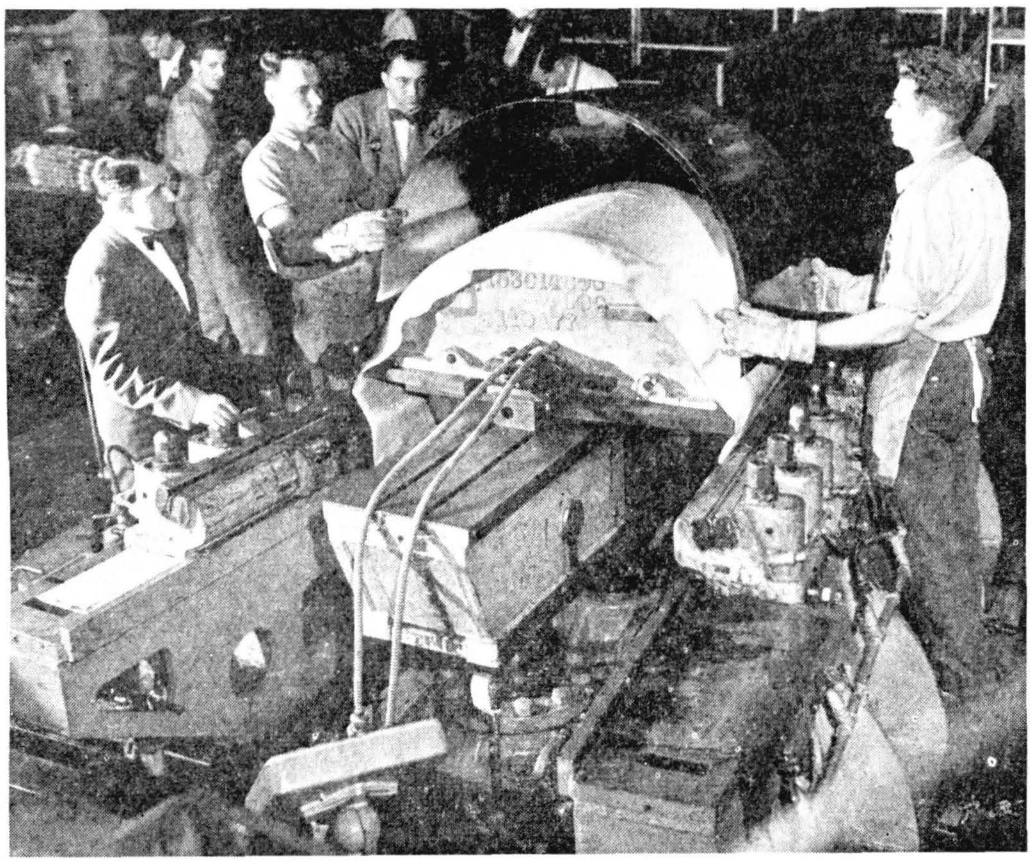
A New Technique Developed at the Glenn Martin Factory at Baltimore to Overcome Difficulties in the Hot Forming of Magnesium Sheets

SPUN glass, woven into thin blankets, is being used by the Glenn L. Martin Company, Baltimore, in the stretch forming of magnesium sheets as a successful substitute for other, less efficient materials.

The Problem

Originally, in the stretch forming of sheet aluminium, adhesion between the surfaces of the sheet and the stretch block caused an uneven flow of the metal, producing an unsatisfactory, irregular, wavy-surfaced finished product. In some cases adhesion also caused ruptures in the surface of the sheet or damage to the forming die if some separating medium were not placed between the part and the form block.

The practice often used in industry for the solution of this problem is to paint the material to be formed and the stretching block as well with a heavy coating of grease. With the presence of grease between the stretch block and the material, co-extensive movement becomes possible in the sheet metal. That is, the desired extension is effected without excessive friction.



Photograph showing how the Martin spun glass blanket is stretched over the former. Note the heating equipment and the gloves used for handling the heated magnesium panel

TABLE I: COMPARATIVE TIME ANALYSIS OF GLASS CLOTH vs GRAPHITE AS A FRICTION REDUCING AGENT IN STRETCH FORMING MAGNESIUM

Part description	*Operations Required using Graphite Method*	*Time required*	*Operations Required using Glass Cloth Method*	*Time required*
Magnesium Skin 0·125 in. × 4 g. × 72 in.	(1) Spray parts with graphite	5·00 min.	(1) Heat form block to 550° F. initially (Connect terminals and throw switch)*	0·20 min.
	(2) Paint form block with graphite	0·40 min.	(2) Place skin between pre-heat platens for heating to 650° F.	1·50 min.
	(3) Heat form block to 550° F. initially (Connect terminals and throw switch)	0·20 min.	(3) Place glass cloth blanket over form block	0·20 min.
	(4) Place skin between pre-heat platens for heating to 650° F.	1·50 min.	(4) Remove skin from pre-heat platens and clamp in stretch press	2·00 min.
	(5) Remove skin from pre-heat platens and clamp in stretch press.	2·00 min.	(5) Stretch form to proper contour	0·50 min.
	(6) Stretch form to proper contour	0·50 min.	(6) Remove from stretch press and stack	0·50 min.
	(7) Remove from stretch press and stack	0·50 min.		
	(8) Remove graphite lubricant by scrubbing in chromic acid-calcium nitrate bath and stack†	60·00 min.		
	Total time per part	70·1 min.	Total time per part	4·9 min.

Disadvantages of Grease

However, though this method solved one problem, it immediately produced several new ones. It was very unsatisfactory because of the messy and dangerous working conditions created by the large quantity of grease deposited on the material and the press as well as the dangerously slippery condition of the floor and walkway caused by the accumulation of excess lubricant. The handling of the formed parts in a greasy condition was very hazardous to the workers and provided an opportunity for hand cuts and bodily injury resulting from slips and falls. Another objection of great importance was the fact that grease removal proved to be a costly and time-consuming processing operation.

The Solution for Aluminium

The substitution of a sheet of rubber for the grease effected favourable results and continues to be a satisfactory solution for the cold-forming of aluminium sheets. However, with the advent of magnesium the necessity for hot-forming this material made the use of rubber impracticable because it smoked and smudged under the heat. Reversion to grease, oil, graphite or other lubicants was equally undesirable in a hot-forming operation. Oil, for example, had a flash point of 425 deg. F. The others brought back the old, wasteful uneconomical and dangerous conditions which the company had sought to avoid from the beginning.

After considerable investigation by Martin manufacturing research engineers, R. E. Berger and H. P. Hessler, a spun glass blanket, 0.027 in. thick, was found to be the perfect solution to all problems—far superior in use to all lubricants as well as to rubber. In fact, experiments proved it to be unique in this particular application. For example, in a comparison of two forming operations, identical except in the substitution of the glass blanket for graphite, it was demonstrated that 70.1 minutes were consumed using the old method and only 4.9 minutes with the glass blanket—a net saving of 65.2 minutes in favour of the new Martin development.

Properties of the Blanket

Experience with the glass blanket shows that its high effectiveness is due to:

(*a*) Its heat resistance.

(*b*) Its very high tensile strength when drawn tight.

(*c*) The hard, smooth surface which the fibres of the glass blanket present to both form block and sheet metal, thus promoting a sliding action between them.

(*d*) The relatively low thermal conductivity of the blanket (when heated sheet metal and unheated form block is used).

(*e*) An accompanying passivity of the glass cloth which permits it to elongate partially with the sheet metal during the stretching operation; this being due to the natural flexibility and looseness of the weave.

(*f*) Practicability of stretch-forming heated sheet metal over an unheated form block since the glass blanket acts as a heat resistant insulator, retarding transfer and loss of heat from material to form block.

Use of the glass cloth thus far at the Martin Company indicates that it (1) facilitates production, (2) eliminates operations, (3) produces more satisfactory parts. With further experience in this practice more data will become available on the life expectancy of the spun glass blankets when utilized under these conditions.

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*In many cases heating of the form block is unnecessary because of the insulating effect of the glass cloth which permits retention of the heat in the part being formed.

†All lubricant must be removed from the part or the graphite particles will form individual galvanic cells on the magnesium surface and thereby induce corrosion.

Research Reports and Memoranda

Under this heading are published regularly abstracts of all Reports and Memoranda of the Aeronautical Research Council, Reports and Technical Notes of the United States National Advisory Committee for Aeronautics and publications of other similar Research Bodies as issued

U.S.A.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WARTIME REPORTS

Secretary, N.A.C.A., Washington, D.C.

These reports are reprints of papers originally issued by the N.A.C.A. to provide rapid distribution of advance research results to authorized persons during the war period. They are here merely listed as it is impossible to find space for printing summaries. The first number is the serial number under which they are filed by the British Ministry of Supply. The second number (within brackets) is the N.A.C.A. reference number. Any of them is available on loan from the Editor.

N.A.C.A. T.I.B. 1550 (M.R. April 1944). A Laboratory-tested Constant-level Oil Sump to Prevent Aeration of Scavenged Oil from an Aircraft Engine. By I. Irving Pinkel and Howard D. Plumply.

N.A.C.A. T.I.B. 1551 (M.R. No. E5A05). The Influence of Exhaust Pressure on Knock-limited Performance. By Harvey A. Cook, Louis F. Held, and Ernest I. Pritchard.

N.A.C.A. T.I.B. 1552 (M.R. Jan. 1943). Full-scale Tunnel Tests of a Flying Model of the Curtiss XP-55 Aeroplane. By William J. Biebel.

N.A.C.A. T.I.B. 1553 (M.R. No. E5E21). Relation between Fuel Economy and Crank Angle for the Maximum Rate of Pressure Rise. By Harvey A. Cook and Virginia L. Brightwell.

N.A.C.A. T.I.B. 1554 (M.R. No. E5C30). Operating Stresses in Aircraft-Engine Crankshafts and Connecting Rods. I Slip-Ring and Brush combinations for Dynamic-Strain Measurements. By Francis J. Dutee, Franklyn W. Phillips and Richard H. Kemp.

N.A.C.A. T.I.B. 1555 (C.M.R. No. L4J19). Résumé of N.A.C.A. Stability and Control Tests of the Bell P-63 Series Aeroplane. By Harold I. Johnson.

N.A.C.A. T.I.B. 1556 (M.R. April 1944). Spin-Tunnel Tests of a 1 57th 33-Scale Model of the Northrop XB-35 Aeroplane. By Robert W. Kamm and Philip W. Pepon.

N.A.C.A. T.I.B. 1557 (A.C.R. No. E4H10). Supercharged-Engine Knock Tests of Methyl tert-Butyl Ether. By Henry C. Barnett and James W. Slough, Jr.

N.A.C.A. T.I.B. 1558 (A.C.R. No. E4G08). The Knock-Limited Performance of Several Miscellaneous Fuels Blended with a Base Fuel. By Donald R. Bellman.

N.A.C.A. T.I.B. 1559 (M.R. No. E5J11). A Relation between Knock-Limited or Pre-ignition-Limited Air-Fuel Ratio at Lean Mixtures and Fuel-Air Ratio at Rich Mixtures. By John C. Evvard.

N.A.C.A. T.I.B. 1560 (M.R. No. E5E12a). The Effect of Six Aromatic Amines on the Pre-ignition-Limited Performance of 28-R Aviation Fuel in a C.F.R. Engine. By Donald W. Male.

Nos. T.I.B. 1561-1570 have not been received. [EDITOR.]

N.A.C.A. T.I.B. 1571 (A.C.R. No. E4H03). Engine and Inspection Tests of Methyl tert-Butyl Ether as a Component of Aviation Fuel. By Henry C. Barnett, Carl L. Meyer and Anthony W. Jones.

N.A.C.A. T.I.B. 1572 (A.R.R. No. E5H31). The Performance of a Single-Stage Impulse Turbine having an 11.0-inch Pitch-line Diameter Wheel with Cast Air-foil-shaped and Bent Sheet-Metal Nozzle Blades. By David S. Gabriel and L. Robert Carman.

N.A.C.A. T.I.B. 1573 (M.R. No. L5D03). A Method for Correlating the Cooling Data of Liquid-Cooled Engines and its Application to the Allison V-3420-11 Engine. By George F. Kinghorn, Albert H. Schroeder and William K. Hagginbothom, Jr.

N.A.C.A. T.I.B. 1574 (M.R. June 1942). Free-spinning Tunnel Tests of a 1 23.75-Scale Model of the Douglas DC-3 Aeroplane. By Oscar Seidman and George F. MacDougall, Jr.

N.A.C.A. T.I.B. 1575 (M.R. No. L5D12a). Tests of 0.14-Scale Models of the Control Surfaces of Army Project MX-511 in Attitudes Simulating Spins. By H. Page Hoggard, Jr., and John R. Hagerman.

N.A.C.A. T.I.B. 1576 (M.R. Oct. 1942). Aerodynamic Characteristics and Flap Loads of the Brake-Flap Installation on the 0.40-Scale Model of the F4F-3 Left Wing Panel. By Paul E. Purser and Robert B. Liddell.

N.A.C.A. T.I.B. 1577 (M.R. Nov. 1942). Cooling Investigation of a B-24D Engine-Nacelle Installation in the N.A.C.A. Full-Scale Tunnel. By Robert R. Lehr, George F. Kinghorn, and Eugene R. Guryansky.

N.A.C.A. T.I.B. 1578 (M.R. June 1942). Tests of Four Models Representing Intermediate Sections of the XB-33 Aeroplane including Section with Slotted Flap and Ailerons. By Ira H. Abbott.

N.A.C.A. T.I.B. 1579 (M.R. Jan. 1942). Pressure-Distribution Measurements of Two Airfoil Models with Fowler Flaps Submitted by Consolidated Aircraft Corporation as Alternative Wing Sections of the XB-32 Aeroplane. By Ira H. Abbott.

N.A.C.A. T.I.B. 1580 (M.R. No. L6F21). Flight Investigation of Factors affecting the Carburettor Ram and Nacelle Drag of an A-26B Aeroplane. By J. Ford Johnston, Bernard B. Klawans and Edward C. B. Danforth, III.

N.A.C.A. T.I.B. 1581 (M.R. Jan. 1943). Tests of Two Models representing Intermediate Inboard and Outboard Wing Sections of the XB-36 Aeroplane. By Seymour M. Bogdonoff.

N.A.C.A. T.I.B. 1582 (M.R. Dec. 1941). Preliminary Drag Tests in Flight of Low-Drag Wing on the Curtiss XP-60 Aeroplane. By Eastman N. Jacobs.

N.A.C.A. T.I.B. 1583 (A.C.R. Oct. 1939). Effects of Propellers and of Vibration on the Extent of Laminar Flow on the N.A.C.A. 27-212 Airfoil. By Manley J. Hood and M. Edward Gaydos.

N.A.C.A. T.I.B. 1584 (M.R. No. E5F20)(M.R. No. E5112). Smoking Characteristics of Various Fuels as Determined by Open-Cup and Laboratory-Burner Smoke Tests. By Earl R. Ebersole and Henry C. Barnett.

N.A.C.A. T.I.B.. 1585 (M.R. No. E4L19). Analysis and Correlation of Data obtained by Six Laboratories on Fuel-Vapour Loss from Fuel Tanks during Simulated Flight. By Charles S. Stone, Sol Baker, and Gerald W. Englert.

N.A.C.A. T.I.B. 1586 (M.R. July 1943). Selection of Oil Coolers to Avoid Congealing. By Dennis J. Martin.

