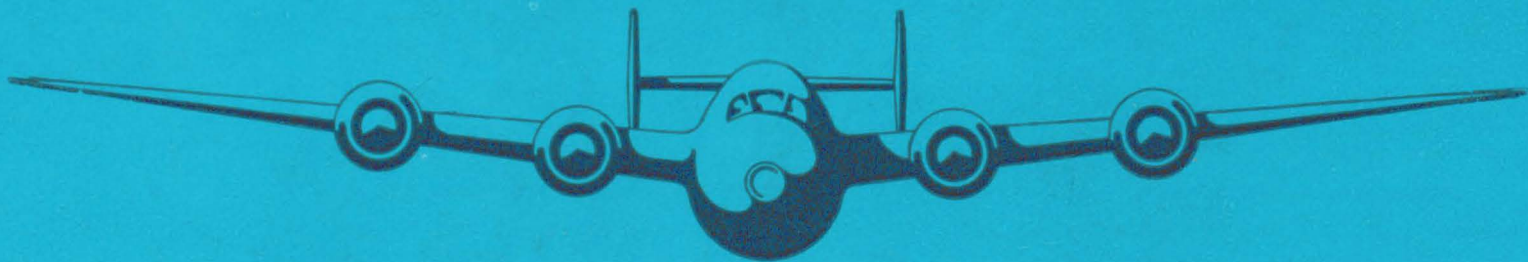


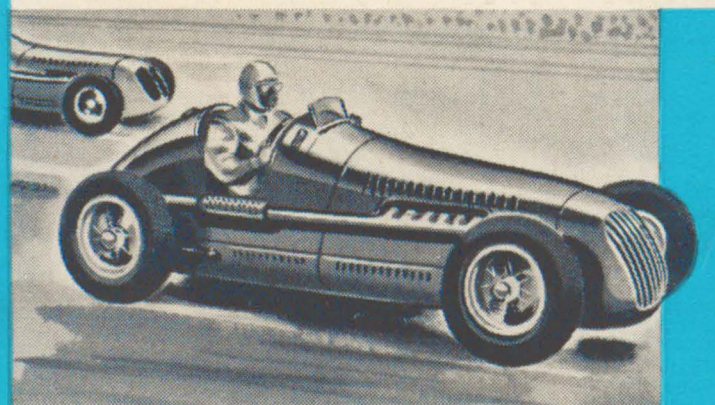
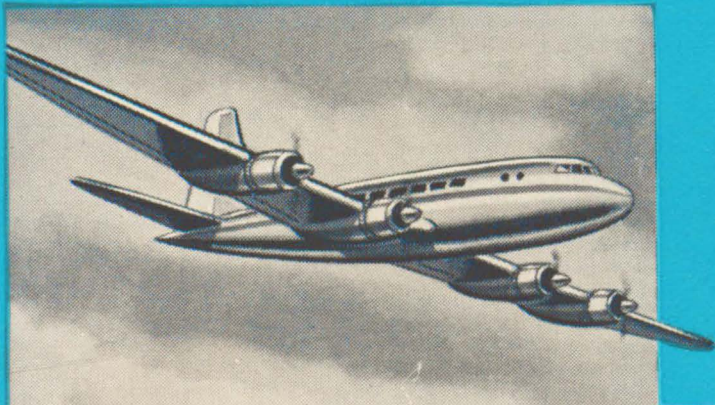
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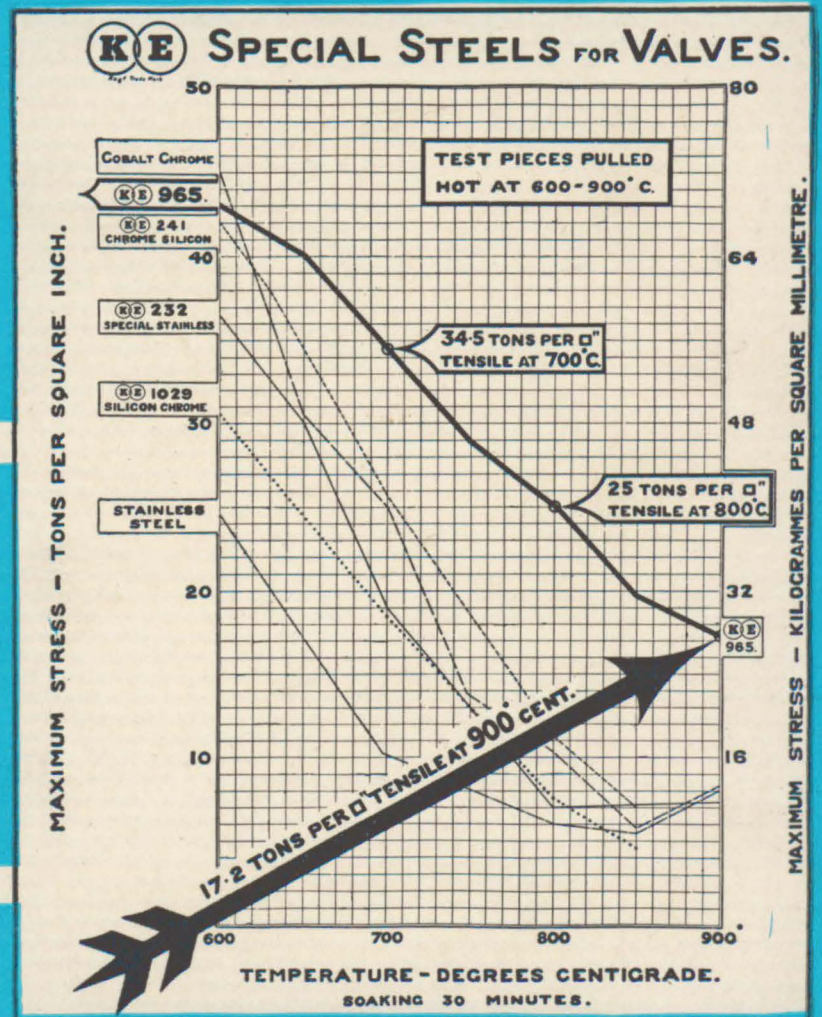
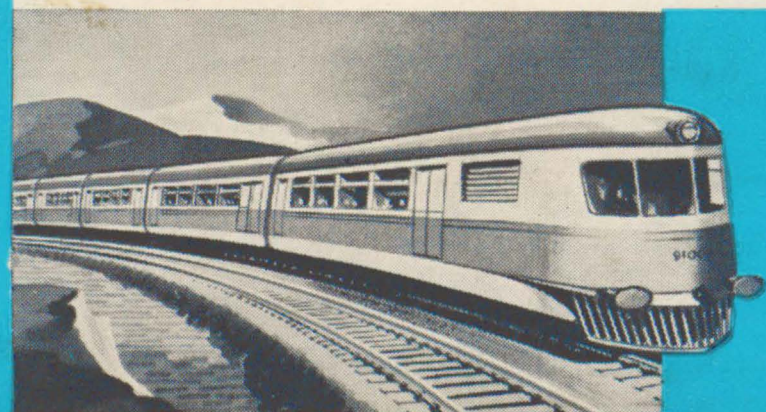
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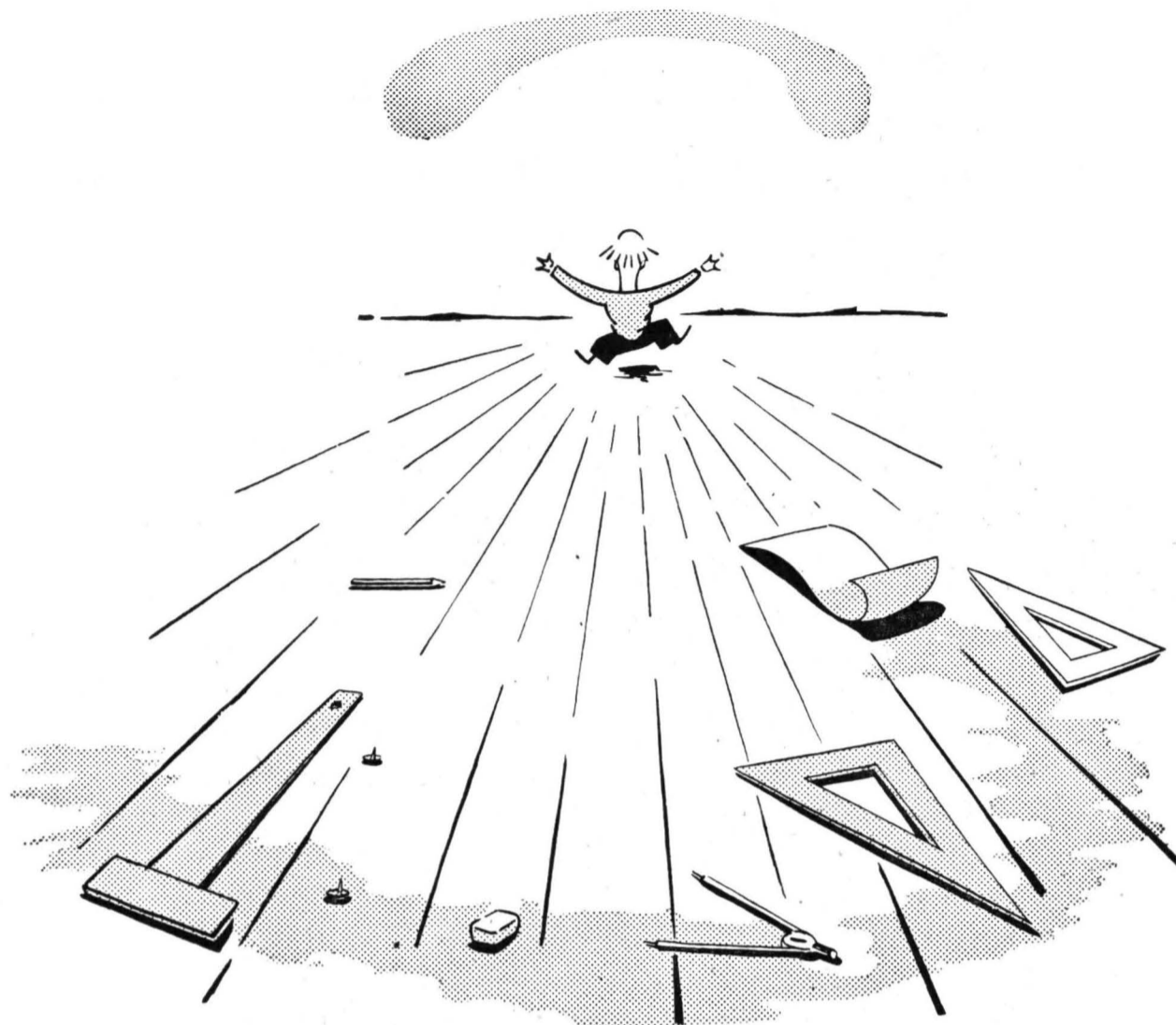