N.A.C.A. T.I.B. 1587 (M.R. No. E5D19). Characteristics of the B.M.W. 801D2 Automatic Engine Control as Determined from Bench Tests. By M. E. Scharer and A. N. Addie.

N.A.C.A. T.I.B. 1588 (A.C.R. No. E5G27). Rubber Conductors for Aircraft Ignition Cables. By Clyde C. Swett, Jr. and Joseph R. Dietrich.

N.A.C.A. T.I.B. 1589 (M.R. No. L4K18a). Vibration-Response Tests of a 1 5-Scale Model of the Grumman F6F Aeroplane in the Langley 16-ft. High-Speed Tunnel. By Theodore Theodorsen and Arthur A. Regier.

N.A.C.A. T.I.B. 1590 (A.R.R. No. E5G31) Elimination of Galling of Pendulum-Vibration Dampers used in Aircraft Engines. By Andre J. Meyer, Jr.

N.A.C.A. T.I.B. 1591 (A.C.R. July 1940). Requirements for Unit Fuel-Injection Systems. By Edred T. Marsh.

N.A.C.A. T.I.B. 1592 (M.R. No. E5F26). Nitrous Oxide Supercharging of an Aircraft-Engine Cylinder. By Max J. Taushek, Lester C. Corrington and Merle C. Huppert.

N.A.C.A. T.I.B. 1593 (A.R.R. No. E5K06). Calculations of the Performance of a Compression-Ignition Engine-Compressor Turbine Combination. I.—Performance of a Highly Supercharged Compression-Ignition Engine. By J. C. Sanders and Alexander Mendelson.

N.A.C.A. T.I.B. 1594 (M.R. Aug. 1944). Gasoline-Water Distribution Coefficients of 27 Aromatic Amines. By Walter T. Olson, Adelbert O. Tischler and Irving A. Goodman.

N.A.C.A. T.I.B. 1595 (M.R. June 1943). Tank Tests of a 1 8-Size Dynamic Model of the PB2Y-3 Aeroplane with Simulated Jet Motors—N.A.C.A. Models 131j, 131J-1, and 131J-2. By Joe W. Bell and Robert F. Havens.

N.A.C.A. T.I.B. 1596 (M.R. Dec. 1942). High-speed Wind-Tunnel Tests of a 1 6-Scale Model of a Twin-Engine Pursuit Aeroplane. By Victor M. Ganzer.

N.A.C.A. T.I.B. 1597 (M.R. Nov. 1941). Tests of a 0.1475c Aileron with a Tab on Low-Drag Section for Curtiss XP-630 Aeroplane in the Low-Turbulence Tunnel. By A. E. von Doenhoff and W. J. Underwood.

N.A.C.A. T.I.B. 1598 (M.R. June 1941). Wind-Tunnel Investigation of an N.A.C.A. 23012 Airfoil with a 30 per cent Chord Maxwell Slat and with Trailing-Edge Flaps. By John G. Lowry and John W. McKee.

N.A.C.A. T.I.B. 1599 (M.R. Sept. 1941). Tests of Bell XP-63 Low-Drag Wing Model with Split Flap. By W. J. Underwood.

N.A.C.A. T.I.B. 1600 (M.R. July 1943). Water Tolerance of Aviation Gasoline containing Xylidines. By Joseph Revilock and Walter T. Olson.

N.A.C.A. T.I.B. 1601 (M.R. Aug. 1943). Anti-knock Effectiveness of Xylidines in Small-Scale Engines. By J. Robert Branstetter and Carl L. Meyer.

N.A.C.A. T.I.B. 1602 (M.R. Sept. 1943). The Effect of Xylidines on the Load-carrying Capacity of an Aircraft-Engine Oil. II. By Walter T. Olson and Robert A. Sipurr.

N.A.C.A. T.I.B. 1603). The Effect of Xylidines on the Stability of an Aircraft-Engine Lubricating Oil. By Walter T. Olson and Emanuel Meyrowitz.

N.A.C.A. T.I.B. 1604 (M.R. July 1943). The Effect of Xylidines on the Corrosiveness of Aircraft-Engine Oil. By Emanuel Meyrowitzand Walter T. Olson.

N.A.C.A. T.I.B. 1605 (M.R. No. E5H18). Operating Stresses in Aircraft-Engine Crankshafts and Connecting Rods. II Instrumentation and Test Results. By Francis J. Dutee, Franklyn W. Phillips and Howard F. Calvert.

N.A.C.A. T.I.B. 1606 (M.R. No. E4L21). Knock-Limited Performance of Blends of an-F-28 Fuel Containing 2 per cent Aromatic Amines IV. By Henry E. Alquist annd Leonard K. Tower.

N.A.C.A. T.I.B. 1607 (M.R. Aug. 1944). Knock-Limited Performance of Blends of an-F-28 Fuel Containing 2 per cent Aromatic Amines III. By Henry E. Alquist and Leonard K. Tower.

N.A.C.A. T.I.B. 1608 (A.R.R. No. E5H10). The Effect of Inlet Temperature and Pressure on the Efficiency of a Single-Stage Impulse Turbine having a 13.2-inch Pitch-Line Diameter Wheel. By Ernest R. Chanes and L. Robert Carman.

N.A.C.A. T.I.B. 1609 (M.R. Sept. 1944). Effect of Water Injection on Knock-Limited Performance of a V-Type 12-Cylinder Liquid-Cooled Engine. By Myron L. Harries, R. Lee Nelson and Howard E. Berguson.

N.A.C.A. T.I.B. 1610 (M.R. Oct. 1942). Investigation of Diving Moments of a Pursuit Aeroplane in the Ames 16-ft. High-Speed Wind Tunnel. By Albert L. Erickson.

N.A.C.A. T.I.B. 1611 (M.R. Oct. 1943). Flying Qualities of a Twin-Engine Patrol Aeroplane as Estimated from Wind-Tunnel Tests. By Victor I. Stevens, Jr. and George B. McCullough.

N.A.C.A. T.I.B. 1625 (M.R. No. A5G23). Wind-Tunnel Investigation of the Effects of Spoilers on the Characteristics of a Low-Drag Aerofoil Equipped with a 0.25-Chord Slotted Flap. By Ralph W. Holtzclaw.

N.A.C.A. T.I.B. 1626 (M.R. June 1944). The Low-Temperature Solubility of Aniline, the Toluidines, and Some of Their N-Alkyl Derivatives in Aviation Gasoline. By Walter T. Olson and Richard L. Kelly.

N.A.C.A. T.I.B. 1627 (M.R. Aug. 1943). The Effect of Xylidines on the Load-Carrying Capacity of an Aircraft-Engine Oil I. By Robert A. Spurr and Walter T. Olson.

N.A.C.A. T.I.B. 1628 (A.R.R. No. E5H08). Visual Studies of Cylinder Lubrication. I The Lubrication of the Piston Skirt. By Milton C. Shaw and Theodore Nussdorfer.

N.A.C.A. T.I.B. 1629 (M.R. June 1944). Wind-Tunnel Investigation of Carburettor-Air Scoops for the XTB2D-1 Aeroplane with Emphasis on Means for By-passing the Boundary Layer. By Mark R. Nichols, Arvid L. Keith, Jr., and Robert W. Boswinkle, Jr.

N.A.C.A. T.I.B. 1630 (A.R.R. No. E5H27). Quantitative Analysis for Aromatic Amines in Aviation Fuels by Ultraviolet Spectrophotometry. By Adelbert O. Tischler.

N.A.C.A. T.I.B. 1631 (M.R. No. E4L28). Flight Variable Affecting Fuel-Vapour loss from a Fuel Tank. By Charles S. Stone, Sol Baker, and Dugald O. Black.

N.A.C.A. T.I.B. 1632 (A.C.R. No. E5L18). Occurrence of Iron Oxides on Cast-Iron Engine Surfaces after Operation. By A. S. Nowick and L. O. Brockway.

N.A.C.A. T.I.B. 1633 (A.R.R. No. E6C01). Test-Stand Investigation of Cooling Characterisics and Factors affecting Temperature Distribution of a Double-Row Radial Aircraft Engine. By Michael A. Sipko, Robert O. Hickel and Robert J. Jones.

N.A.C.A. T.I.B. 1634 (A.R.R. No. E5H10a). In-Line Aircraft-Engine Bearing Loads. I Crankpin-Bearing Loads. By Milton C. Shaw and E. Fred Macks.

N.A.C.A. T.I.B. 1635 (M.R. July 1943). Wind-Tunnel Tests of the 1 9-Scale Model of the Curtiss XP-62 Aeroplane with Various Vertical Tail Arrangements. By I. G. Recant and Arthur R. Wallace.

N.A.C.A. T.I.B. 1636 (M.R. No. E6E27). Aerodynamics of the Carburettor Air Scoop and the Engine Cowling of a Single-Engine Torpedo-Bomber-Type Aeroplane. By John K. Kuenzig and Herman Palter.

N.A.C.A. T.I.B. 1637 (M.R. No. E5C20). The Effect of Modified Baflles and Auxiliary-Cooling Ducts on the Cooling of a Double-Row Radial Engine. By Stanley L. Gendler and Robert M. Geisenheyner.

N.A.C.A. T.I.B. 1638 (M.R. No. E5K09). The Low-Temperature Solubility of 42 Aromatic Amines in Aviation Gasoline. By Richard L. Kelly.

N.A.C.A. T.I.B. 1639 (M.R. Aug. 1941). Investigation of Naphthalene as a Possible Aircraft Fuel. By Dana W. Lee and Alois Krsek, Jr.

N.A.C.A. T.I.B. 1640 (M.R. No. E5H08). Flight and Test-Stand Investigation of High-Performance Fuels in Modified Double-Row Radial Air-Cooled Engines III Knock-Limited Performance of 33-Raas Compared with a Triptane Blend and 28-R in Flight. By Calvin C. Blackman and H. Jack White.

N.A.C.A. T.I.B. 1641 (M.R. No. E5J12). Correlation of the Characteristics of Single-Cylinder and Flight Engines in Tests of High-Performance Fuels in an Air-Cooled Engine II Knock-Limited Charge-Air Flow and Cylinder Temperatures. By Kenneth D. Brown, Paul H. Richard and Robert W. Wilson.

N.A.C.A. T.I.B. 1642 (M.R. No. E5B23). Flight and Test-Stand Investigation of High-Performance Fuels in Double-Row Radial Air-Cooled Engines III Comparison of Cooling Characteristics of Flight and Test Stand Engines. By H. Jack White, Calvin C. Blackman and Marcel Dandois.

N.A.C.A. T.I.B. 1643 (M.R. No. E5E08). Tests of Air Valves for Intermittent-Jet Engines at Speeds of 20 and 25 Cycles per second. By Joseph R. Bressman and Robert J. McCready.

TECHNICAL REPORTS

Government Printing Office, Washington, D.C.

Report No. 802. N.A.C.A. Investigation of a Jet-Propulsion System Applicable to Flight. By Macon C. Ellis, Jr., and Clinton E. Brown. (15 cents)

Following a brief history of the N.A.C.A. investigation of jet propulsiom, a discussion is given of the general investigation and analyses leading to the construction of the jet-propulsion ground-test mock-up. The results of burning experiments and of test measurements designed to allow quantitative flight-performance predictions of the system are presented and correlated with calculations. These calculations are then used to determine the performance of the system on the ground and in the air at various speeds and altitudes under various burning conditions. The application of the system to an experimental aeroplane is described and some performance predictions for this aeroplane are made.

Report No. 803. Wind-Tunnel Investigation of the Effects of Profile Modification and Tabs on the Characteristics of Ailerons on a Low-Drag Airfoil. By Robert M. Crane and Ralph W. Holtzclaw. (30 cents)

An investigation has been made to determine the effect of control-surface profile modifications on the aerodynamic characteristics of an N.A.C.A. low-drag aerofoil equipped with a 0·20-chord and a 0·15-chord aileron. Tab characteristics have been obtained for 0·20-aileron chord tabs on two of the 0·20-chord ailerons.

Thickening the aileron profile or thickening and bevelling the trailing edge of the aileron was found to reduce the aileron effectiveness, reduce the slope of the wing-section lift curve, and reduce the hinge-moment coefficients. Thinning the profile had the opposite effect. The effects of profile thickness on the aileron characteristics decreased with increasing angle of attack, there being practically no effect at an angle of attack of 12 deg. For the thickened and bevelled trailing edges the effects were maximum for the bevel, the length of which was 20 per cent of the aileron chord, and decreased for both increasing and decreasing bevel lengths. Thickening the profile or thickening and bevelling the trailing edge caused a slight increase in minimum profile-drag coefficient, but thinning the profile had no effect.

TECHNICAL MEMORANDA (TRANSLATIONS)

Secretary N.A.C.A., Washington, D.C.

No. 1179. Determination of the Stress Concentration Factor of a Stepped Shaft Stressed in Torsion by Mean of Precision Strain Gauges. ('Ermittlung der Formziffer der auf Verdrehung beanspruchten abgesetzten Welle mit Hilfe von Feindehnungsmessungen.' Zentrale für wissenschaftliches Berichtswesen der Luftfahrtforschung des Generalluftzeugmeisters, (ZWB) Berlin Adslerhof, Luftfahrtforschung Band 20, Lieferung 7, p. 217-219, München, July 20, 1943.) By A. Weigand.

The stress distribution in stepped shafts stressed in torsion is determined by means of the electric precision strain gauge by Lehr and Granacher; the stress concentration factor is ascertained from the measurements. It is shown that the test values are always slightly lower than the values resulting from an approximate formula by Sonntag.

No. 1181. Investigations on Reductions of Friction on Wings, in Particular by Means of Boundary-Layer Suction. ('Untersuchungen über Reibungsverminderungen an Tragflügeln, insebsondere mit Hilfe von Grenzschichtabsaugung.' Mitteilungen aus dem Institut für Aerodynamik an der Eidgenössichen Technischen Hochschule in Zürich Herausgegeben von Prof. Dr J. Ackeret Nr. 13.) By Werner Pfenninger.

The drag of an aeroplane consists of the induced drag, the frictional and form drag of wing, fuselage, tail unit, and, occasionally, radiator drag. Investigations have shown the frictional drag to be the main portion of the drag. Thus the reduction of surface friction has gained considerable importance during the last years.

Since the laminar friction is, in general, considerably lower than the turbulent friction, the frictional drag could be reduced by a laminar boundary layer as long as possible. The aim of the tests described here was to keep the boundary layer completely laminar up to the trailing edge of the wing.

No. 1183. Temperatures and Stresses on Hollow Blades for Gas Turbines. ('Temperaturen und Beanspruchеugen an Hohlschaufeln fur Gasturbinen.' Zentrale für wissenschaftliches Berichtswesen der Luftfahrtforschung des Generalluftzeugmeisters (ZWB) Berlin-Adlershof, Forschungsbericht Nr. 1879, München, July 31, 1943.) By Erich Pollmann.

Reports on theoretical investigations and test-stand measurements which were carried out in the BMW Flugmotoren GmbH in developing the hollow blade for exhaust gas turbines. As an introduction the temperature variation and the stress on a turbine blade for a gas temperature of 900 and circumferential velocities of 300 metres per second are discussed. The assumptions on the heat transfer coefficients at the blade profile are supported by tests on an electrically heated blade model. The temperature distribution in the cross section of a blade is thoroughly investigated and the temperature field determined for a special case. A method for calculation of the thermal stresses in turbine blades for a given temperature distribution is indicated. The effect of the heat radiation on the blade temperature also is dealt with. Test-stand experiments on turbine blades are evaluated, particularly with respect to temperature distribution in the cross section; maximum and minimum temperature in the cross section are ascertained. Finally, the appication of the hollow blade for a stationary gas turbine is investigated. Starting from a set up for 550 C gas temperature the improvement of the thermal efficiency and the fuel consumption are considered as well as the increase of the useful power by use of high temperatures. The power required for blade cooling is taken into account. The possibility of applying high circumferential velocities with good efficiency is discussed.