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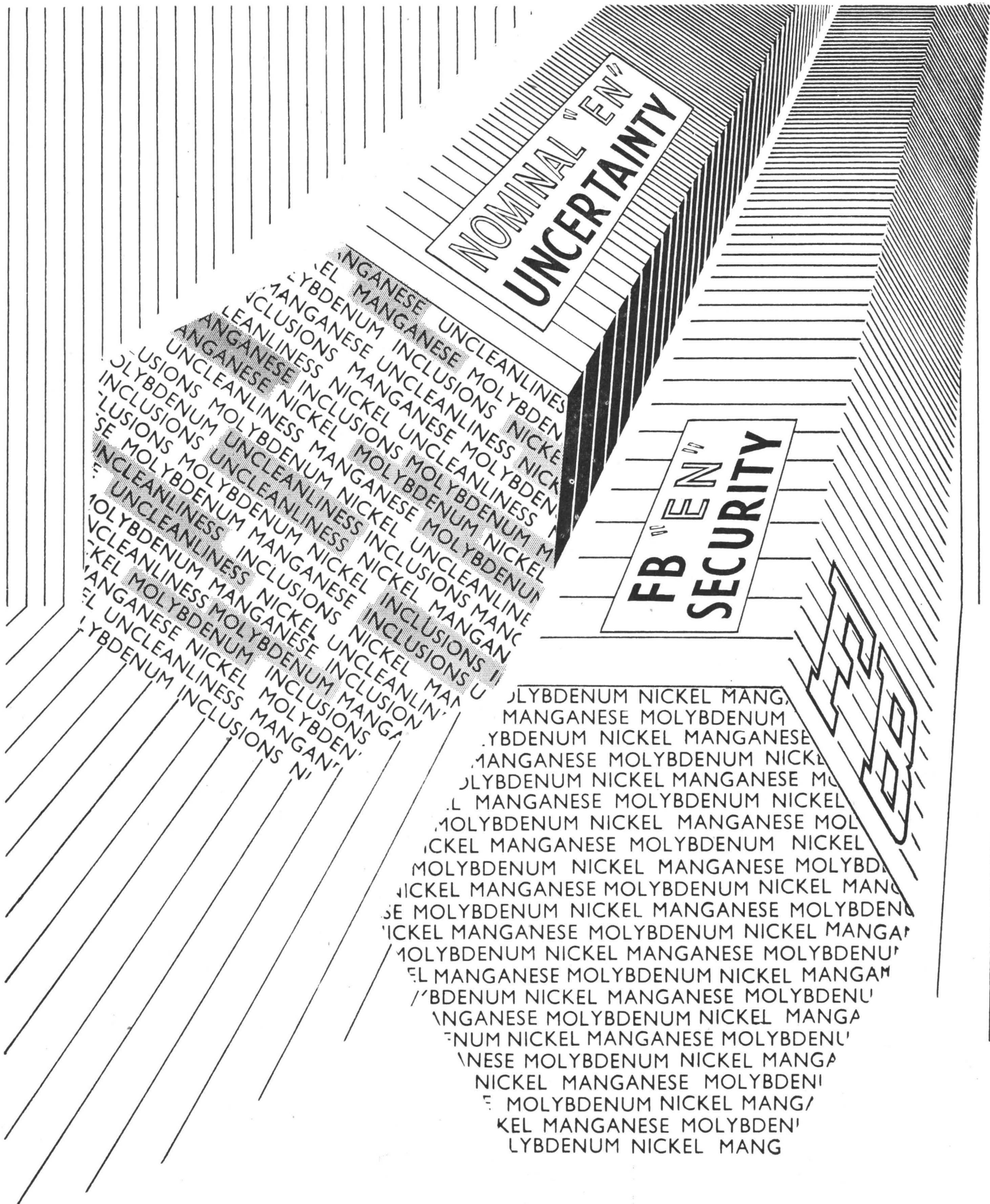
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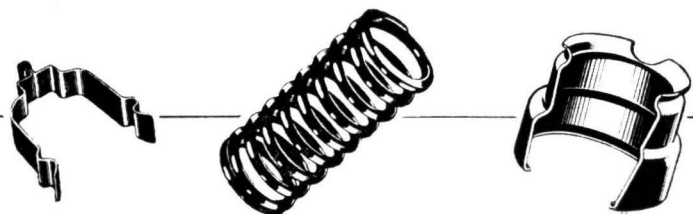
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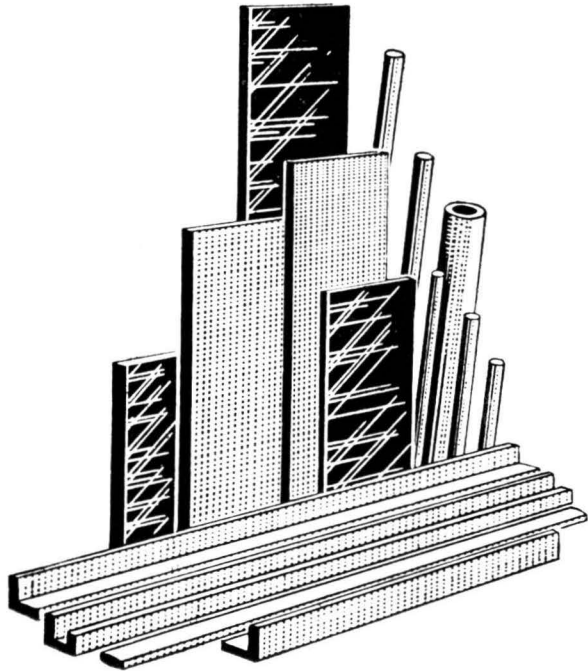
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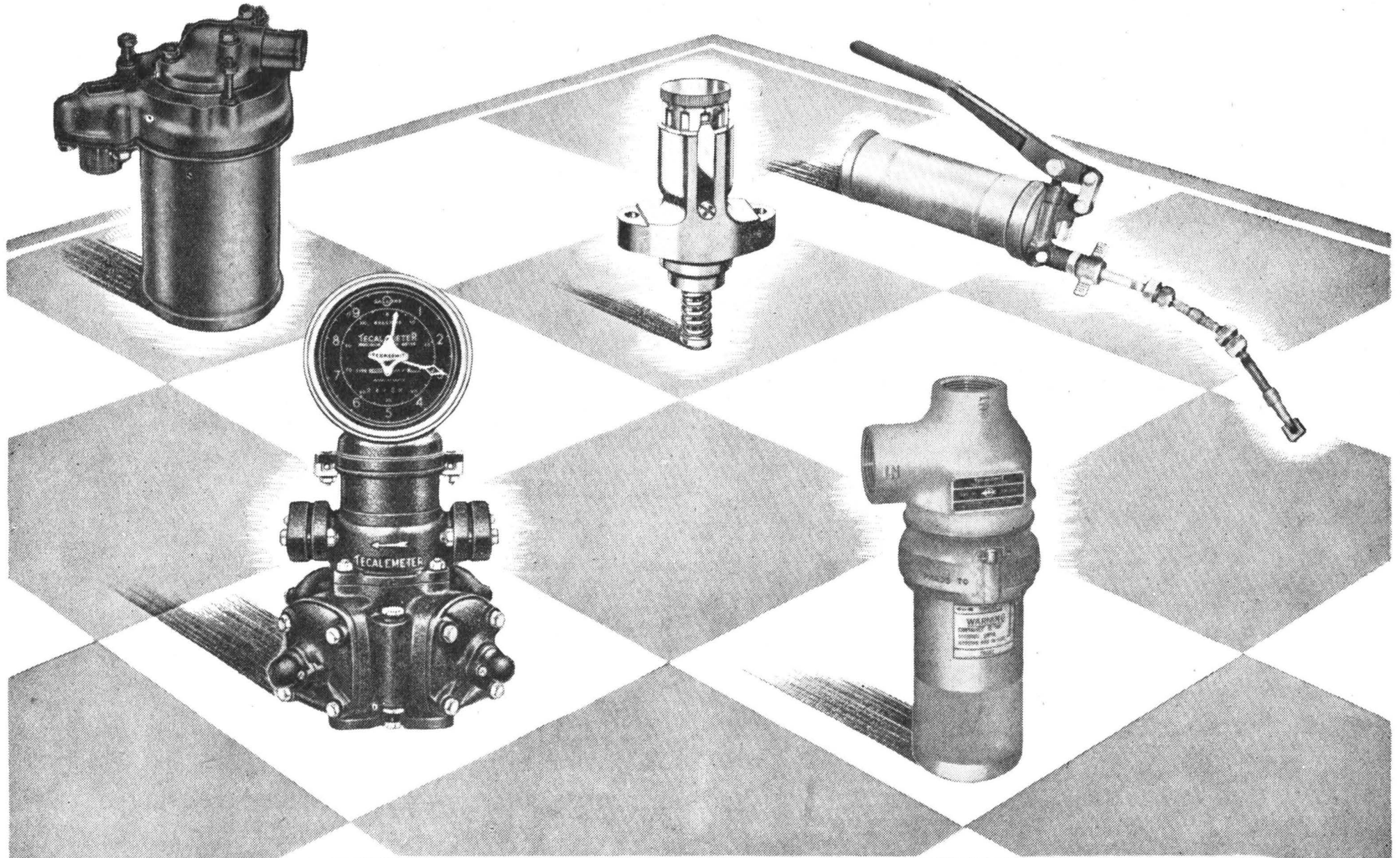
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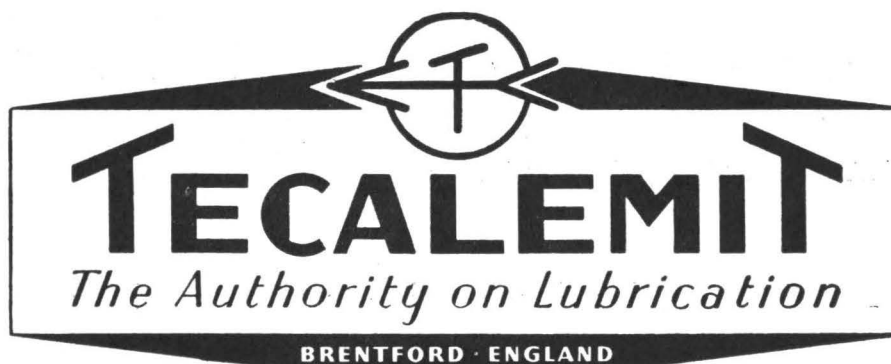
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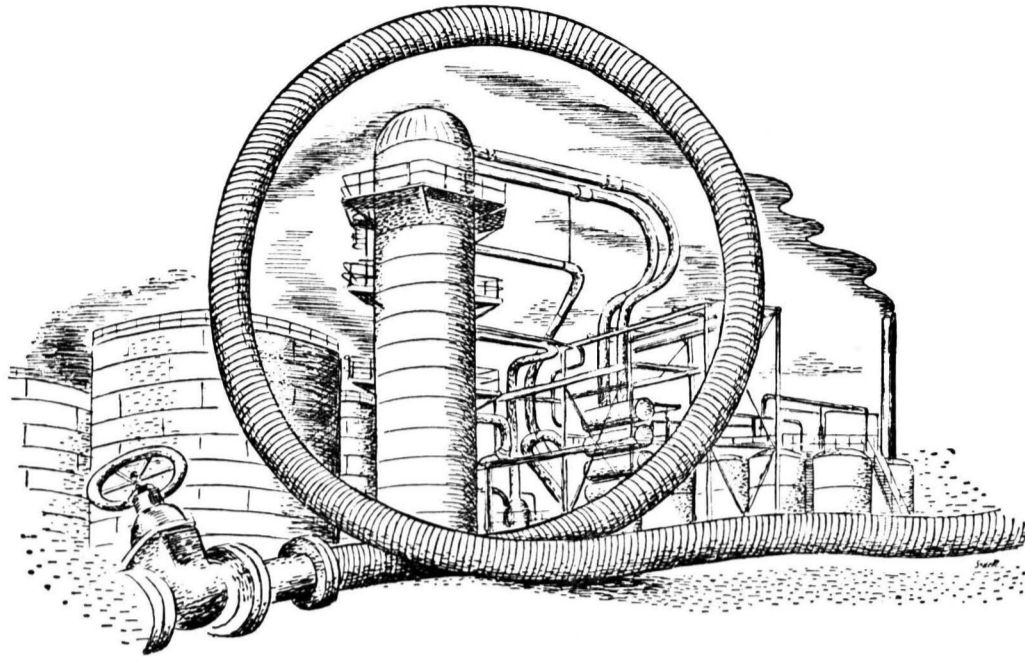
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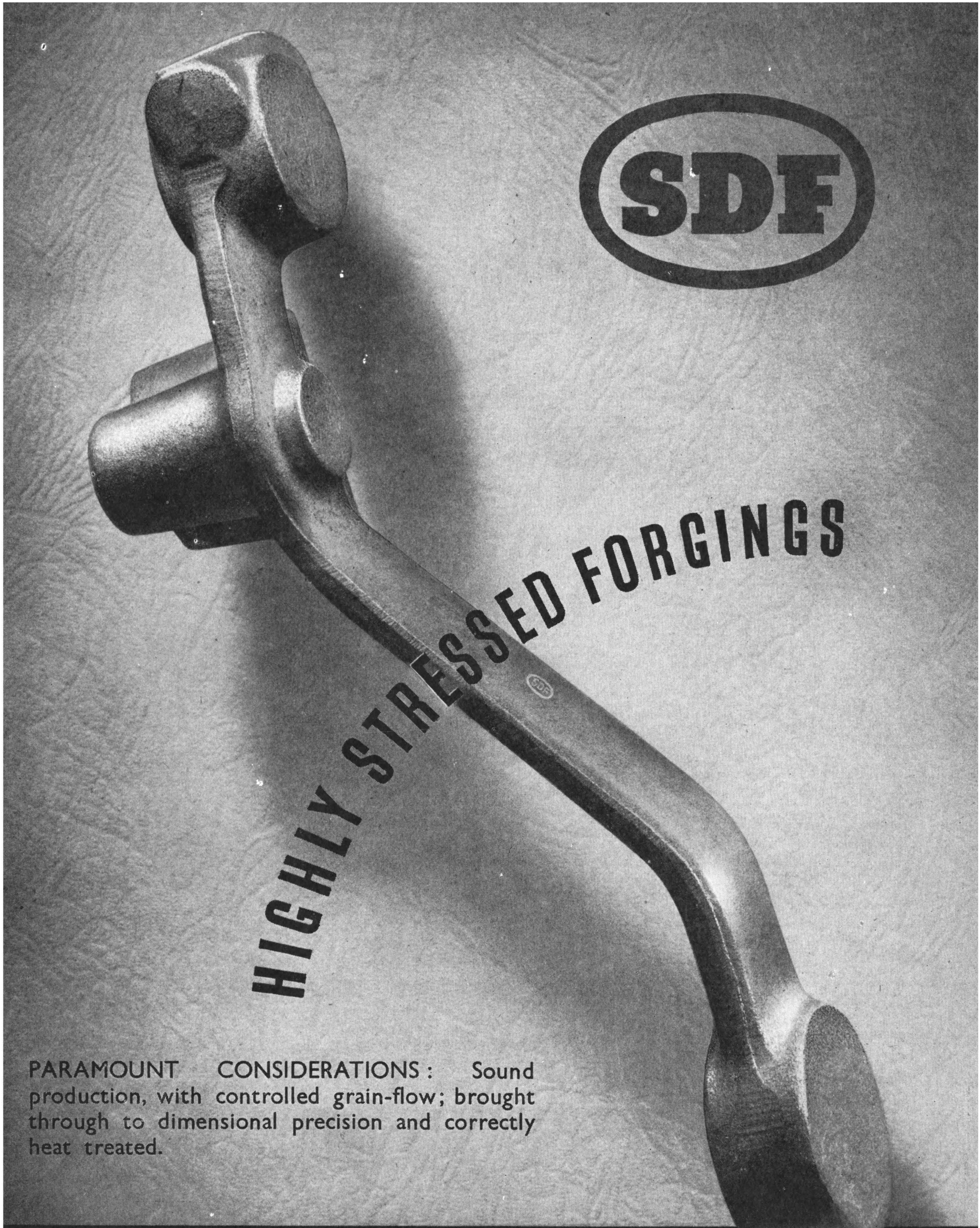
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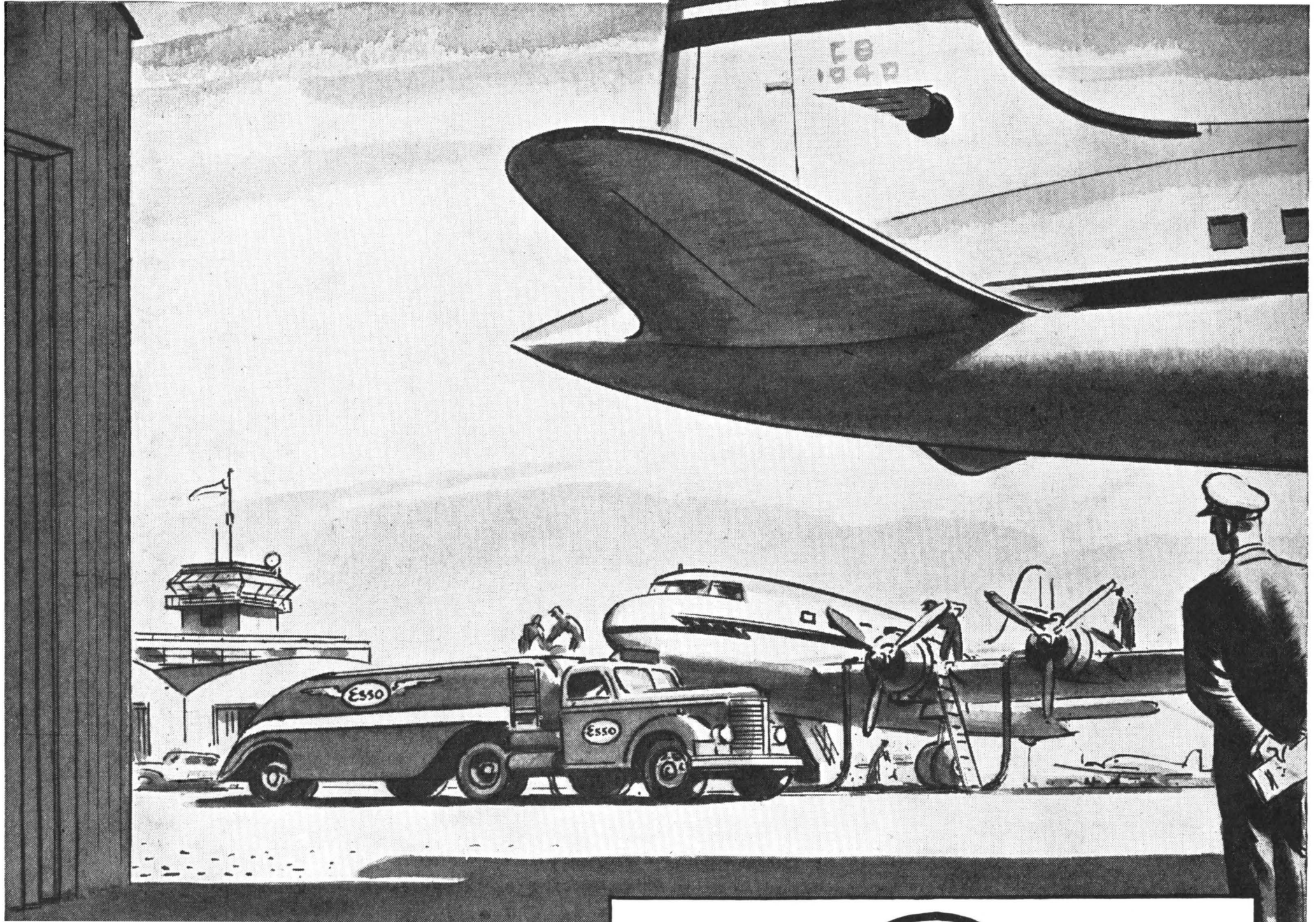
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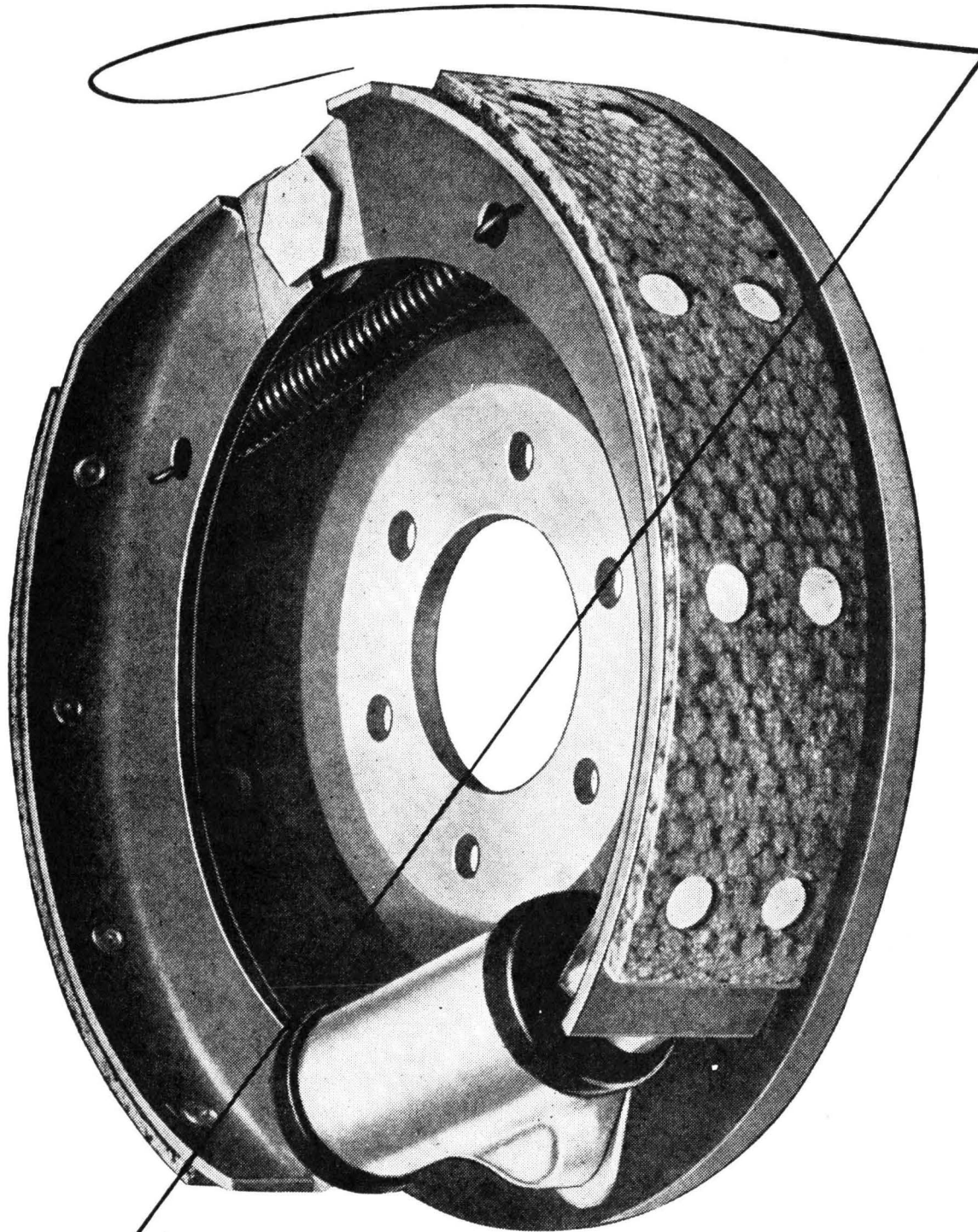
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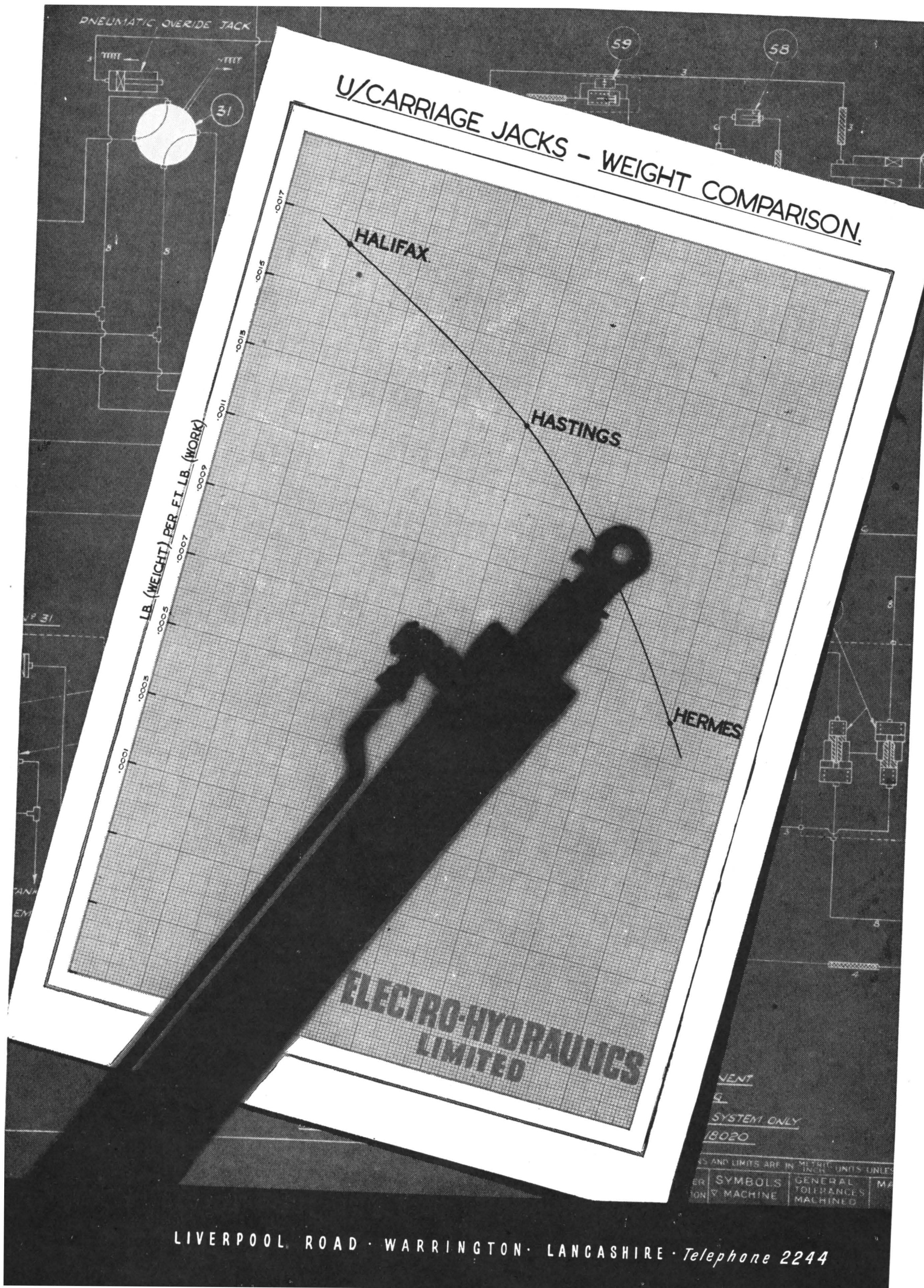


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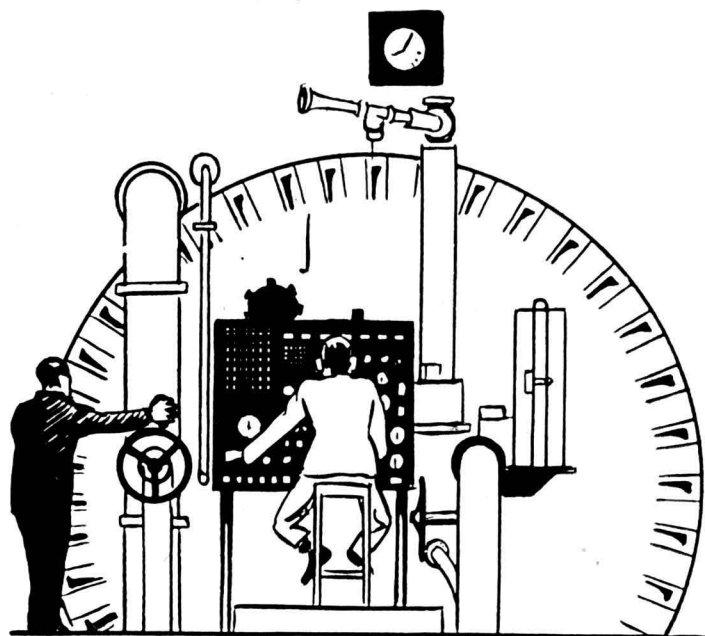
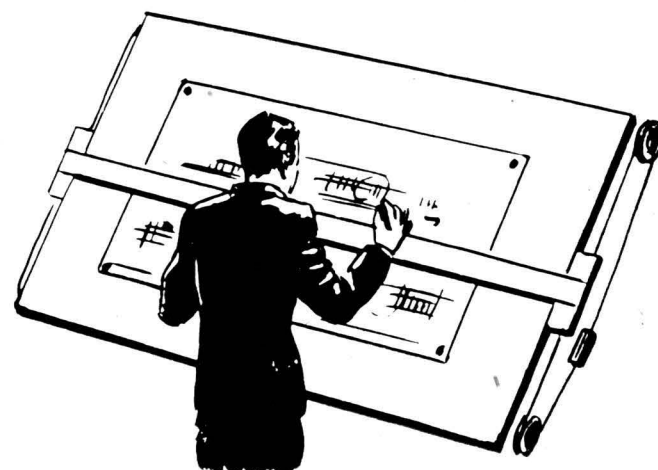
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AUGUST 1949