No. 1184. Development and Construction of an Interferometer for Optical Measurements of Density Fields. ('Entwicklung und Bau eines Interferenzgerates zur optischen Messung von Dichtefeldern.' Zentrale für wissenschaftliches Berichtswesen bel der Deutschen Versuchsanstalt fur Luftfahrt, E. V., Berlin-Adlershof, Forschungsbericht No. 1008, June 30, 1938.) By Th. Zobel.

A method of interference is described in the present report which promises profitable application in aeronautical research. The physical foundation of the method and a simple method of adjustment are briefly discussed. The special technical construction of the instrument is described which guarantees its use also in the case of vibrations of the surrounding space and permits the investigation of unsteady phenomena. It is found that the interference method will make the small differences in density in the flow field around the body even at low speeds (40 m sec.) optically measurable.

No. 1185. Systematic Investigations of the Influence of the Shape of the Profile upon the Position of the Transition Point. ('Systematische Untersuchungen uber den Einfluss der Profilform auf die Lage des Umschlagspunktes.' Zentrale für wissenschaftliches Berichtswesen der Luftfahrtforschung des Generalluftzeugmeisters (ZWB) Berlin-Adlershof, Technische Berichte und Vorabdrucke aus Jahrbuch 1943 der deutschen Luftfahrtforschung, Band 10 (1943), Heft 9, Sept. 15, 1943, IA 010, pp. 1-19.) By K. Bussmann and A. Ulrich.

The position of the beginning of the transition laminar turbulent as a function of the thickness and the camber of the profile at various Reynolds numbers and lift coefficients was investigated for series of Joukowsky profiles. The calculation of the boundary layer was carried out according to the Pohlausen method which may be continued by a simplified stability calculation according to H. Schlichting. A list of tables is given which permits the reading off of the position of the transition point on suction and pressure side for each Joukowsky profile.

No. 1186. Comparison of Drop and Wind-Tunnel Experiments on Bomb Drag at High Subsonic Speeds. ('Vergleich zwischen Abwurf- und Windkanalversuchen hinsichtlich des Widerstandes von Bomben bei hohen Unterschallgeschwindigkeiten.' Zentrale für wissenschaftliches Berichtswesen der Luftfahrtforschung des Generalluftzeugmeisters (ZWB) Berlin-Adlershof, Forschungsbericht Nr. 1570, April 17, 1942.) By B. Göthert.

The drag coefficients of bombs at high velocities (the highest velocity of fall was 97 per cent of the speed of sound) are determined by drop tests and compared with measurements taken in the DVL high-speed closed wind tunnel and the open jet at AVA-Göttingen.

No. 1187. Equations for Adiabatic but Rotational Steady Gas Flows without Friction. ('Gleichungen für Adiabatische, aber Wirbelbehaftete Stationäre Gasströmungen ohne Reibung.' Lehrstuhl für Technische Mechanik an der Technischen Hochschule Dresden, Archiv. Nr. 44 1.) By Manfred Schafer.

The flowing gases are assured to have uniform energy distribution. This is correct, for example, for gas flows issuing from a region of constant pressure, density, temperature, and velocity and is not destroyed by compression shocks because of the universal validity of the energy law.

The gas behaves adiabatically, not during the compression shock itself but both before and after the shock. However, the adiabatic equation is not valid for the entire gas flow with the same constant C but rather with an appropriate individual constant for each portion of the gas. For steady flows, this means that the constant C of the adiabatic equation is a function of the stream function. Consequently, a gas that has been flowing 'isentropically', that is with the same constant C of the adiabatic equation throughout (for example, in origination from a region of constant density, temperature, and velocity) no longer remains isentropic after a compression shock if the compression shock is not extremely simple (wedge shaped in a two-dimensional flow or cone shaped in a rotationally symmetrical flow).

The solution of nonisentropic flows is therefore an urgent necessity.

No. 1188. The Elasto-Plastic Stability of Plates. ('Uprugo-plasticheskaya Ustoichivost Plasteen.' Prikladnaya Matematika i Mekhanika X, 1946, pp. 623-638.) By A. A. Ilyushin.

In this article are developed the results of the author's work (T.M. No. 1116) 'The Stability of Plates and Shells beyond the Elastic Limit.' A significant improvement is found in the derivation of the relations between the stress factors and the strains resulting from the instability of plates and shells. In a strict analysis the problem reduces to the solution of two simultaneous nonlinear partial differential equations of the fourth order in the deflection and stress function, and in the approximate analysis to a single linear equation of the Bryan type. Solutions are given for the special cases of a rectangualr plate buckling into a cylindrical form, and of an arbitrarily shaped plate under uniform compression. These solutions indicate that the accuracy obtained by the approximate method is satisfactory.

TECHNICAL NOTES

Secretary, N.A.C.A., Washington, D.C.

We are informed by the Ministry of Supply, T.P.A.3/T.I.B., that the extremely limited number of the N.A.C.A. Technical Notes received by them from America for distribution in Great Britain does not permit of their making them available on loan. In view of this, there seems no object in continuing to list the titles, as we have recently been doing, since they are for all practical purposes not available to our readers, even for consultation.

GREAT BRITAIN

THE COLLEGE OF AERONAUTICS

Librarian, Cranfield, Beds

Report No. 11. September, 1947. Application of the Linear Perturbation Theory to Compressible Flow about Bodies of Revolution. By A. D. Young and S. Kirkby.

The linearized theory is developed in some detail in order to clarify the difference between two-dimensional and axi-symmetric flow. In agreement with other authors it is concluded that the perturbation velocity on a thin body of revolution in compressible flow is $1/\beta^2$ times the perturbation velocity in incompressible flow on a thinner body at reduced incidence obtained by reducing the lateral dimensions of the original body in the ratio $\beta : 1$.

This result is applied to a representative family of streamline bodies of revolution at zero incidence. It is found that, without an undue loss of accuracy, the results of the calculations can be presented in a relatively simple form in a diagram showing the variation of velocity with Mach number for a range of values of velocity on the surface of a streamline body in incompressible flow. This variation is always less than that predicted by the Glauert law but approaches it with increase in the basic incompressible flow velocity.

Report No. 12. December, 1947. The Aerodynamic Derivatives with Respect to Sideslip for a Delta Wing with Small Dihedral at Supersonic Speeds. By A. Robinson and Squadron-Leader J. H. Hunter-Tod.

Expressions are derived for the sideslip derivatives on the assumptions of the linearized theory of flow for a delta wing with small dihedral flying at supersonic speeds. A discussion is included in the appendix on the relation between two methods that have been evolved for the treatment of aerodynamic force problems of the delta wing lying within its apex Mach cone.

When the leading edges are within the Mach cone from the apex, the pressure distribution and the rolling moment are independent of Mach number but dependent on aspect ratio. There is a leading edge suction, which is a function of incidence, aspect ratio and Mach number, that contributes as well as the surface pressure distribution to the sideforce and yawing moment.

When the leading edges are outside the apex Mach cone, the non-dimensional rolling derivative is, in contrast to the other case, dependent on Mach number and independent of aspect ratio: the other derivatives and the pressure, however, are dependent on both variables. There is no leading edge suction force in this case.

Report No. 13. December, 1947. Assessment of Errors in Approximate Solutions of Differential Equations. By W. J. Duncan.

The term assessment is applied to any process which enables us to set rigid bounds to the error or to estimate its value. It is shown that upper and lower bounds can be assigned whenever the Green's function of the problem is one-signed; this is true in many important problems. Another method is applicable to step-by-step solutions of ordinary differential equations, linear or non-linear, and depends on use of the 'index' of the process of integration. Lastly, the error in a linear problem can be estimated when an approximation to the Green's function is known.

Report No. 14. April, 1948. Note on the Limits to the Local Mach Number on an Aerofoil in Subsonic Flow. By A. D. Young.

It has been noted in some experiments that the local Mach number just ahead of a shock wave on an aerofoil in subsonic flow is limited; values of the limit of the order of 1·4 are usually quoted. This note presents two lines of thought indicating how such a limit may arise. The first starts with the observation that the pressure after the shock will not be higher than the main stream pressure. The second approach is based on the fact that a relation between stream deflexion and Mach number for the flow in the limited supersonic regions on a number of aerofoils has been derived from some experimental data. Further anaylsis of experimental data is required before this relation can be accepted as general. If it is accepted, however, then it indicates that the Mach numbers increase above unity for a given deflexion is about one-third of that given by simple wave theory. An analysis of the possible deflexions on aerofoils of various thicknesses then indicates that deflexions corresponding to local Mach numbers of the order of 1·5 or higher are unlikely except at incidences of the order of 5 deg. or more, and may then be more likely for thick wings than for thin wings. Flow breakaway will make the attainment of such high local Mach numbers less likely.

AERONAUTICAL RESEARCH COUNCIL

H.M. Stationery Office, London

R. & M. No. 2146. The Effect of Wing Planform, Speed and Height on the Design of Large Aircraft. November 1945. By P. E. Montagnon and D. M. Hallowes (3*s*.)

Earlier work on large aircraft design was based on a very high cruising speed requirement and it was shown that a high wing loading was of considerable advantage. This report by considering a range of speeds and heights brings out the effects of planform and wing loading on the payload carried. It also shows the penalty of high speed in terms of payload and that the variation of percentage payload with all-up weight is by comparison a small quantity.

It is also concluded that aspect ratio is a comparatively unimportant variable and that for speeds of about 200 m.p.h., above which payload falls off considerably, a wing loading of 50 lb./sq. ft. at take-off is sufficient.

An appendix considers the relative merits of a flying boat and a landplane and concludes that the flying boat is in general worse than the landplane but improves with increasing weight and decreasing speed. At 200 m.p.h. and a weight of 240,000 lb. there is little to choose between them.

R. & M. No. 2195. Empirical Laws for the Effect of Compressibility on Quarter-chord Moment Coefficient, and for the Choice of an Aerofoil with small Compressibility Effects on Centre of Pressure. March 1943. By W. F. Hilton. (3*s*.)

An empirical relation is advanced for the estimation of the effect of compressibility on the quarter-chord moment coefficient at zero lift at subsonic speeds up to the moment critical, which is about 0.1 Mach number higher than the drag critical. The formula has been derived from a study of results for seven cambered aerofoils tested in the High Speed Tunnel, and of the theoretical values for one aerofoil as calculated by von Kármán's formula. Better agreement has been obtained in all cases than that given by using Glauert's relation.

Although the proposed relation is empirical, it must not be thought that a free choice exists from an infinite number of equations; on the contrary, the boundary and limiting conditions determine the type of equation fairly precisely.

It is felt that although the proposed formula is not necessarily final, it does represent a great improvement on the Glauert relation, and will enable designers to calculate tail loads at high speeds with greater accuracy. A comparison of the formula with experimental results is given.

R. & M. No. 2201. Tests of High-speed Flow in Diffusers of Rectangular Cross-section. July 1944. By A. D. Young and G. L. Green.

The diffusers tested all diffused in one plane, so that they were of constant width, and they all had the same exit and entry areas, the ratio of these two areas being 4 : 1. The semi-angles ranged from 4 deg. to about 16 deg. The investigation included measurements of the losses involved, of the pressure distributions along the diffusers, of the total-head distributions at the exits, and observations by means of a schlieren installation of the flow and shock-wave patterns in the diffusers. By varying the applied pressure ratio the tests were carried in each case from a low entry Mach number to well beyond the point at which the diffuser choked; i.e. the point for which overall sonic conditions were attained at the beginning of the diffuser. The main conclusions are:

(*a*) For entry Mach numbers below choking the optimum semi-angle for minimum loss is about 4-5 deg.

(*b*) For entry Mach numbers above choking all diffusers become very inefficient. The fractional total-head loss then becomes a rapidly increasing function of the applied pressure ratio, independent of the diffuser angle. This function is reasonably close to that predicted on simple theoretical grounds.

(*c*) The losses in a short wide-angled diffuser can be very effectively reduced by means of a dividing vane.

R. & M. No. 2202. Elevator Control on Firefly F. Mk. I and N.F. Mk. II Aircraft. March, 1947. By Squadron-Ldr. D. R. H. Dickinson. (2*s*. 6*d*.)

A number of tests have been made by the A. & A.E.E. of various versions of the tailplane and elevator on Firefly aircraft, which were successive steps in the development of a satisfactory elevator control for the aircraft. The object of this Memorandum is to collect the various sets of results, all of which have been issued as separate A. & A.E.E. reports, explain the sequence of the development, and bring out the salient points of each version tested.

R. & M. No. 2203. Lift Characteristics for Thin Clark Y Propeller Sections at Low and Negative Angles of Incidence. August, 1945. By A. R. C. MacDougall. (1*s*.)

This investigation was made to extend to lower and negative angles of incidence the existing data on the high-speed lift characteristics of a propeller. It is based on tests in the R.A.E. 24-ft. tunnel of the standard de Havilland Spitfire I propeller and of a thinned version, and provides lift data on Clark Y sections from 4·5 to 7 per cent thick.

In this range the values of the critical Mach number for lift from this analysis are much lower than would be expected by extrapolating linearly the lift data of R. & M. 2036. This suggests that care must be taken (when dealing with Clark Y and RAF 6 sectioned propellers, but not necessarily with high speed sectioned propellers) not to reduce the tip incidence too much in the hope of reducing the tip losses.

R. & M. No. 2204. A Family of Streamline Bodies of Revolution suitable for High-speed or Low-drag Requirements. August 1945. By A. D. Young and Miss E. Young. (3*s*.)

A family of basic shapes having a fineness ratio of 0.2 is calculated by the method of R. & M. 2071. It is shown that these shapes can be simply scaled up or down to any required fineness ratio to give streamline shapes having smooth unpeaked velocity distributions of the kind necessary where high-speed or low-drag requirements are important. The ranges covered of the basic parameters, velocity gradients and positions of maximum velocity, are sufficiently wide, it is believed, to ensure that there is always one or more of the family suitable for any particular purpose. The ordinates of the basic shapes are tabulated, and examples of velocity distributions on these shapes at various angles of yaw are given to illustrate the range of angles over which low-drag properties may be expected.

R. & M. No. 2206. The Pressure Distribution on some Flat Laminar Aerofoils at Incidence at Supersonic Speeds. March, 1946. By G. N. Ward. (2*s*. 6*d*.)

When a body in a stream moving at supersonic speed is of such a form that it provides no fundamental length in the field, or in some part of the field, the velocities can depend only upon angular or non-dimensional variables and must be constant along all lines meeting in some fixed point. Such velocity fields have been called cone-fields.

The properties of cone-fields are investigated on the assumption of small disturbances in the main stream velocity. It is shown how certain finite wings of polygonal planform may be treated by superposition of such fields. The results are given in the form of pressure distributions over certain semi-infinite wings which can be combined to give the pressure distribution for wings of finite span.

R. & M. No. 2207. Design of a Fixed-pitch Pusher Propeller coupled to a Free-running Turbine. March, 1946. By A. B. Haines. (2*s*. 6*d*.)