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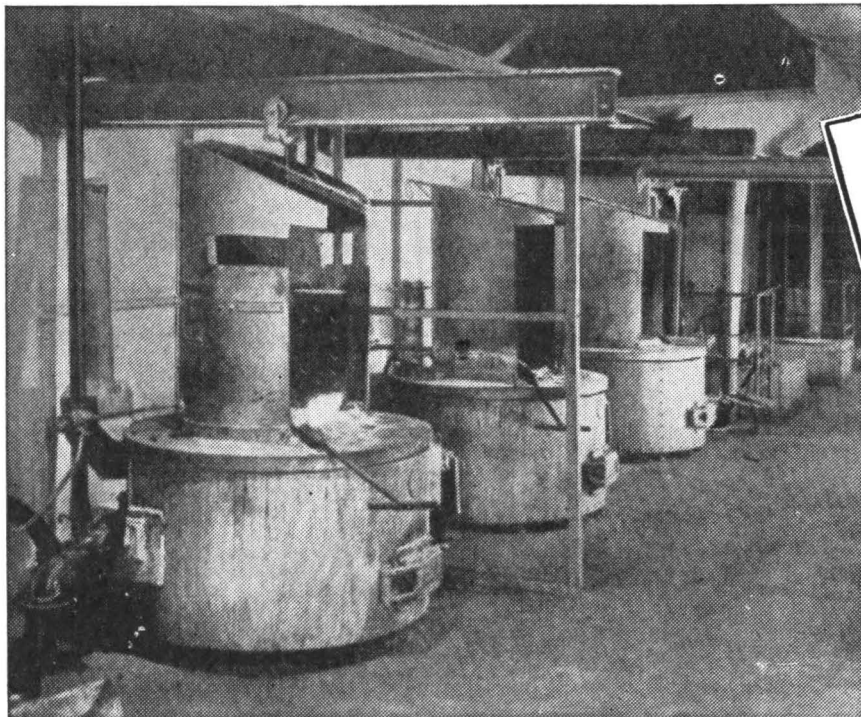
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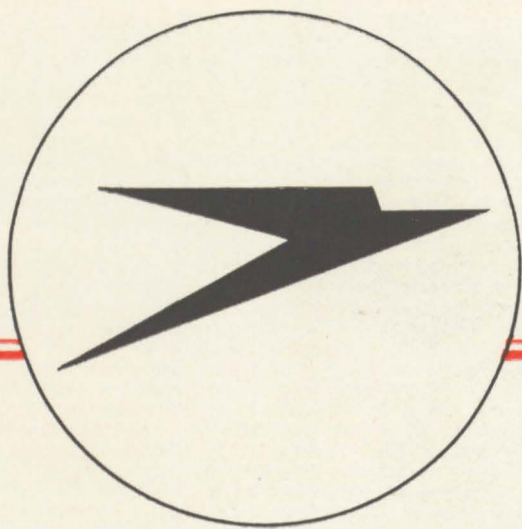


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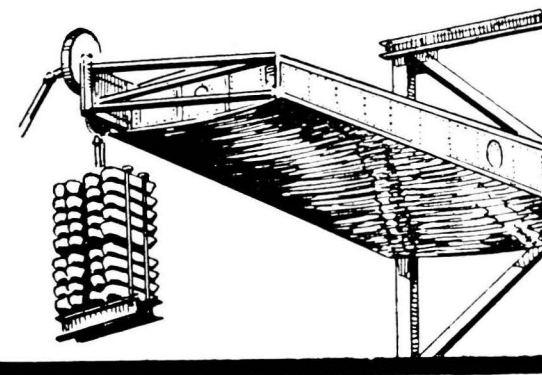
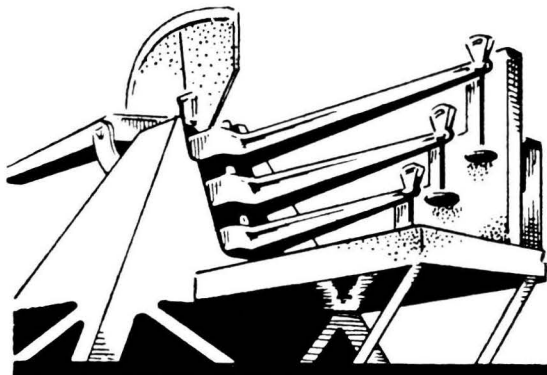


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VOL XXI No 246

AUGUST 1949

Clearing the Ground

THROUGHOUT the twenty years' career of AIRCRAFT ENGINEERING, we have consistently tried to be of assistance to the stressman by publishing articles on his craft. This has been particularly the case since the advent of stressed-skin construction with its introduction of so many problems hitherto unknown to engineers, and our files bear witness to the large proportion of our space that has been devoted to various aspects of the subject.

Our Problem

The difficulty has always been that the contributions sent to us have so often suffered from the defect of being too detailed. Authors have tended to devote their energies to an explanation of how they have dealt with some comparatively minor problem. While these articles have been useful, in a comparatively large number of instances they have set out in considerable, and sometimes we fear unnecessary, detail the step-by-step calculations leading to the solution of some individual case which has presented itself, and have been in fact merely instances of particular applications of general principles which are to be found in any good up-to-date textbook. While, as we say, such articles have their uses and are undoubtedly helpful, on the other hand they have at times displayed an undeniably limited point of view and have perhaps tended to encourage a somewhat 'hand to mouth' outlook. They have to a considerable extent put the cart before the horse by picking out some problem of restricted scope while by-passing the wider theories on which a solution should be based.

It is, of course, true that until comparatively recently many detail matters could only be approached in this way by a more or less rule of thumb adaptation of well-known methods of attacking somewhat analogous problems in more conventional engineering structures. It is no doubt to a large extent an historical fact that it is only in this way that a general theory enabling a fundamental approach to the new science of analysing stressed-skin structures has been gradually built up over the past decade or so.

However that may be, it has in the few years immediately past been borne in upon us that what was required was a clear and general statement of the basic principles on which the stressing of modern aeroplane structures was founded. It had also frequently been pointed out to us that pages of abstruse mathematics had a definitely deterrent, not to say alarming, effect on readers and it was suggested that the most helpful type of article at this time would be one of the widest possible scope in which mathematics was kept to the barest minimum.

The Solution

The result has been the series by MR W. S. HEMP which is concluded in this issue. MR HEMP has gone even further than our most

optimistic hopes by succeeding in eliminating mathematics altogether from his treatise—for it is nothing less. He has succeeded in bringing off what is undoubtedly a real *tour de force* in covering the whole ground of the stress investigations involved in the design of a modern aeroplane written entirely in perfectly simple normal language without resorting to a single formula from beginning to end. In the result, he has produced what is so far as we are aware the first complete exposition of the theory of modern stressed-skin construction. Such an account is undoubtedly a very real need and we are glad indeed to have been the means through which it has been made available to students and the staffs of stress departments in the industry. In addition to his position at Cranfield MR HEMP is, as most of our home readers will know, exceptionally well qualified to lay down the fundamental principles of the subject through his close association with the small band of workers who have been engaged for some time in formulating them.

A New Feature

In this issue there appears the first of a series of reference sheets which will in future be a regular feature of our pages—in September, we shall be publishing similar information on the Dove. Our intention is to provide engineering data of a type not usually included in descriptive articles on the aeroplanes concerned. The series will be designed to give useful details of British civil aeroplanes for the benefit of Licensed Aircraft Engineers and others so that they may have by them for reference material data on types in which they are interested, or with which they may come in contact, but in connexion with which they have not been issued with the official manuals. It will also make it possible to look up quickly such details as the makes of accessories fitted. Every effort will be made to ensure that all the data given is as accurate and reliable as possible and it is our intention to bring the sheets up to date from time to time by issuing them in revised form.

We would welcome comments and criticisms, whether in the form of suggestions for the incorporation of additional information or for the omission of details that may be readily available elsewhere.

These first two examples should, indeed, be looked upon largely as exemplifications of the sort of thing we are aiming at rather than the finished product and, as we have said, we shall be glad of every assistance in making the series in its ultimate form of the maximum possible value to those concerned. Unfortunately, owing to the need for going to press unwontedly early with the September issue, in view of the opening date of the S.B.A.C. Display, the Dove article will already be in print by the time these words appear—too late for modifications to be incorporated—but all suggestions will be borne in mind for future use. If there should prove to be sufficient demand we shall make the sheets available, after publication in AIRCRAFT ENGINEERING, in the form of separate reprints.

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An Account of the Problems Involved and the Means by which they have Been Overcome in a New French Installation

By A. de Rosen†

THE problem of silencing test houses for turbo-jet engines is, acoustically, analogous to that for test beds for piston engines¹ and² but is more complicated owing to the working conditions of turbo-jet engines.

The very high temperatures and speeds of the exhaust gases raise problems in regard to the materials to be used and in regard to the thermal insulation of the outlet ducts, which make a satisfactory solution extremely difficult.

At the same time, from the acoustic point of view, theoretical calculations and results of laboratory tests on models may be modified by the variation in the speed of propagation of sound in the heated gases.

Nevertheless, by analysing qualitatively the influence of all these factors, it is possible, with the experimental data which we have obtained in regard to the silencing of test houses over a period of ten years, to prescribe methods of silencing test houses for turbo-jets with a sufficient degree of accuracy.

The attenuation of noise, resulting from the acoustic treatment at the test house installation for turbo-jets at Le Bourget,§ comprising three test beds for engines of different types, has made it possible to verify these estimated results.

A description and a detailed table of the results of these measurements are given later in this paper.

CHARACTER OF NOISE PRODUCED BY TURBO-JETS

The noise produced by turbo-jets has two distinct sources

- (a) The noise produced at the intake.
- (b) The noise produced at the jet outlet.

Noise produced at the intake

The spectrum of the noise produced at the intake shows particularly high levels in the case of the high frequencies, with a fundamental frequency which depends on the number of blades and the speed of the compressor.

This frequency varies a little according to the type of turbo-jet actually being considered. The maximum intensity amounts to between 125 and 135 db/s per octave for frequencies above 2,000 cycles per second.

It is possible to establish for a specific turbo-jet a relation between the sound intensity and the speed or thrust of the engine.

Noise produced at the exhaust tube

The noise produced at the jet outlet has a

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more uniform spectrum and includes a high level of intensity for the low frequencies. Here again, however, the spectrum and the intensities differ according to the type of turbo-jet and their position in the engine room, the value of the thrust and also the shape of the exhaust tube.

If the spectrum is analysed in narrow bands it is seen that there is a variation of intensity at certain frequencies, amounting to ± 3 to 4 db.

The jet pipe noise is caused by turbulence of the gases inside and particularly to shock waves produced at the outlet of the jet pipe.

This last hypothesis is verified by the following consideration: the maximum intensity of noise is found to be at between 45 deg. to 60 deg. to the axis of the jet pipe which corresponds to the direction of the propagation of shock waves.

In addition, however, the intensity of the noise depends on the flow conditions of the gases and an improvement in these may result in a decrease in the intensity of the noise produced for a given thrust.

For thrusts of from 3,500 to 4,950 lb. the intensity of the spectrum amounts to between 125 to 130 db. per octave, in the region of 100/200 c/s with a certain falling off in the high frequency zone. This falling off, however, only occurs for the type of engine running relatively slowly since for the others the intensity increases progressively towards the higher frequencies.

The total intensity of the noise produced at the exhaust (W/sq. cm.) is approximately proportional to the 7th to 10th power of the speed of the exhaust gases and amounts to 140 db.

For certain types of jets having speeds of the order of from 10,000 to 12,000 r.p.m. the increase in the intensity of the high frequency noises, as a function of the speed, is twice as great as that for low frequency noises. For jets working at speeds of 5,000 to 6,500 r.p.m. the increase in the total

intensity appears to be uniform for the whole spectrum.

These indications, however, are only valid, within relatively narrow limits, if the engine is running between 60 per cent and 90 per cent maximum power.

The relation between the intensity and the speed of the gases or of the thrust is given by the following formula:

$$I = C + (70 \text{ to } 100) \log \frac{V}{V_0} \text{ db.}$$

Where V_0 = chosen reference value for the speed C = a constant

In order to make calculations for the silencing of test beds, it is necessary to add to the noise produced at the outlet of the exhaust tube, the noise produced in the acoustic installation itself which depends on the speed of the gases through this.

For silencers having a diameter from 3 ft. to 5 ft. the speed of the exhaust gases through the silencer has a certain influence on the residual noise outside the test bed.

It is advantageous, therefore, to reduce the speed of the gases through the silencing installation both from this point of view and from the point of view of losses due to back pressure.

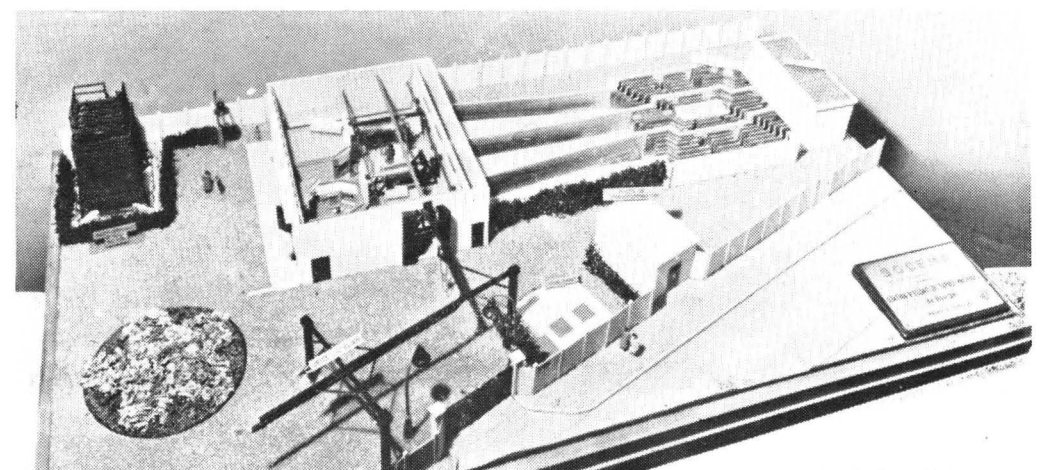
Acceptable noise intensities

Since the silencing of the test house installation depends not only on the characteristics and form of the acoustic installation proper, but also on the general layout of the building, its method of construction and the running conditions of the engine and the gas flow, the design and execution of the silencing should not be separated from the general constructional problem, as is often the case. This practice usually results in a compromise solution of which the efficiency is doubtful, since the desired result can only be achieved if all aspects of the problem are considered together. If it is appreciated that the acoustic insulation value of the building elements should be in line with the attenuation obtained in the acoustic installation proper and that in accordance with the law for the addition of noise intensities it is useless to reinforce or dangerous to weaken one part of the work above or below the mean value, it is equally indispensable to study the layout of the acoustic installation taking into consideration the flow of gases and air. However, the acoustic efficiency of an installation is often in inverse proportion to its aerodynamic characteristics.