The report investigates the design and performance of a fixed-pitch pusher propeller directly coupled to a free-running turbine fitted in the exhaust duct of a turbine jet engine. The principal aim is to increase the available cruising thrust without adding appreciable weight or complication or raising the fuel consumption. A cruising speed of 400 m.p.h. at 20,000 ft. was considered in the present report and it was found that propulsive efficiencies of between 75 and 80 per cent were achieved in this condition. Such a performance enabled the overall cruising thrust to be increased and hence the specific fuel consumption decreased by as much as 38 per cent (over that of the simple jet) at the expense of an increase of only 34 per cent in overall weight, i.e. the thrust weight is slightly increased. Even at take-off, gains of overall thrust of 29 and 50 per cent were obtained. The best propeller design will be determined by the aircraft application but it appears that it will be possible to limit the tip speed to avoid excessive noise or loss in performance at speeds above the design cruising speed. In short, from an aerodynamic point of view, the scheme appears very promising.

Trade Announcements

Under this heading are published monthly news of recent professional appointments, industrial developments and business changes, etc.

New Director of Armstrong Siddeley Motors

Armstrong Siddeley Motors Ltd., of Coventry, announce that Mr W. F. Saxton, chief engineer, has been appointed a director of the Company.

College of Aeronautics

The following awards have been made at the conclusion of the two-year course 1946-48 at the College of Aeronautics, Cranfield. Specialization is denoted in brackets:

DIPLOMA WITH DISTINCTION: A. Lightbody, A. O. Ormerod, J. J. Spillman (Aerodynamics), J. H. Junter-Tod, R. J. Rackham, V. A. B. Rogers, J. Seddon, N. H. Wood, L. Wookey (Aircraft Design), W. E. Morris (Aircraft Propulsion).

DIPLOMA: D. C. Bain, P. F. Crawley, F. T. Davies, D. H. Earle, E. G. Havard, E. F. Lawlor, G. E. Preece, R. J. Ross, P. H. S. Wroe (Aerodynamics), H. B. Grant, R. A. Harriss, R. S. Hooper, D. K. R. Hopkins, P. G. Mobsby, A. J. Monk, L. S. D. Morley, L. W. Richards, M. R. A. Rizvi, P. A. L. Watson, A. A. J. Willitt (Aircraft Design), H. Caplan, P. J. Cooper, P. K. Hickman, W. S. Knowles, F. R. Spurrier, A. Stone (Aircraft Propulsion).

The Board of Governors of the College have appointed Mr J. V. Connolly, B.E., A.F.R.Ae.S., as Professor of Aircraft Economics and Production. Professor Connolly, who was born in Australia, is a graduate of Sydney University. Since 1937, he has held appointments at the Air Ministry, the Air Registration Board, Ministry of Aircraft Production and Ministry of Supply; from 1942 he was Assistant Director of Planning and later Assistant Director of Aircraft Production.

Controller of Ground Services

The Ministry of Civil Aviation announces that, as a result of certain measures of reorganization recently approved, the vacant posts of Controller of Technical and Operational Services and Controller of Aerodromes have been combined in a new post, the occupant of which will be known as Controller of Ground Services. He will have the rank of Deputy Secretary (salary £2,500) and will report to the Permanent Secretary.

The object of this change is to bring under one departmental head those functions of the Ministry which are executive (as distinct from policy-making or regulative), namely, the administration and management of aerodromes and the provision of navigational services such as telecommunications, air traffic control and operations generally.

The Minister of Civil Aviation has, with the Prime Minister's approval, appointed Mr A. S. Le Maitre, C.B., M.C., to this new post, with effect from July 1, 1948.

Fairchild Corporation and Wellworthy

Fairchild Engine and Airplane Corporation has concluded a licensing agreement with Wellworthy Piston Rings Ltd., of Lymington, Hants, covering use of Fairchild's Al-Fin process for bonding aluminium to iron, steel, and other metals.

Gerrard & Co.

Sir Alliott Roe has joined the Board, as Chairman, of Gerrard & Co. Ltd., 37 Windermere Road, Muswell Hill, N.10, of which his brother, Mr H. V. Roe, is Managing Director. The firm handles 'Roe's Laminated Aluminium', the material specially developed for shims which is widely used in the British aircraft industry.

Hawker Siddeley Group Ltd.

The name of the Hawker Siddeley Aircraft Co. Ltd. has now been changed to Hawker Siddeley Group Ltd., whose address is 18 St James's Square, S.W.1. Telephone Whitehall 2064.

H. Morris Helicopter Blades

H. Morris & Co. Ltd., the furniture manufacturers of Glasgow, whose London address is 27 Hill Street, W.1, have developed a new blade for the Cierva 'Air Horse' helicopter, which has three rotors, each with a set of three blades. The new blades, which are a result of two years of extensive research and scientific experiments, have skins moulded under pressure and heat by a process developed in the Morris factory. The skins are entirely made from Canadian birch and are one-eighth of an inch thick. Each blade is 21 ft. long but weighs only 125 lb., being without internal ribs.

National Gas Turbine Establishment

Mr H. Constant, M.A., has been appointed Director of the Ministry of Supply's National Gas Turbine Establishment, in succession to Dr Roxbee Cox, who is to take up an appointment with the Ministry of Fuel and Power.

Norwegian Air Lines (D.N.L.)

Major-General Hjalmar Riiser-Larsen has taken office as President of the Norwegian Air Lines—D.N.L.—one of the partners in the Scandinavian Airlines System (S.A.S.).

Major-General Riiser-Larsen was born in 1890 and became a pilot in the Royal Norwegian Naval Air Force in 1915. In 1921 he trained in Great Britain as an airship captain. In the years 1921-1927 he was chief secretary for the Aviation Council of the Norwegian Ministry of Defence, during which period he made several flights to the Polar regions. In 1928 he led the expedition which went to find Roald Amundsen, who disappeared in the Arctic Ocean on his attempt to rescue the Italian dirigible *Italia*. In 1929-30 he led expeditions to the Antarctic. In 1933 Major-General Riiser-Larsen was appointed president of the 'old' Norwegian air lines, which position he held until the outbreak of war. In 1940 he arrived in Great Britain and was appointed Commander-in-Chief of the Royal Norwegian Air Force. He left this command in 1946 and returned to civil aviation. From 1947 until recently he was attached to the Head Office of the Scandinavian Airlines System in Stockholm with the special task of planning the new Scandinavian air routes to South Africa and the Far East.

Plessey and Bendix Agreement

A wide range of Bendix radio equipment which includes mobile, ground and aircraft radio communication systems and navigational aids, is to be produced under licence by the Plessey Company Ltd., Ilford, who have recently completed patent arrangements with the Bendix Corporation of America for the manufacture and sale of its equipment.

Static ground equipment to be produced at Ilford includes MF HF and MF HF VHF transmitters, VHF fixed frequency receivers and lightweight VHF cathode ray DF sets, while the mobile ground equipment will include mobile VHF communication units for all forms of road transport and taxis as well as for railways. Fixed stations for use with this mobile equipment will also be produced.

Automatic radio compasses, HF and MF transmitters and communication receivers, HF transmitter receivers, marker beacon receivers and intercom. amplifiers represent the range of airborne equipment to be produced in the first instance, while multi-channel VHF receivers with full navigational facilities and a multi-channel VHF transmitter will be available later.

S.B.A.C. Officers

The following Officers and Management Committee of the Society of British Aircraft Constructors have been elected for the year 1948-49:

President: Sir Roy H. Dobson, C.B.E., F.R.Ae.S.
Vice-President: Mr W. T. Gill, C.A.
Deputy President: Mr W. R. Verdon Smith, M.A., B.C.L.

Management Committee: Mr Robert Blackburn, O.B.E., Mr H. Burroughes, Mr B. W. A. Dickson, Mr H. P. Folland, M.B.E., Sir Arthur Gouge, Major Sir Hew R. Kilner, M.C., Mr J. D. North, Sir Frederick Handley Page, C.B.E., Mr J. J. Parkes, Mr F. E. N. St Barbe, Sir Frank Spencer Spriggs, K.B.E., Mr C. C. Vinson, Mr Walter Hackett, Junr. (Group A Associate Members), Mr E. J. Earnshaw (Group B Associate Members).

TRADE PUBLICATIONS

Gee Ground Stations. Part 1—A General Description

Cossor 300 *Watt Transmitter. A Brief Description*
[Cossor Radar Ltd., Highbury Grove, N.5]

Controlled Cycle Centreless Grinding Machines
[Arthur Scrivener Ltd., Tyburn Road, Birmingham]

Cabin Atmosphere Control Equipment

Cabin Atmosphere Control in Military Aircraft
[Normalair Ltd., Yeovil]

'*Astra*', *Vol.* 1, *No.* 1, *June* 1948
[Air Service Training Ltd., Hamble. 1*s.*]

'*Potential*', *Vol.* 1, *No.* 3, *July* 1948
[College of Aeronautics, Cranfield, Beds.]

Precision Standard Tools and Gauges
[The Plessey Co Ltd., Ilford, Essex]

'*Bristol Review*', *Vol.* 1, *No.* 1, *June* 1948
[The Bristol Aeroplane Co., Ltd., Filton, Bristol]

Hiduminium 51
[High Duty Alloys Ltd., Slough, Bucks]

Westool Muffles

Westool Coils

Westool D.C. Solenoids

Westool A.C. Solenoids
[Westool Ltd., St Helen's Auckland, Bishop Auckland, Durham]

Aero Research Technical Notes
Bulletin No. 66. *A New Adhesive for Industry* ('*Araldite*')
Bulletin No. 67. '*Aerolite*' *Bonding in Modern Gliders*
[Aero Research Ltd., Duxford, Cambs.]

Gas Carburising with Prepared Town Gas
[Wild-Barfield Electric Furnaces Ltd., Watford, Herts.]

Wiggin Nickel Alloys
[Henry Wiggin & Co., Ltd., Wiggin Street, Birmingham, 16]

Current Collection
[The Morgan Crucible Co., Ltd., Battersea Church Road, S.W.11]

Lodge Aviation Plugs. Servicing Instructions
[Lodge Plugs Ltd., Rugby]

Seldex Control Master
[Seldex Ltd, Westwood Road, Witton, Birmingham, 6]

'*Leader*' *Typists and Office Chairs*
[Marsh, Matterson & Co., 6/10 Clinton Street East, Nottingham]

Nickel Alloy Steels. A Summary of Their Properties and Applications
[The Mond Nickel Co. Ltd., Grosvenor House, Park Lane, W.1]

Prolite Tipped Woodworking Tools
[Protolite Ltd., Central House, Upper Woburn Place, W.C.1]

Hiduminium Technical Data
[High Duty Alloys Ltd., 89 Buckingham Avenue, Slough]

Armstrong Siddeley Apprentice Training Scheme
[Armstrong Siddeley Motors Ltd., Coventry]

The Sponson Tribian 3/4 *Seater*
[Sponson Developments Ltd., 3 Albemarle Street, W.1]

The Tandem News. Summer 1948
[The Eyre Smelting Co. Ltd., Merton Abbey, S.W.19]

The David Brown Muir MT 15 *Hobbing Machine*
[David Brown Machine Tools Ltd., Britannia Works, Sherborne Street, Manchester, 3]

*Hymatic All Purpose Mobile Unit—Type H.P.S.*2
[The Hymatic Engineering Co. Ltd., Redditch]

The Sperry Review, Vol. 2, *No.* 1, *Spring* 1948
[The Sperry Gyroscope Co. Ltd., Brentford, Mdx.]

Liquid Spring Undercarriages
[Dowty Equipment Ltd., Cheltenham]

Utility Helicopter Model K-190
[The Kaman Aircraft Corp., Bradley Field, Windsor Lock, Conn., U.S.A.]

Aircraft Engine Gantry, Carriers, Trucks and Trolleys
[B. F. Collingridge Ltd., Belvedere Works, Feltham, Middlesex]

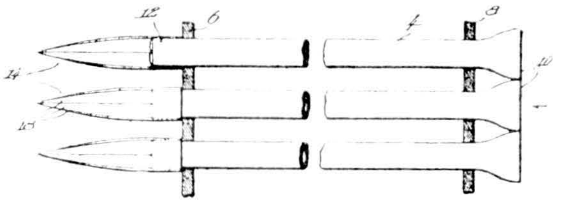
Naiad Gas Turbine Aero Engine
[D. Napier & Son Ltd., Acton, W.3]

I.C.A.O. What it is and what it does
[The International Civil Aviation Organization, Montreal, Canada]

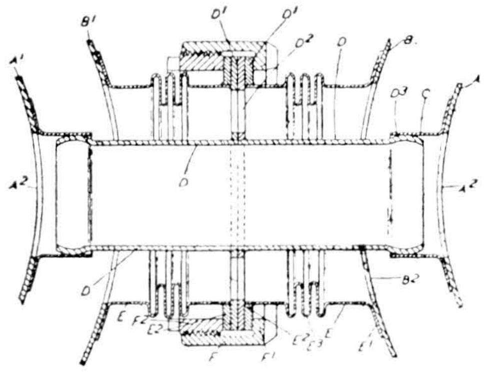
Facts About I.A.T.A.
[International Air Transport Association, Central Station Building, Montreal, Canada]

U.S. Patent Specifications

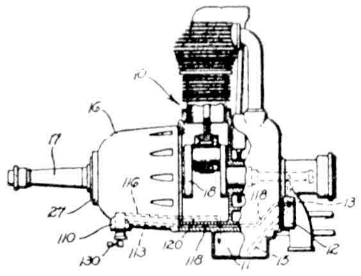
These details and drawings of patents granted in the United States are taken, by permission of the Department of Commerce, from the 'Official Gazette of the United States Patent Office'. Printed copies of the full specification can be obtained, price 10 cents each, from the Commissioner of Patents, Washington, D.C., U.S.A. They are usually available for inspection at the British Patent Office, Southampton Buildings, Chancery Lane, London, W.C.2.



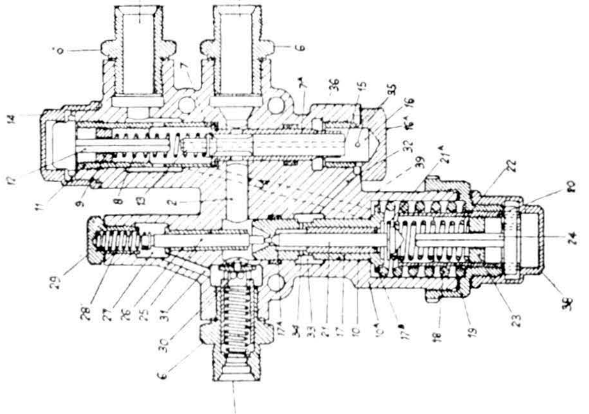
2,437,287. Heat Exchange Apparatus. John E. Woods, Brookline, Mass., assignor by mesne assignments to Standard-Thomson Corporation, Boston, Mass., a corporation of Delaware. Application December 15, 1943. Serial No. 514,383. 2 Claims. (Cl. 257—2.)



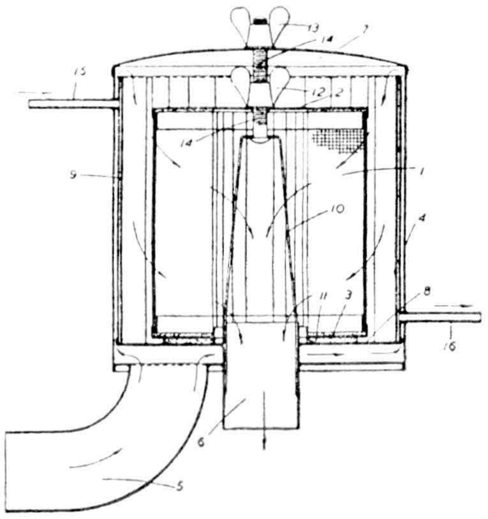
2,437,385. Jet Propulsion Plant. Frank Bernard Halford, Edgware, England, assignor to The De Havilland Aircraft Company Limited, Edgware, England, a company of Great Britain. Application July 20, 1943. Serial No. 495,516. In Great Britain November 21, 1941. Section 1, Public Law 690, August 8, 1946. Patent expires November 21, 1961. 6 Claims. (Cl. 285—90.)



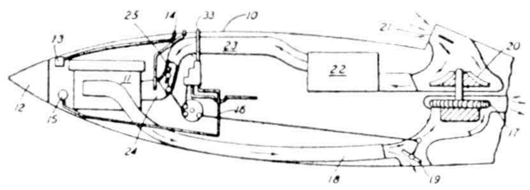
2,437,467. Variable-Speed Drive for Propellers. Earl R. Herring and Charles P. Sander, Glendale, Calif., assignors, by direct and mesne assignments, to Kinner Motors, Inc., a corporation. Application January 3, 1942. Serial No. 425,524. 14 Claims. (Cl. 74—290.)



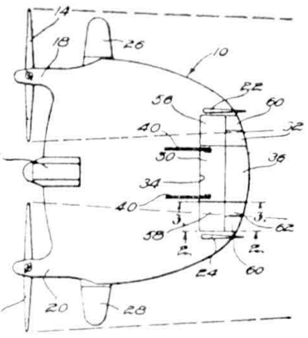
2,437,480. Valve. Cyril Alphonso Pugh and Douglas Gerhard Booth, Ilford, and Rudolph William Rough, Romford, England, assignors to The Plessey Company Limited, Ilford, England, a British company. Application March 31, 1945. Serial No. 585,896. In Great Britain December 18, 1944. 6 Claims. (Cl. 137—153.)



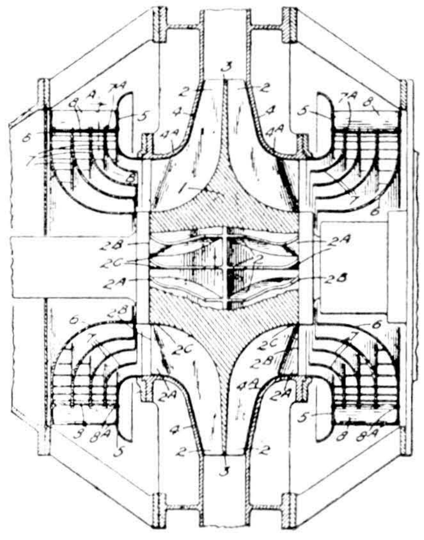
2,437,489. Air Filter with Heat Exchange Arrangements. Cecil Gordon Vokes, London, England, assignor to Vokes Limited, Guildford, Surrey, England. Application March 15, 1944. Serial No. 526,572. In Great Britain January 31, 1943. 2 Claims. (Cl. 183—32.)



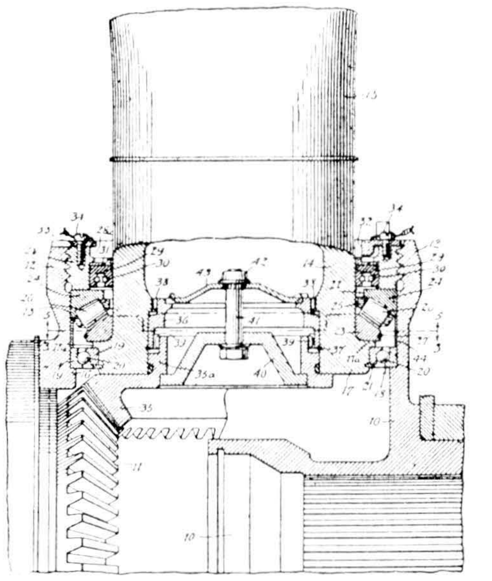
2,437,546. Supercharged Engine Control. Edward B. Meripol, Los Angeles, Calif., assignor to Lockheed Aircraft Corporation, Burbank, Calif. Application March 18, 1943. Serial No. 479,669. 2 Claims. (Cl. 170—135.6.)



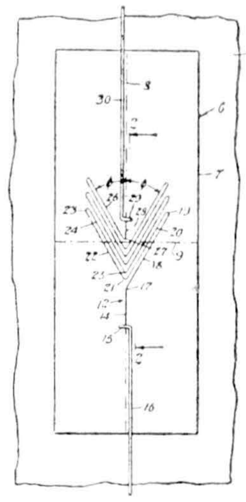
2,438,309. Control Device for Airplanes. Charles H. Zimmerman, Nichols, Conn., assignor to United Aircraft Corporation, East Hartford, Conn., a corporation of Delaware. Application April 11, 1944. Serial No. 530,541. 14 Claims. (Cl. 244—13.)



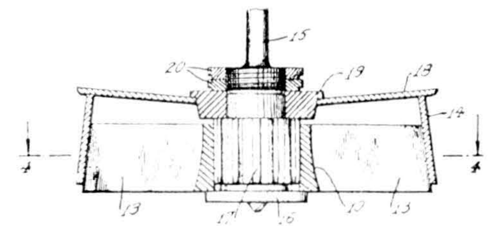
2,438,426. Centrifugal Compressor. Frank Whittle, Rugby, England, assignor to Power Jets (Research and Development) Limited, London, England. Application November 24, 1942, Serial No. 466,804. In Great Britain December 19, 1939. Section 1, Public Law 690, August 8, 1946. Patent expires December 19, 1959. 5 Claims. (Cl. 230—128.)



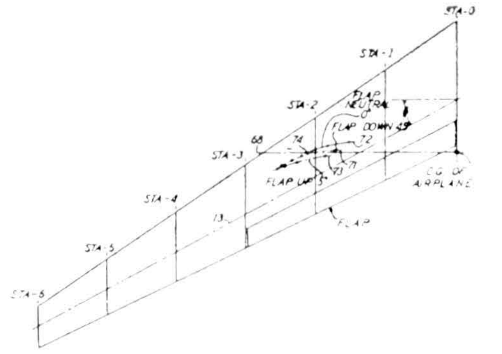
2,438,542. Propeller Blade, Bearing, and Sea Assembly. Maurice E. Cushman, Verona, N.J., assignor to Curtiss-Wright Corporation, a corporation of Delaware. Application September 7, 1944. Serial No. 553,089. 2 Claims. (Cl. 170—162.)



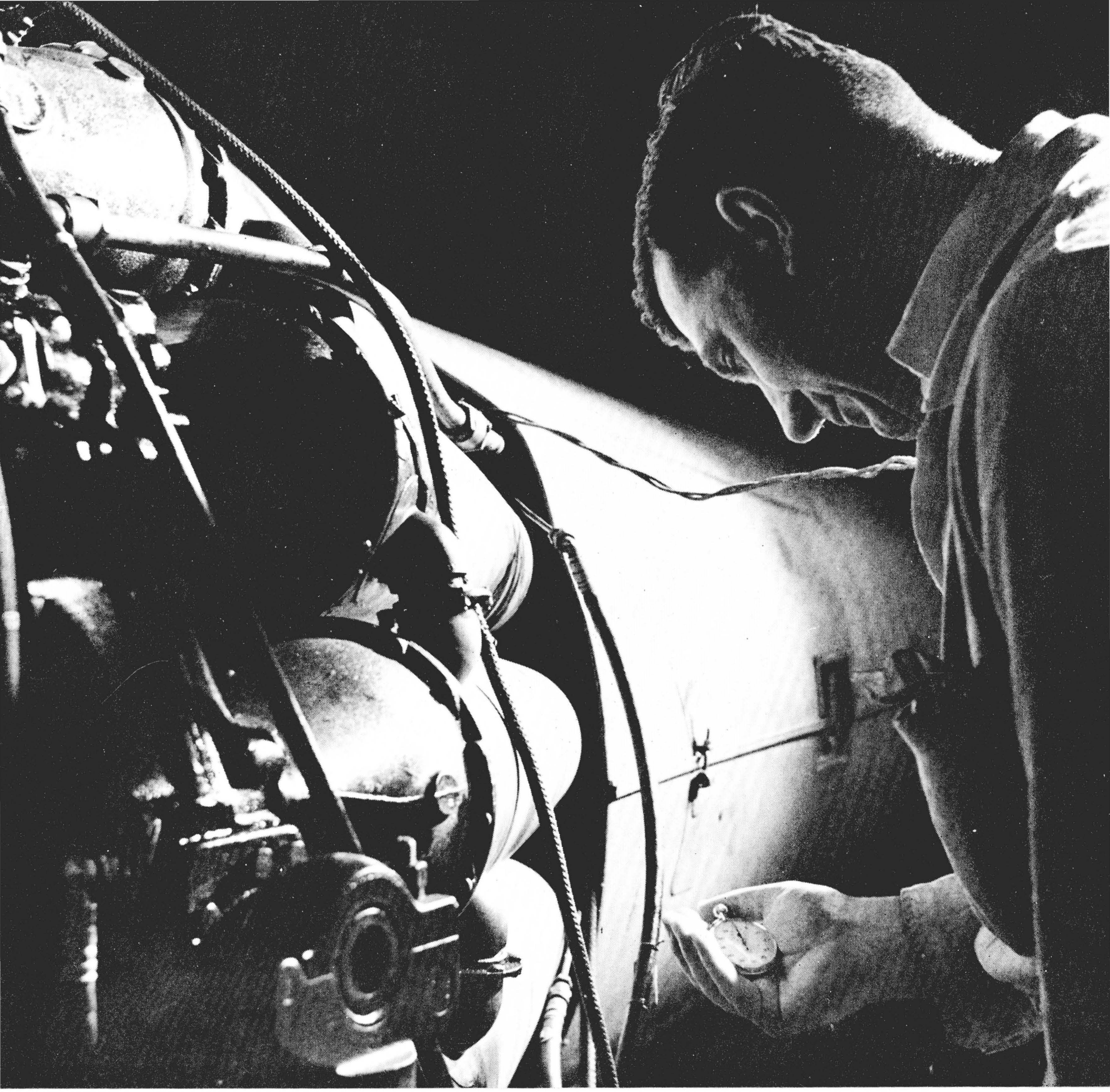
2,438,589. Electric Strain Gage. Elwood C. Walker Caldwell, N.J., assignor to Curtiss-Wright Corporation, a corporation of Delaware. Application August 30, 1946. Serial No. 693,899. 8 Claims. (Cl. 201—63.)



2,438,867. Method of Assembling Shrouds on Impellers. Albert M. Rockwell, Glastonbury and Albert H. Beaufrere, Manchester, Conn., assignors to United Aircraft Corporation, East Hartford, Conn., a corporation of Delaware. Application June 1, 1945. Serial No. 597,130. 2 Claims. (Cl. 29—156.8.)



2,439,048. Tailless Airplane. Walter H. Korff, Burbank, Calif., assignor to Lockheed Aircraft Corporation, Burbank, Calif. Application October 5, 1942. Serial No. 460,797. 4 Claims. (Cl. 244—13.)



Goblin survives severest 500-hour test

462 repetitions of the gruelling sequence of a 65-minute interception—take-off, maximum climb, maximum cruise, full-power combat, descent, 10-minute stand-by—have been completed with negligible maintenance and no loss of performance

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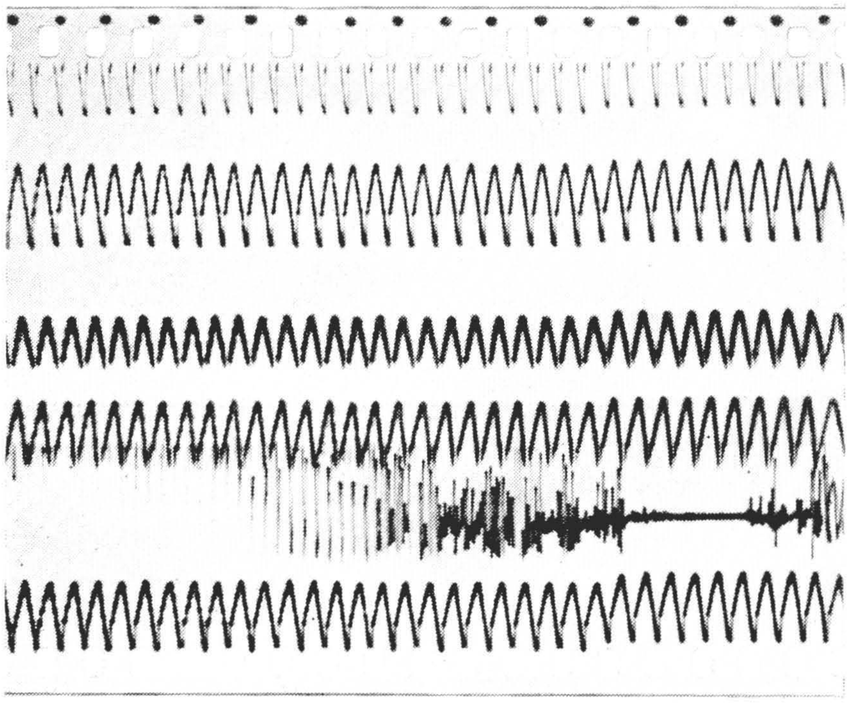

TRANSIENT EVENTS ARRESTED

The first Avimo Oscillograph was a specially built Camera designed to provide records of Cathode Ray Traces to a scale which permitted accurate measurement, side by side on continuous film, so that precise relationships could be determined.

Success in this specialized field led to demands for Cameras to record other kinds of transient events, so that within the Avimo range listed below there are, today, Instruments to meet nearly any requirement of the Research or Laboratory worker.