The true solution can only be found in a satisfactory compromise, the influence of flow resistance in ducts with bends being usually greatly exaggerated.

It is common practice to present the problem to the civil engineer in accordance with a certain general arrangement and then to ask the acoustic engineer to arrange for the silencing, but this practice runs a grave risk of achieving only costly and mediocre results.

Model of the silenced installation at Le Bourget



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† Director of the Acoustic Dept., Les Travaux Souterrains, Paris, formerly Consulting Engineer to the E.R.A.T. of Ministère de l'Air.

§ The special arrangement of the splitters used for the Test Houses at Le Bourget is fully covered by British Patents Nos. 504795, 520757, 614404 and 30019 46 by the Cementation Co. Ltd., who were responsible for the silencing of the Test Houses of The Bristol Aeroplane Co. Ltd., also referred to in the paper.

§ Built by S.O.C.E.M.A. on behalf of the Ministère de l'Air at Le Bourget.

There is an essential difference in studying the acoustic problem and that of the strength of materials from the point of view of civil engineering or mechanical engineering and this difference has a considerable influence on the spirit with which the problems are approached both during the design period and during the actual construction.

In effect, while in the case of all problems regarding the strength of the materials which decide the characteristics of civil engineering work, one can calculate with factors of safety in relation to the elastic limits, factors which have been chosen from the results of wide experience, when working with acoustic materials, one works always near the limit, since the adoption of factors of safety of the same order would result in an unwarranted increase in the quantities of materials required for the job. In this sense the analogy with aerodynamic problems is complete, each project being considered as a particular case both as regards the characteristics of the motors tested and the external conditions and the general surroundings of the installation.

From the acoustic point of view, the determination of the efficiency of this or that acoustic treatment is further complicated by the fact that the attenuation of noise in an installation can vary to a considerable degree, according to the type of engine tested and its r.p.m. This has been found to be the case both for the test beds at Bristol, Sigma and for American test houses.

Another source of variations in the results arises from errors in the measurements and above all the very important variations in acoustic pressure at all frequencies which is found in the space in the immediate vicinity of propellers and engines.

The experimental data are not conclusive unless they have been obtained from actual installations and not on models in the laboratory, and on the other hand, theoretical calculations require to be interpreted and this is not possible except as a result of long experience.

One of the supplementary problems in regard to the silencing of test houses is the determination of the level and the composition of the spectrum of the acceptable residual noise outside the test house, which depends on the location of the test house in respect of other buildings and the character of these buildings: namely industrial or dwelling houses.

The determination of this level and of a suitable spectrum presents great difficulties which M. Baron, Engineer of the E.D.F., has explained in his paper on 'The possibilities and limitations of objective measurements of noise' recently presented to the French acoustic group.³

We cannot in this paper go into this question in the same degree of detail and we are therefore only proposing to define certain conditions for the purpose of establishing specifications. These proposed conditions are based on the practical experience of results observed on some 120 test houses silenced by our methods and also on the examination of results obtained from abroad, particularly in America.

These conditions consist in practice of achieving the following results, which have been verified for the test houses at Le Bourget:

- (a) The residual noise from the intake at 60 ft. does not interfere with the operation of a system of control by means of loud-speakers at a goods yard.
- (b) The residual noise on the axis of the exhaust is no longer perceptible in a quiet street at a distance of 250 yd.
- (c) The residual noise in an office with doors and windows shut, at a distance of 60 ft. from the test house, is no longer noticeable.

Similar results have been measured at the test house of Sigma at Venissieux with a Pratt and Whitney 1,200 h.p. engine.²

Owing to the fact that the subjective effect of the noise does not depend only on its absolute intensity, but also upon the distribution of the in-

tensity over the spectrum (that is to say, in respect of the frequency) it is insufficient and dangerous only to specify a noise level, or the attenuation to be obtained in an installation, by a single value expressed in decibels, or in phons—representing in the latter case the overall reduction of the intensity.

This latter practice, which is often adopted, has recently been unanimously condemned by a committee of acousticians concerned with the international standardization of measurements of noise who refused for the same reason to define the term 'the mean attenuation' of a building element in decibels or in phons, without reference to the spectrum of the noise.

An indication of the overall reduction of intensity is therefore necessary but only constitutes one of the characteristics of a silencing installation which has to be completed either by an indication of the attenuation as a function of frequency, or by the assessment of the intensity, as a function of frequency, of the residual noise outside the test houses, if the noise source is known and is constant.

Standards of Intensity

(a) **Overall attenuation of the intensity in decibels or in phons:** This last value tends in practice to be debatable since the determination of the intensity of a noise in phons is subject to serious errors.³

(b) **Surface Index:** The Surface Index is the proportion of the ground surface outside the test house for which the intensity of the noise exceeds a certain level, chosen arbitrarily. If for two test houses *A* and *B*, one considers outside these, Areas *S_a* and *S_b* for which the residual noise level is *X* db, the ratio *S_b/S_a*, is called the Surface Index; the area *S_a* being taken as the reference level. The choice of this index is justified by the fact that other conditions being equal the number of persons residing or working in the vicinity of a test house can be considered as being proportional to the surface area of the ground. The Surface Index perhaps may eventually be replaced by an index of distance which represents the ratio of the distances from *A* and *B*, at which the same noise level is obtained.

The above two criteria are only applicable to the influence of the overall noise level, and as far as the objective measurement of this is concerned may be considered as exact.

Spectrum Standards

(a) The attenuation of the noise in the silencing installation in db./Octave or db./cycle.

(b) The spectrum of the residual noise outside the test house in db./Octave or db./cycle.

The composition of the spectrum of the noise has a much greater influence on the aural sensation of that noise than its absolute level.

Experience has shown that the degree of annoyance depends essentially on the shape of the spectrum, particularly on the intensity of the medium and high frequency sounds, a condition which is not sufficiently taken into account by measurements in phons.

Value of the spectrum for the residual noise outside the test houses should decrease at the rate of 5 to 7.5 db./Octave, above the octave of 50 to 100 c/s or 37.5 to 75 c/s, assuming that in this latter region the maximum is of the order of 90 to 100 db.⁴

Intelligibility test

The character of the spectrum for the residual noise recommended as the result of the experimental data which we have been able to consider does not allow of the degree of annoyance being expressed by a single value.

This deficiency is partially made good by the intelligibility test for speech developed in the United States⁵ which enables one to evaluate the

percentage of separate words understood by a listener, placed at a predetermined distance, in the presence of the noise.

The percentage of words understood depends on a value termed 'the Index of Articulation' defined as the ratio of the surface of the spectrum of the speech masked (between 250 to 6,500 c/s) by the disturbing noise, to the total surface contained between the minimum and maximum limits of intensity of the speech, db/cycle/sec. over the same range.

These minimum and maximum limits can be defined for different conditions of hearing; namely, the distance of the listener and the mean intensity of the voice, for example:

Soft voice	Total R.M.S.	57 db. at 1 metre
Normal voice	" "	63 " " "
Loud voice	" "	69 " " "

The Index of Articulation is higher or lower according to whether the masking noise, in our case the residual noise of the test houses, comprises less or more medium and high frequency sounds.

A minimum value of 40 per cent is necessary for this index to give satisfactory understanding of loud speech at a distance of 3 ft. The sensation of annoyance during working hours being often estimated by the ease of understanding of speech, it is evident that this test is, if not an absolute criterion, at least a very decisive indication of the conditions requiring to be fulfilled and the efficiency of the silencing installation.⁶

One may consider on occasions, however, that the residual noise levels have a higher Index of Articulation than less loud noises of which the spectrum comprises a great proportion of medium and high frequency sounds.

Thus the residual noise from test house R2 is 91 phons at 90 yd. with an articulation index of 38 per cent (thrust 5,000 lb.) while that of test house H10 may be 87 phons, with an articulation index of only 3 per cent (thrust 3,000 lb.).

At the same distances and for the same powers the characteristics of the Le Bourget test houses are respectively 80 phons and 68 phons with indexes of 66 per cent and 90 per cent.

It should be noted that the value of the index depends on the reference level of the speech. Thus an index of 40 per cent, for an intensity of 'loud' speech of 69 db. corresponds to an index of 60 per cent for an intensity of 'normal' voice of 63 db. at 3 ft.

An increase in the masking noise results in the necessity of raising the voice in order to be understood which produces an additional fatigue.

The values of the articulation index or the percentage of words understood, indicated in the paper refer always to the level of 'normal' speech, 63 db. at 3 ft. distance.

This test is not the only one which can be used to evaluate the significance of the spectrum of the residual noise.

According to M. Baron, one may choose as the means of comparison the spectrum of a known noise; for example, the normal traffic noise or the ambient noise level in a factory, etc. This done, it remains to determine the acceptable level of masking noise, taking into consideration the degree to which the reference noise remains constant.

The degree of annoyance does not only depend on the subjective intensity of the noise or the distribution of the intensity in the spectrum, but ultimately upon a personal appreciation which means that each case must be regarded as a special case.

The standardization of a tolerable noise level in an industrial zone, is only applicable to certain types of factory; there is only one sure criterion: the residual noise should be inaudible in the presence of the given ambient noise level.

Immediately one allows the perception of a noise of a certain level, the choice of this level depends on subjective judgment, which even if based on a large number of individuals nevertheless has the character of a statistical value which may be debatable in individual cases. Under these

circumstances it is evident that the level can only be fixed within a certain margin and the design of the installation must allow of subsequent modifications.

METHODS OF SILENCING

While one can divide the silencing installations for exhaust ducts of test houses for turbo-jets into two different categories, the silencing of the intakes is generally of the type already become classic, namely absorption by splitters.

Silencers (detuner)

Silencers of this type generally consist of a metal tube lined on the inside with absorbent material either with or without expansion chambers.

These silencers, of which the principle is derived from the silencers for ordinary motor cars, are generally characterized by a poor acoustical effect and very high speeds of the gas flow into the free air giving a corresponding noise at the outlet.

The gases are not cooled to any appreciable extent during their passage through the silencers. The residual noise levels from such installations measured at a 100 yd. distance are of the order of 85 to 100 dbs. at 200 c/s and vary between 65 and 85 dbs. in the region between 400 and 200 c/s.

For the higher octaves the intensity is 50 to 72 dbs. With the best of such systems the intensity at 100 yd. is 87 phons but with an articulation index less than 3 per cent, at 'normal' voice level, which confirms the very high intensity in the part of the spectrum affecting the comprehension of the human voice, that is to say from 250 to 6,800 c/s.