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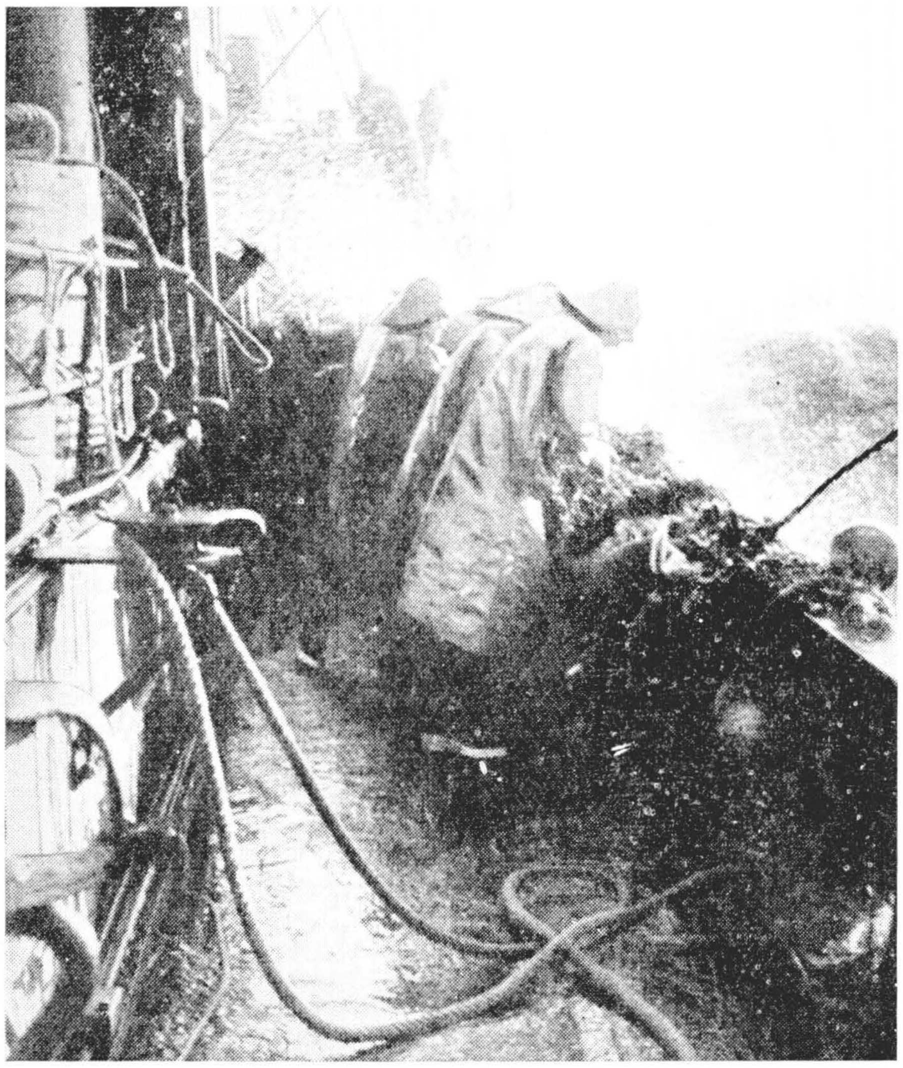

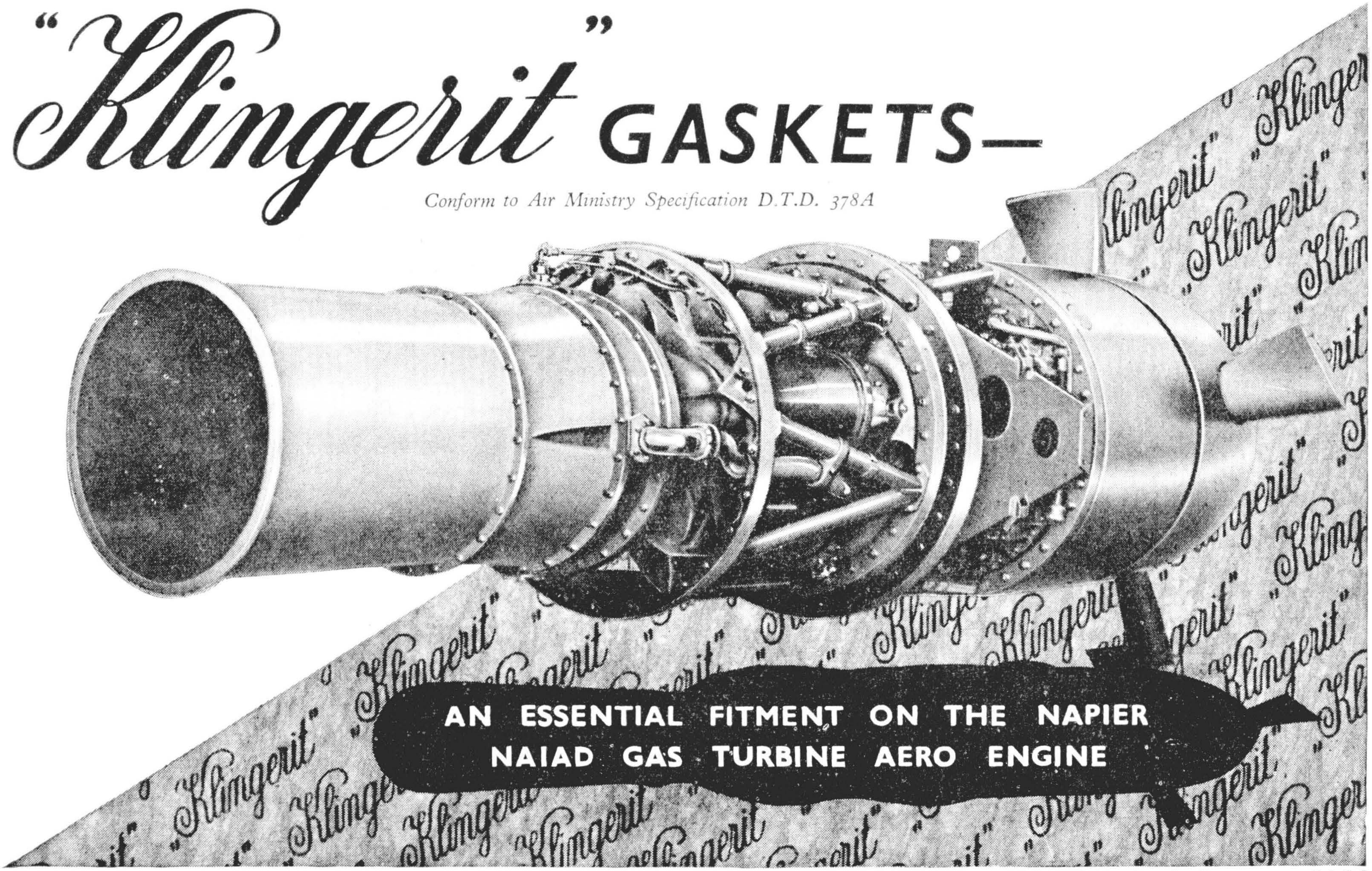

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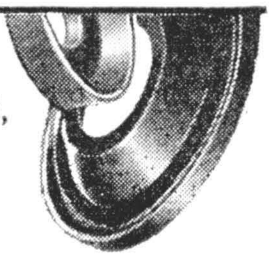


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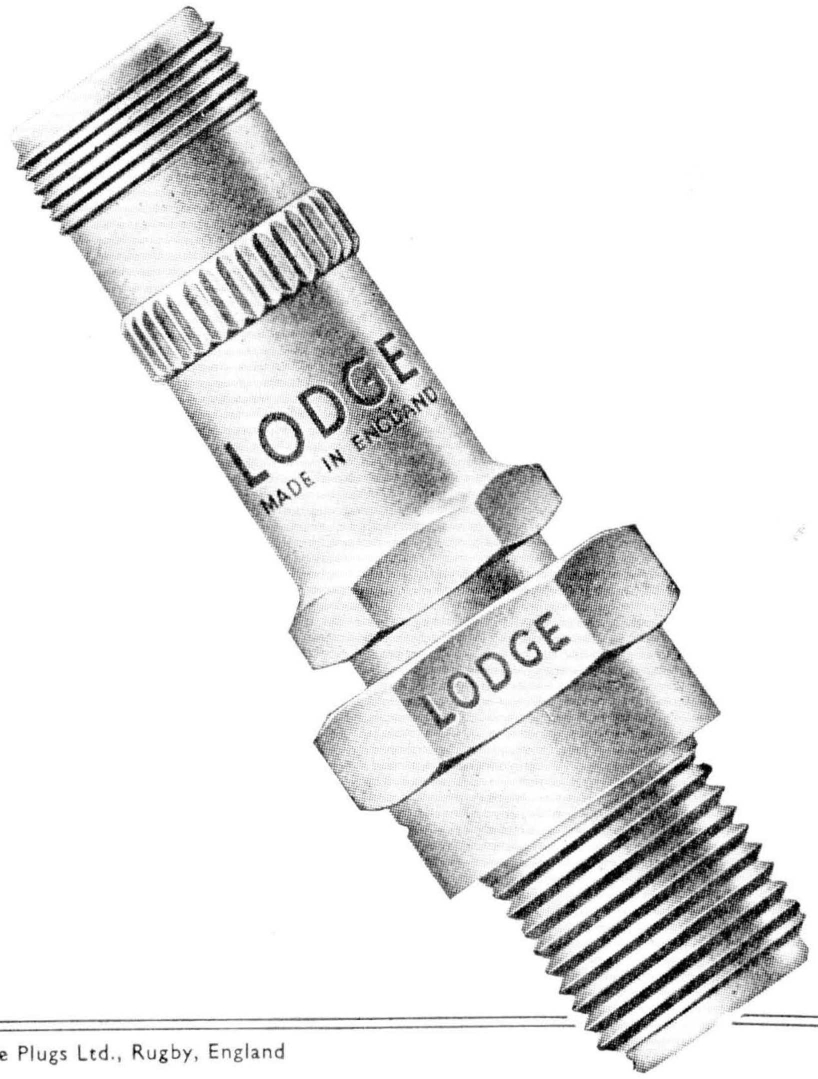
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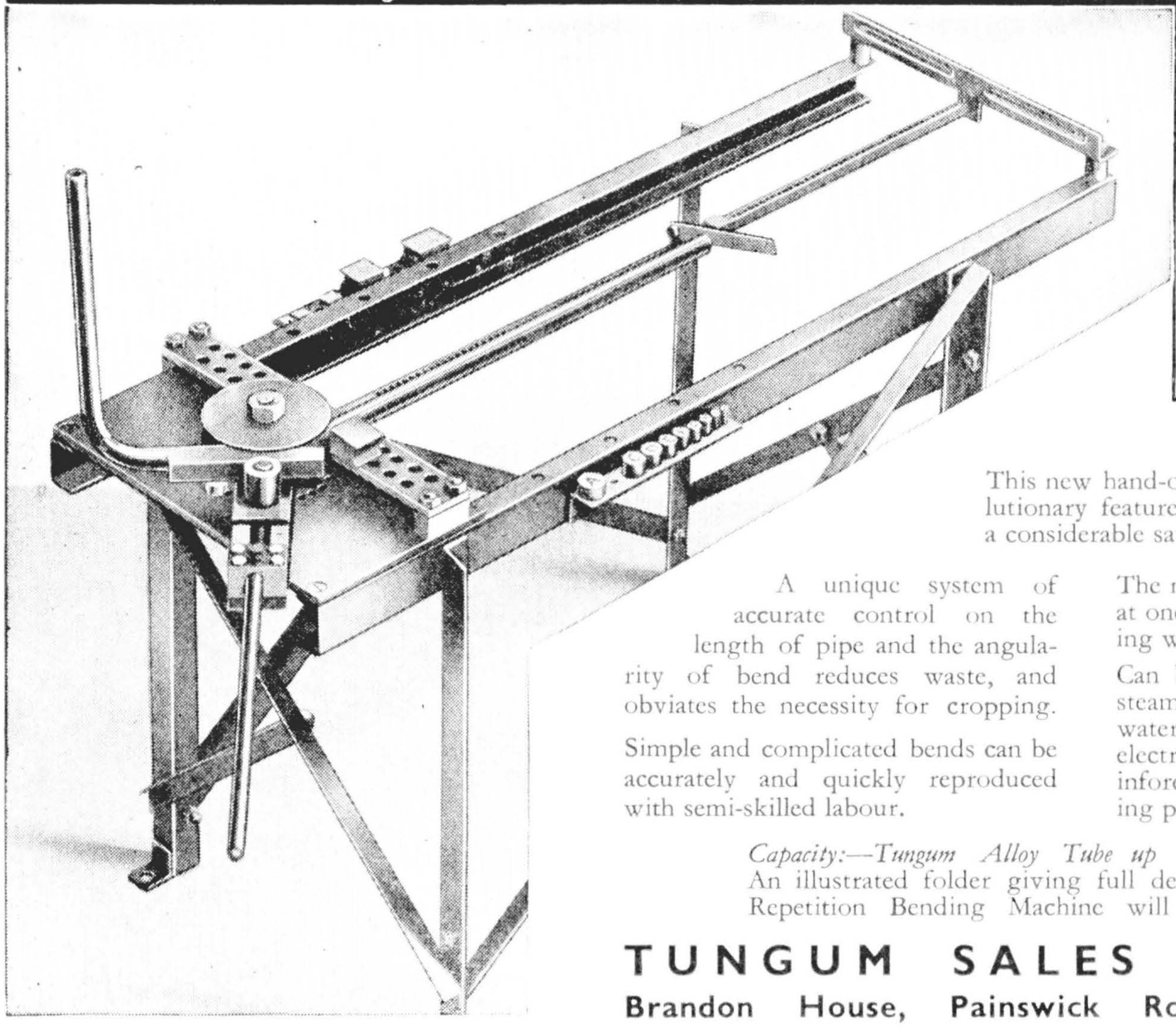

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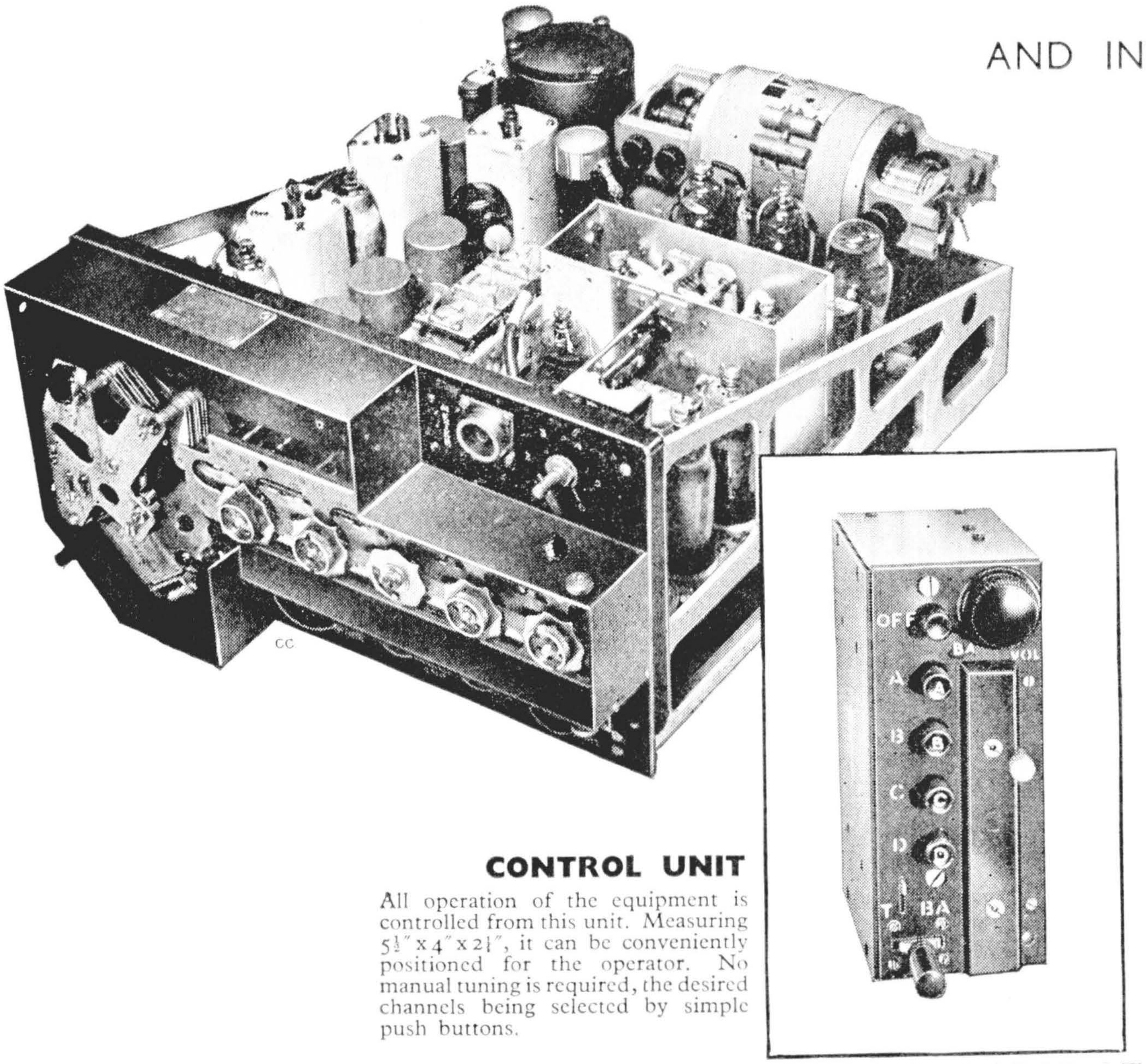

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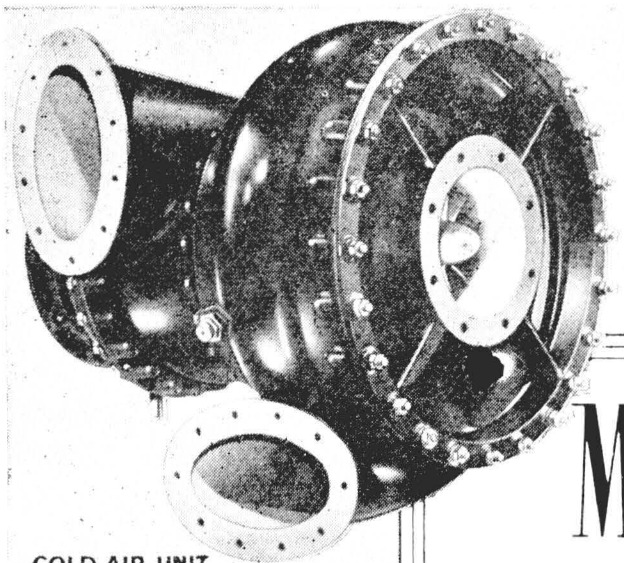

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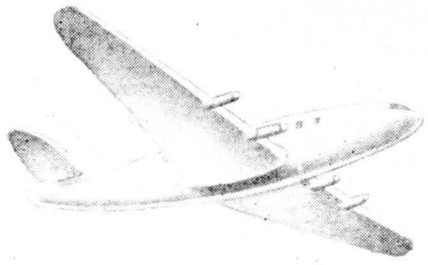

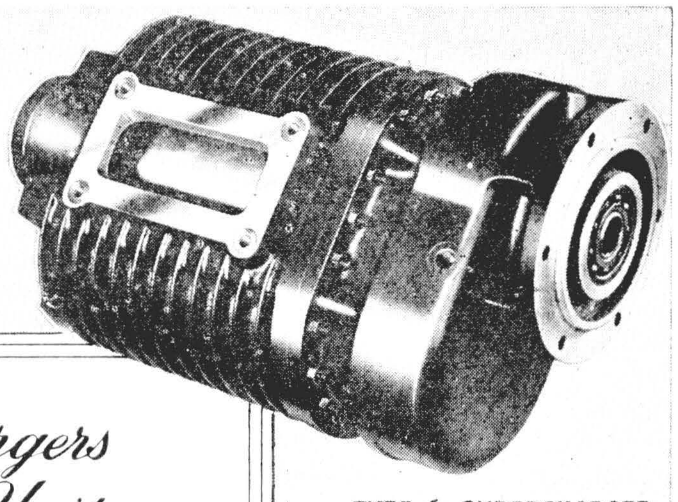

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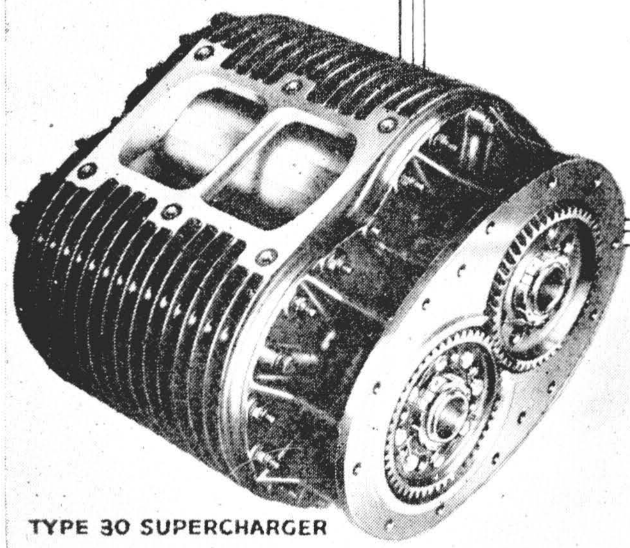

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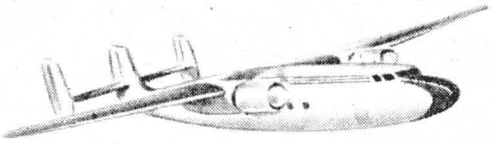

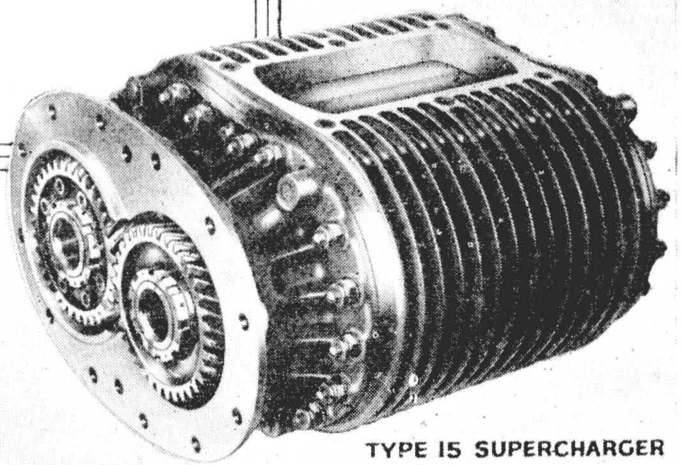

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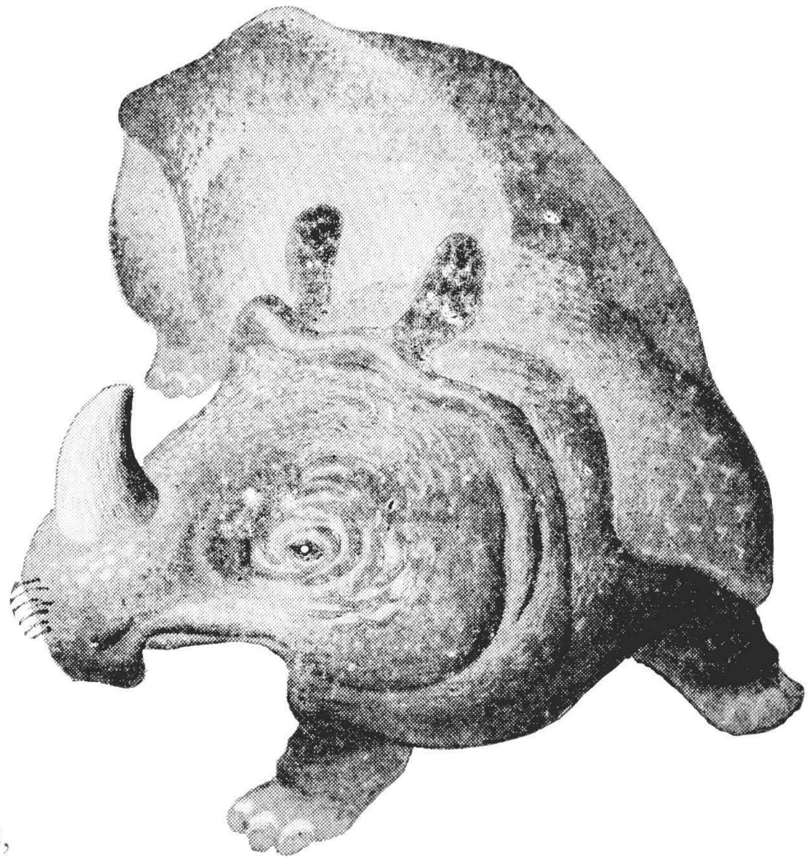

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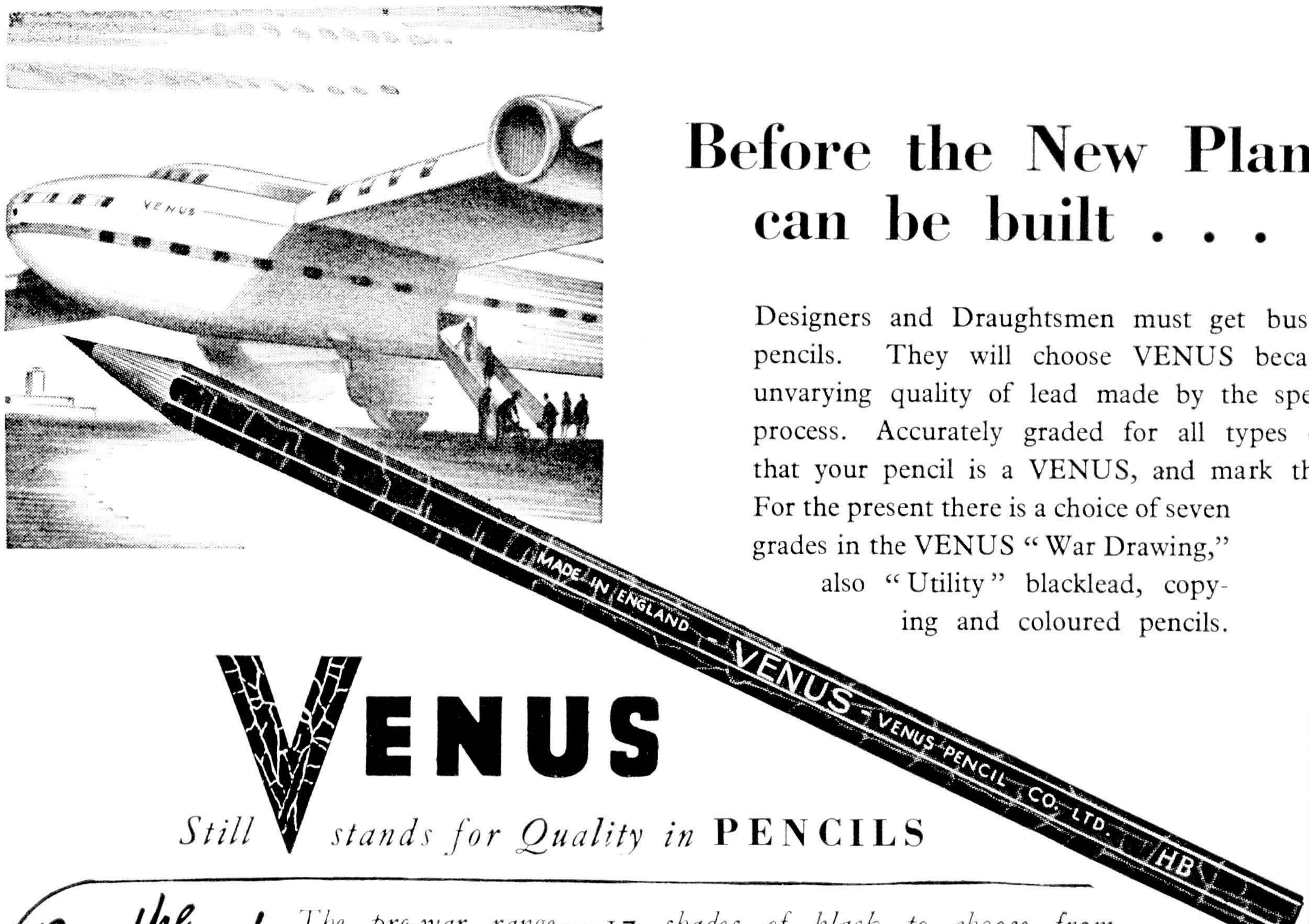
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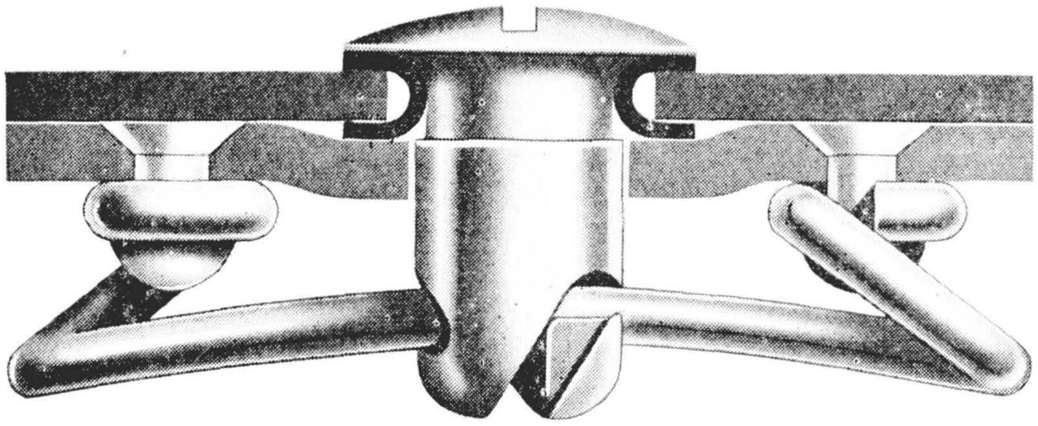

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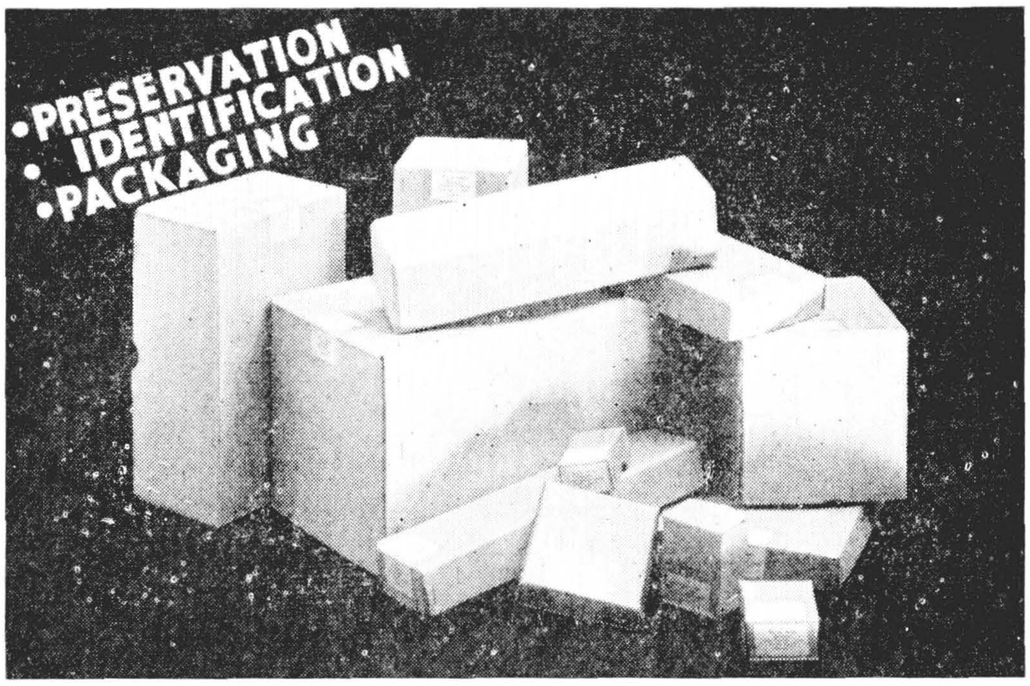