The intensity of the residual noise is higher than 60 to 65 dbs. in the whole of the zone above 400 c/s for a thrust of 4,850 lb.

A peculiarity of these silencers for exhaust ducts is that on account of the speed of the gas at the outlet the radiation of noise is not uniform and gives a pronounced maximum at 45 deg. or 60 deg. to the axis.

It should be noted that the residual noise from test houses with silencers, even for thrusts of 3,300 lb. exceeds 90/95 dbs. in the 50/200 cycles range and does not drop below 45/50 dbs. up to 8,000 cycles.

These values apply at a distance of 75 yd. The Index of Articulation in this case is practically nil and one must consider the residual noise will cause annoyance even at a distance of half a mile.

Silencing of Exhaust by Means of Absorbent Splitters

The second method of silencing the exhaust of turbo-jets consists of providing outlet tunnels with absorbent splitters, a method derived from the silencing installations for test houses for piston engines.

This method gives far superior results to those obtained with detuners, particularly in regard to frequencies between 400/6,800 cycles, i.e. precisely in the frequency range of sounds which interfere with the spectrum for the human voice.

The use of this method necessitates appreciable cooling of the exhaust gases, which is effected by entraining fresh air into the exhaust tunnel.

One should, however, distinguish between silencing installations of this type in which use is made of the obsolete straight splitters and those employing splitters with bends and expansion chambers and in which some sections of the splitters are staggered in respect to the other sections.

The attenuation along straight absorbent splitters may be calculated by various methods, as for example by the following formula, which gives satisfactory results for the whole spectrum

with the exception of the middle frequencies, for which the values are too high:

$$\Delta I = \frac{5 \cdot 46 \cdot 10^3 \cdot a \cdot \gamma (\beta^2 + \gamma^2 - a^2)^{-\frac{1}{2}}}{e} \text{ db./m.} \dots (1)$$

where

f = frequency in cycles/sec.

c = speed of sound in cm./sec.

a, γ = parameters of pressure distribution which are a function of the spacing of the splitters, the frequency and the acoustic impedance of the splitters.

$\beta = \frac{e \cdot f}{c}$ where e = the net spacing of the splitters, in cm.

ΔI = attenuation in dbs./metre.

with the limiting conditions $a < \beta$

$$\text{and } d \geq 3 \sqrt{\frac{\lambda}{r}} \dots \dots \dots (2)$$

where d = thickness of the splitters in cms.

λ = wavelength of the sound in cms.

r = flow resistance of the material forming the splitters.

Equation 2 enables one to determine the theoretical minimum thickness of the splitters as a function of the properties of the absorbent material used. The application of the formula is limited to non-rigid porous materials.

The sound attenuation of straight splitters depends upon:

- (a) The ratio of absorbent surfaces to the net section of the space between splitters and also the absolute value of this spacing.
- (b) The properties of the material used.
- (c) The general arrangement of the installation and the layout of the splitters.

The curve of attenuation as a function of the frequency has a maximum value in the middle frequencies, the position depending on the spacing (e) of the splitters, and falls off sharply at low and high frequencies.

The low values for the attenuation at the low and high frequencies, relative to the surface area of absorbent material led to the use of splitters having sharp bends, used for the first time for the Bristol test houses (this layout is covered by British and foreign patents).

Since the completion of these test houses during the years 1937-1944, the Sigma test house at Lyons in 1942 and a straight splitter test house in Paris, the writer has been engaged in extensive research in connexion with the design of the silencing installation for a Wind Tunnel for the E.R.A.T. at Toulouse,⁷ as a result of which further modifications have been evolved with the object of increasing the sound reduction at low and high frequencies and of preventing the formation of stationary waves in the ducts (observed both on models and full-scale ducts).

The modifications comprise the following:

- (i) Introduction of breaks in the splitters with bends which serve to form expansion chambers.
- (ii) The staggering of certain sections of the splitters.
- (iii) Variations in the length of the splitters and interruptions in the height at certain points to reduce the formation of stationary waves.

A systematic investigation has made it possible to determine the best arrangement of the bends, both from the acoustic point of view and in regard to back pressure effects which can be kept within reasonable limits (in certain cases about 3 per cent in terms of h.p.), so that the losses due to back pressure in the splitters become of less importance than the losses which normally occur in the engine room itself.

It should be noted in this connexion that these losses may even be reduced by a suitable layout and that the dimensions to be given to the exhaust ducts depend on the natural expansion zone for the air-flow behind the engine.

It is not therefore necessary that the intake and

exhaust ducts should have the same dimensions. On the contrary an unwarranted increase in the size of the exhaust duct will lead not only to unnecessary expense but may also result in incomplete removal of the gases from the engine chamber.

By utilizing such arrangements of the splitters one can fix the ratio of the area of absorbent material S_a to the net free cross section of the duct in the region of $S_a/S_n = 35$.

With straight splitters to obtain the same acoustic result it would be necessary to have a much greater value for the ratio S_a/S_n or alternatively if this is kept to 35 only inferior results will be obtained.

It may be noted here in passing that with this same value of 35 for the ratio S_a/S_n , the splitters with bends used for the Le Bourget test house give results 15 to 20 dbs. higher for the whole spectrum than would have been obtained with straight splitters and at the same time complete removal of the gases is achieved.

The Index of Articulation at 100 yd. for the same thrust, increases from 38 per cent for straight splitters to 68 per cent for splitters with bends with a reduction in thickness of the splitters of 33 per cent.

Any further increase in this ratio would not be worth while, since the medium and high frequencies being already sufficiently absorbed, to achieve a corresponding attenuation of the low frequencies would only result in a disproportionate increase in cost.

Where the running conditions give rise to even more severe conditions than mentioned above, the most advantageous solution may lie in adjusting the general layout so that the test house is moved away from neighbouring buildings.

Intake

The silencing of intake ducts for fresh air does not present the same problems as is the case with exhaust ducts.

Use may be made of straight splitters, or splitters with bends, installed in a duct above the test house, but here again if splitters with bends are used, appreciably better results may be obtained, particularly with regard to frequencies above 1,000 cycles.

SILENCING OF THE TEST HOUSE INSTALLATION FOR JET ENGINES AT LE BOURGET

Requirements

The requirements in regard to silencing for the test house installation for jet engines at Le Bourget, comprising three test beds arranged side by side, were specified by a spectrum of the attenuation to be attained expressed in decibels per octave.

The most essential requirement, however, was to bring the residual noise down to such a level and with a suitable spectrum that it did not interfere with the operation of a loud speaker system used to control the marshalling yard at the Le Bourget station. This loud-speaker system is located at about 50 yd. from the test house.

A careful investigation of the problem indicated that by making use of the intelligibility test, we should aim at a noise spectrum at the outlet of the exhaust having an intensity of 90 to 100 dbs. at the low frequencies decreasing by about 6 db. per octave towards the high frequencies.

A study of results of different systems of silencing led us to rule out entirely the use of a detuner.

Description

We have chosen for the silencing installation of the exhaust a layout for the splitters having bends and expansion chambers.

The necessary cooling of the exhaust gases is achieved by entraining a quantity of fresh air equal to approximately twice the quantity of the exhaust gases.

The silencing installation for the intake is situated above the engine room and serves the three test beds together.

This installation comprises a central intake with straight splitters followed by an expansion chamber leading to two systems of splitters with bends which in turn lead to a common duct connected to the engine room through three openings arranged on the axes on the test beds.

In order to avoid the formation of stationary waves at certain frequencies, the length of the inlet passages is varied.

This precaution was also taken in respect of

the silencing installation for the exhaust duct.

From the point of view of the propagation of the sound outside the test house, it was considered advisable to avoid the construction of a tower which might have led to the transmission of the noise over large distances.

The outlet of the exhaust terminates in a bend which does not exceed 15 ft. in height. The high frequency sounds being attenuated by the silencing installation to the extent that their intensity does not exceed the ambient noise level, are directed upwards.

The propagation of the low frequency sounds takes place in spherical waves with an effective

decrease of the intensity radiated in a horizontal direction, conforming to theoretical forecasts.

Results obtained

Definition: The overall noise level has been measured both in decibels and phons, as also the noise spectra, inside and outside the test house up to a distance of 390 yd. from the exhaust.

The measurements have been made on four different occasions with noise meters of different types.

Even if the measurement of the noise inside and outside the test house does not present any difficulty, the calculation of the attenuation of the

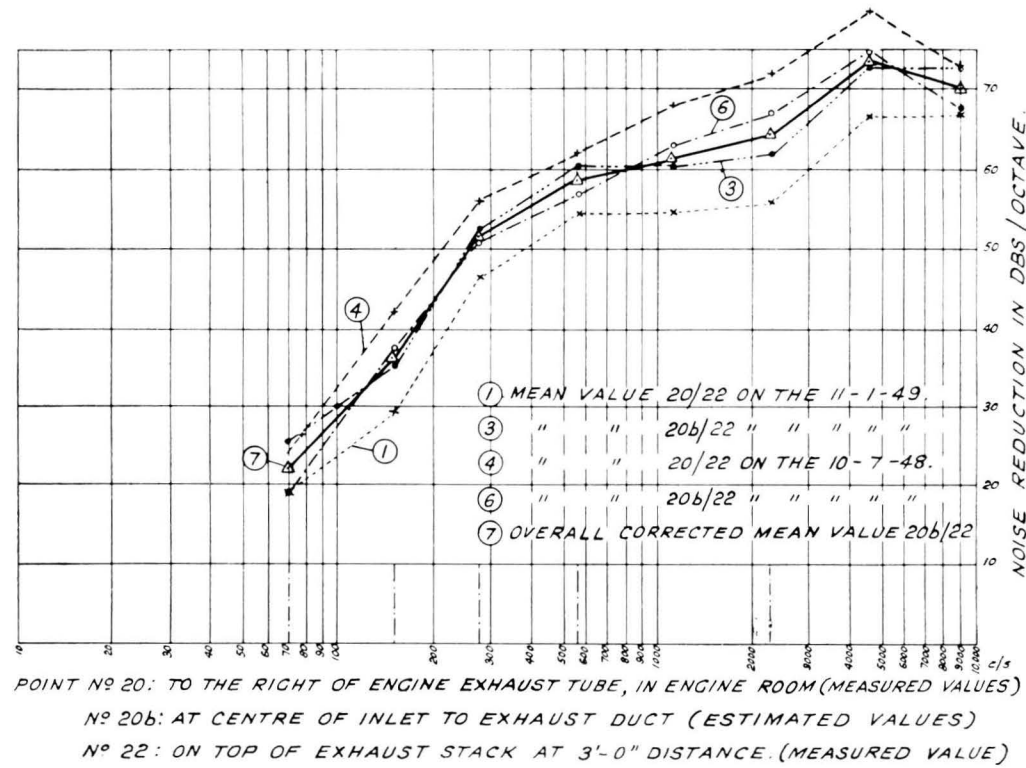


Fig. 1.—Noise reduction between engine room and outlet from exhaust duct, test houses at Le Bourget