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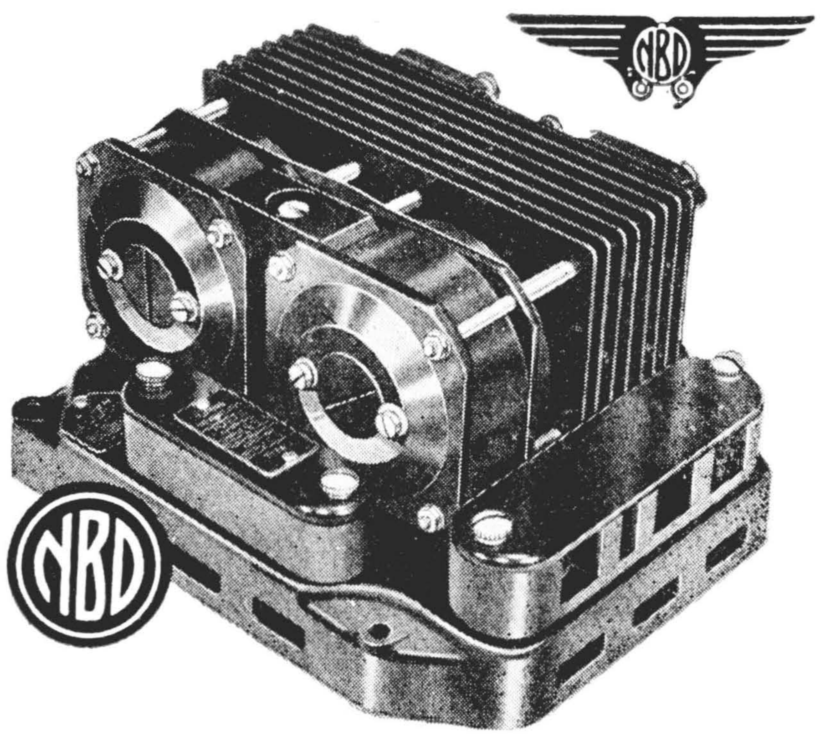

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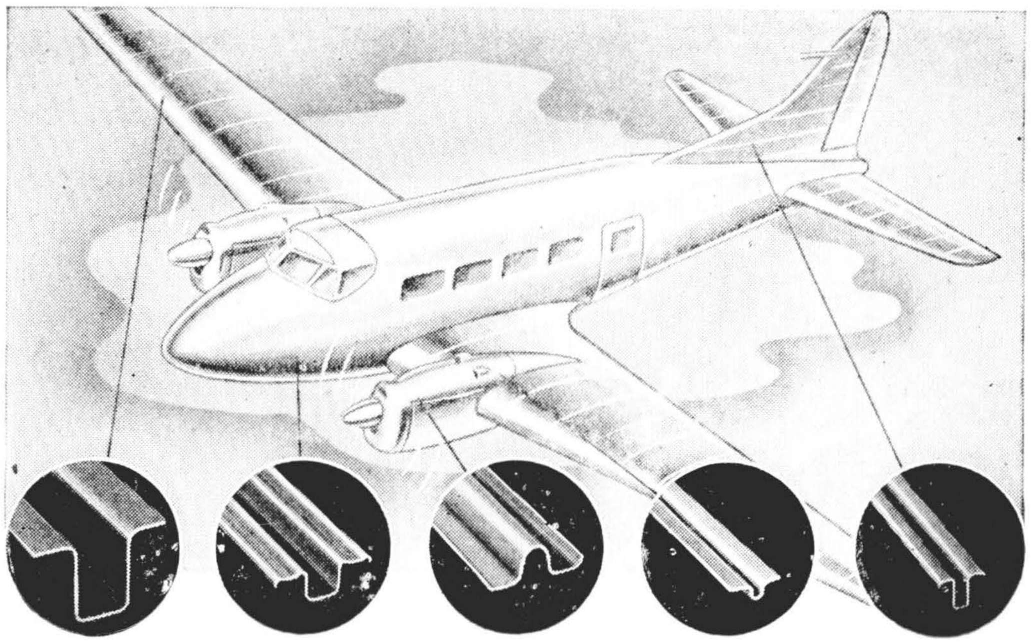

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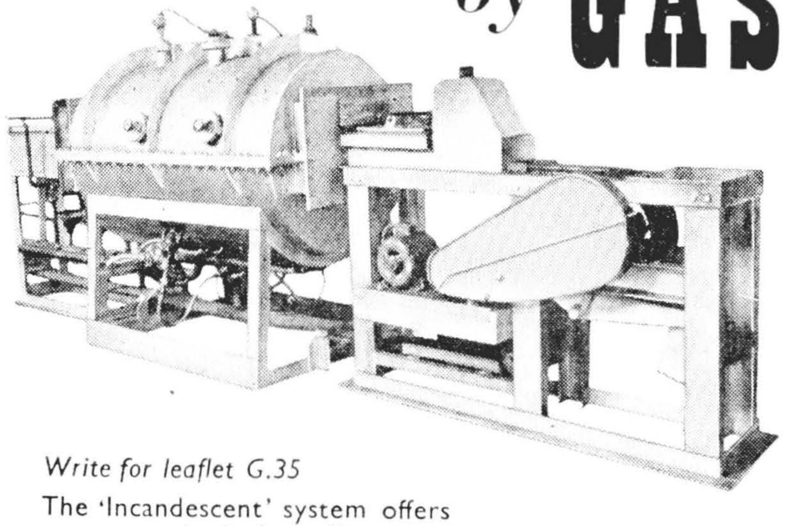

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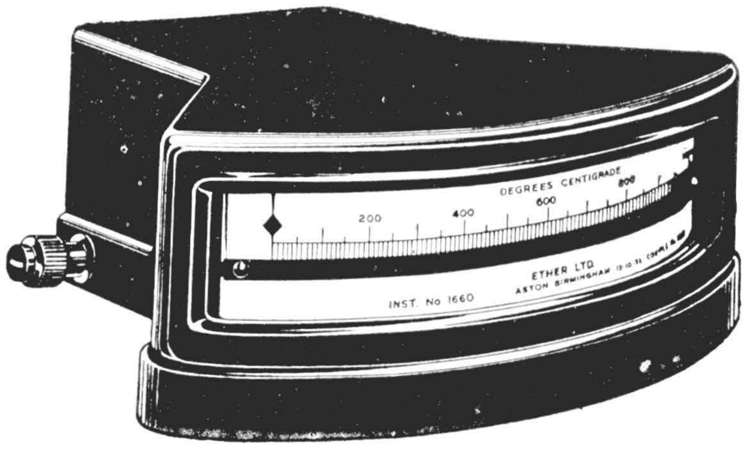

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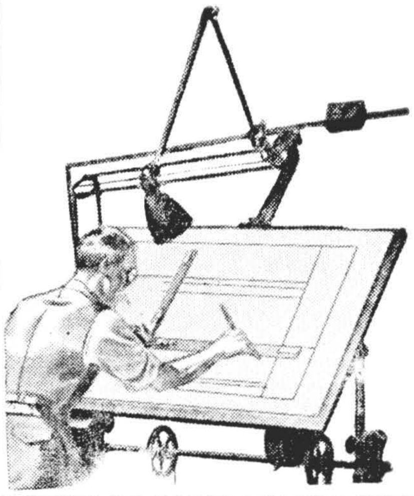

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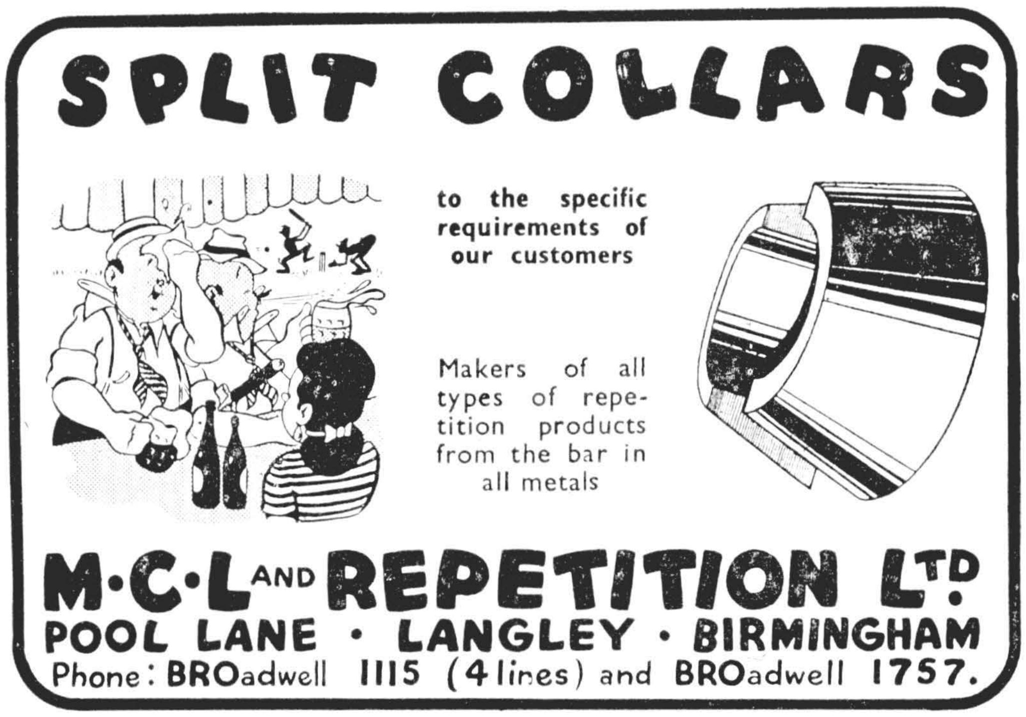

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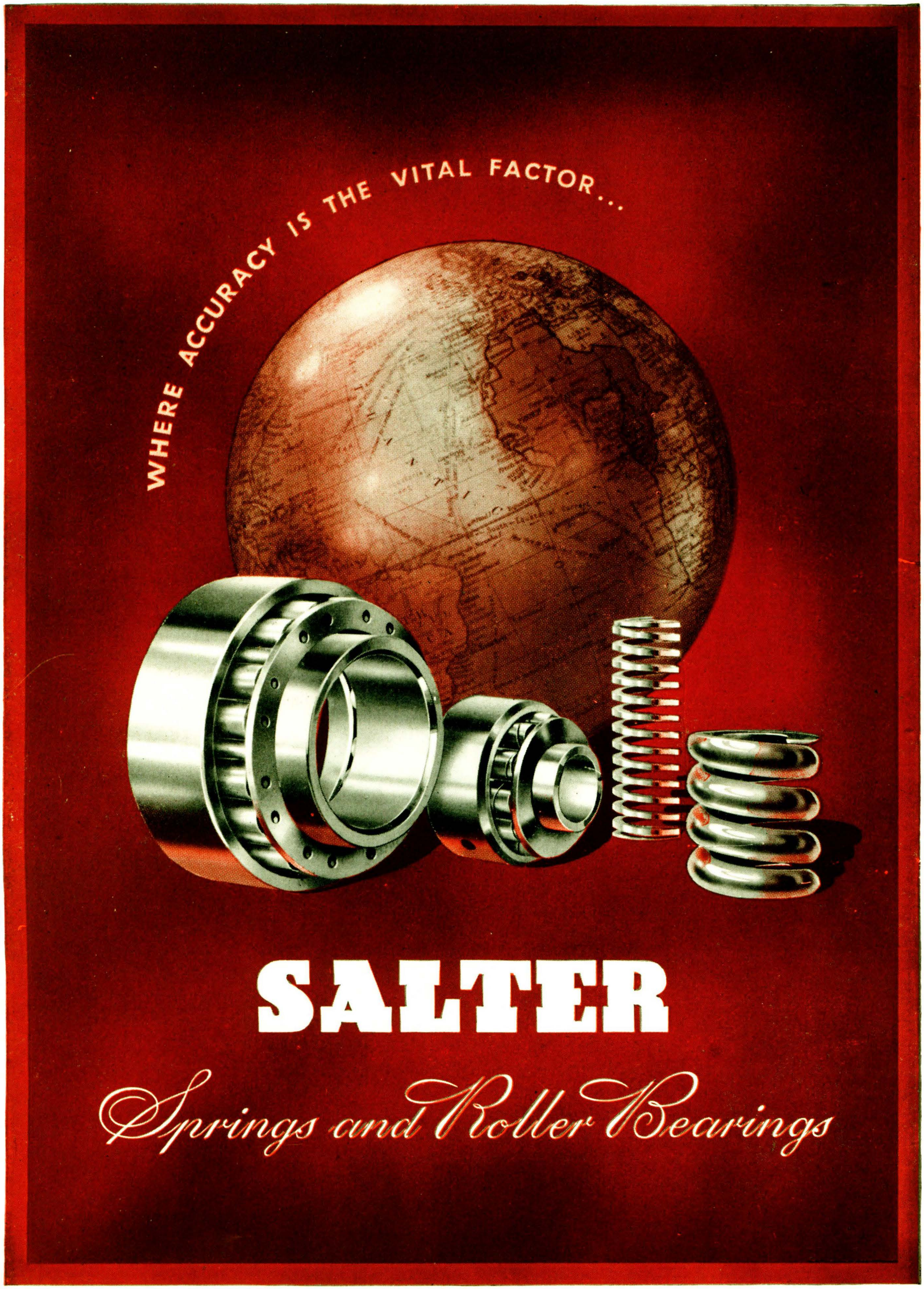

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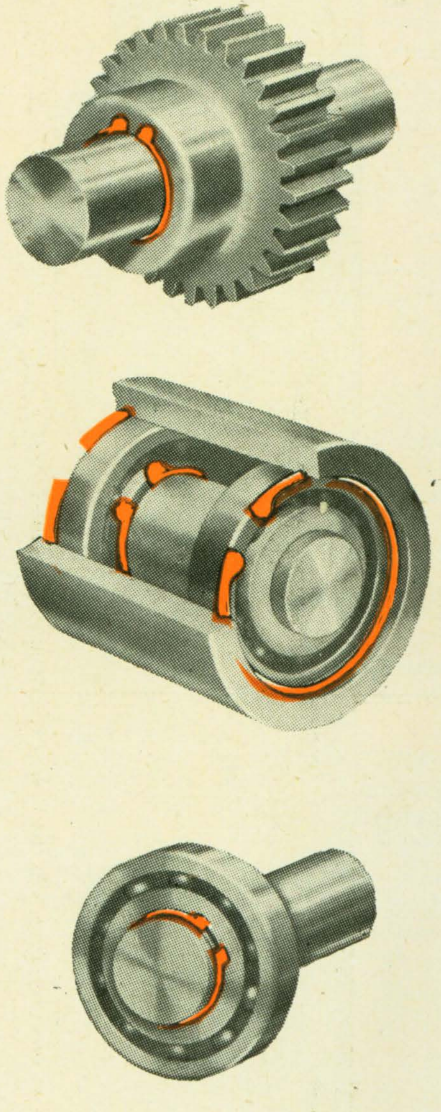

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