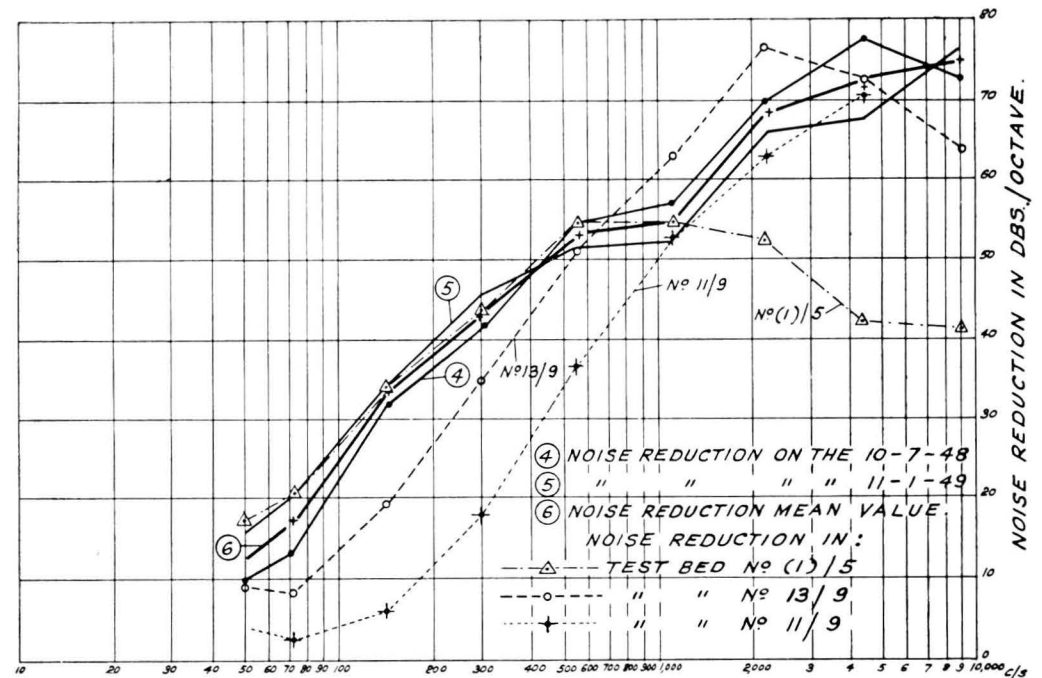


Fig. 2.—Noise reduction between engine room and entrance to air intake, test houses at Le Bourget

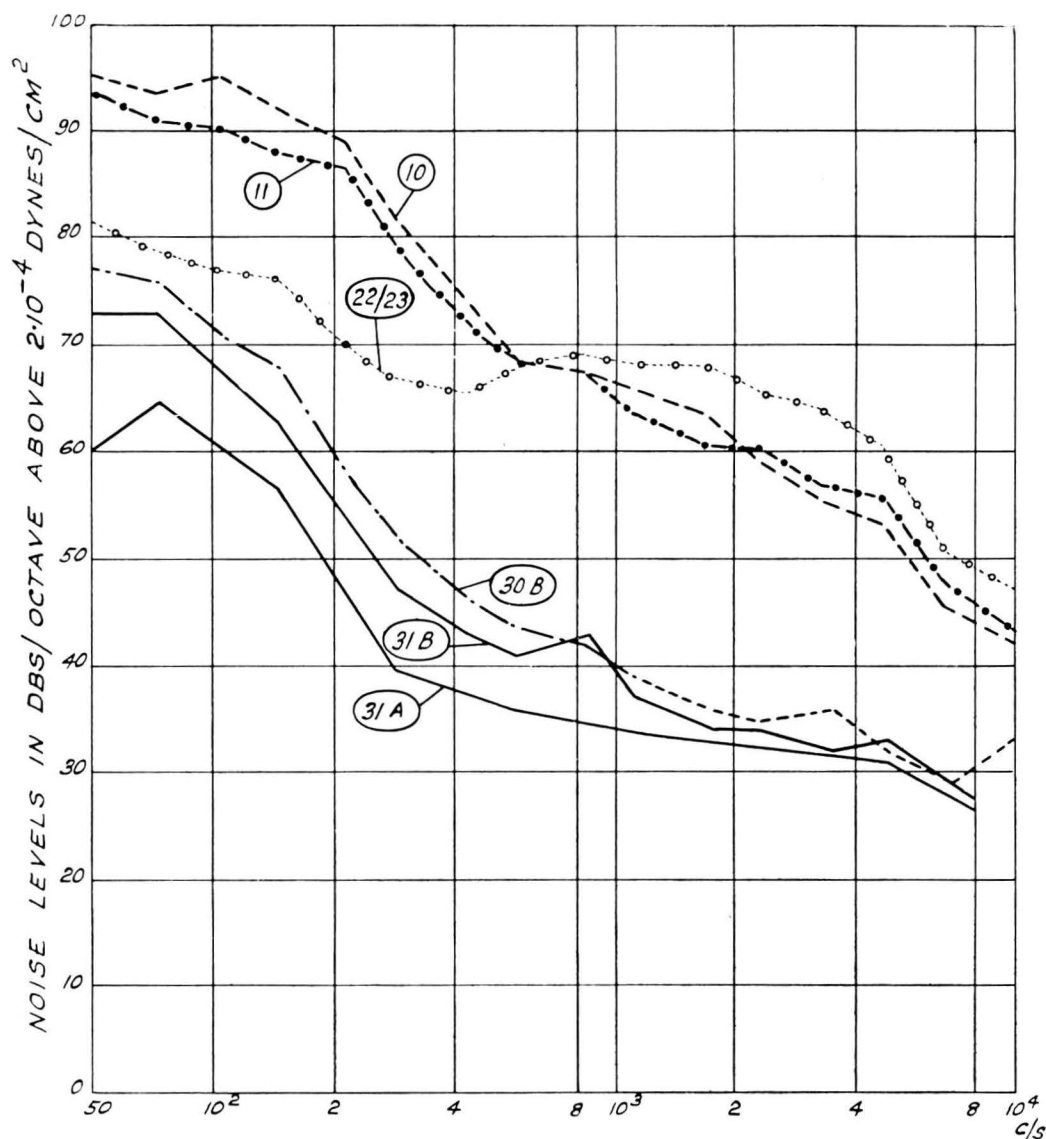


Fig. 3.—Noise levels outside jet test houses at thrusts of 910/1,650 kg., test houses at Le Bourget
31A: at 113 m. from exhaust, jet position A (10.7.1948), thrust 1,650 kg.; 31B: jet position B (11.1.1949), thrust 1,650 kg.; 30B: at 60 m. from exhaust, jet position B (11.1.1949), thrust 1,650 kg.
Test houses with detuners
10, 11: at 76.5 m. from exhaust, thrust 1,340 kg.; 22, 23: at 90 m. from exhaust, thrust 910 & 1,640 kg.

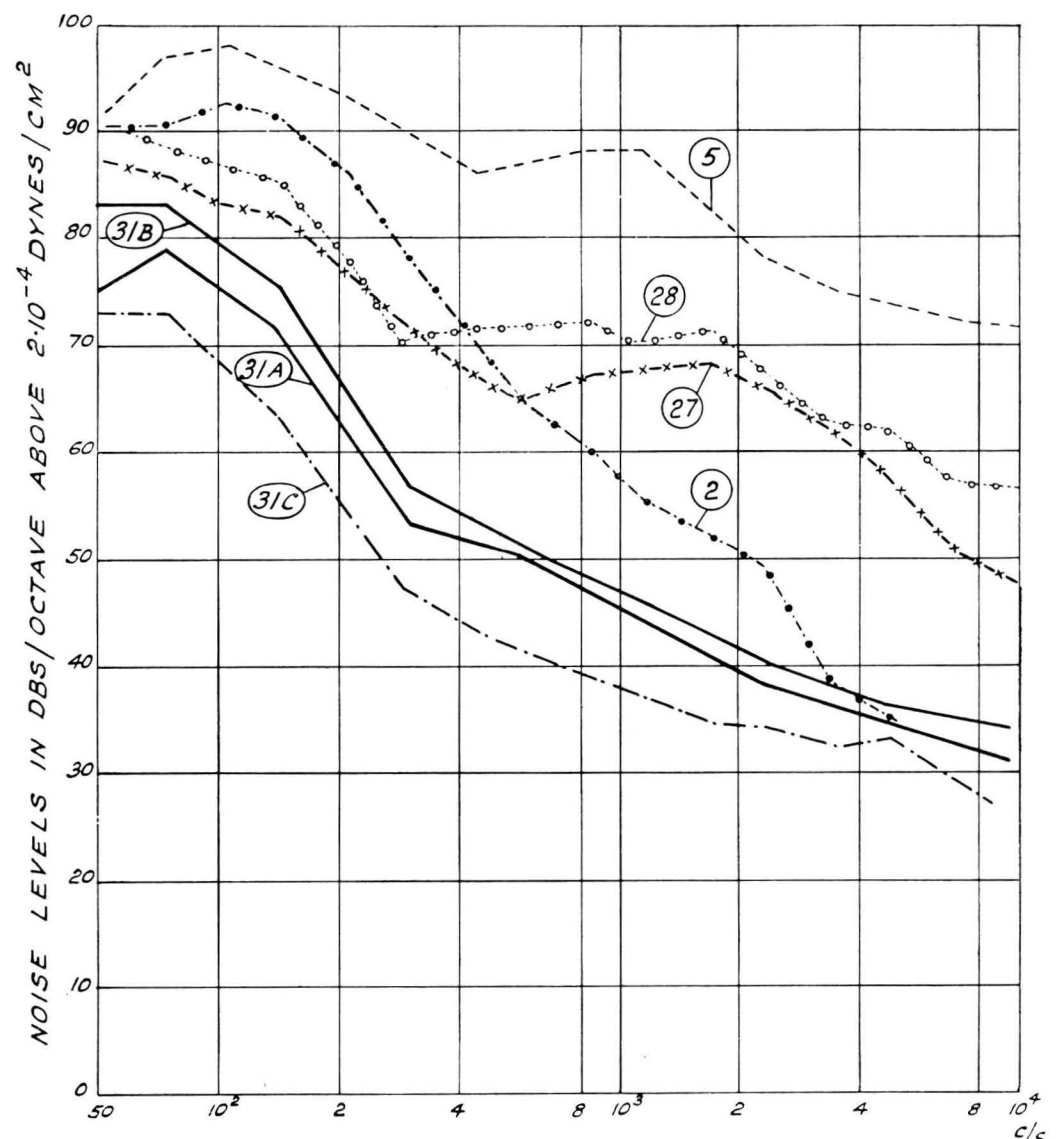


Fig. 4.—Noise levels outside jet test houses, thrusts 2,200/2,270 kg., test houses at Le Bourget
31A: at 113 m. from exhaust, jet position A (10.7.1948), thrust 2,200 kg.; 31B: jet position B (11.1.1949), thrust 2,200 kg.; 31C: (11.1.1949), thrust 1,650 kg.
Test house with straight splitters
2: at 90 m. from exhaust, thrust 2,270 kg.
Test house with detuners
5, 27, and 28: at 90 m. from exhaust, thrust 2,270 kg.

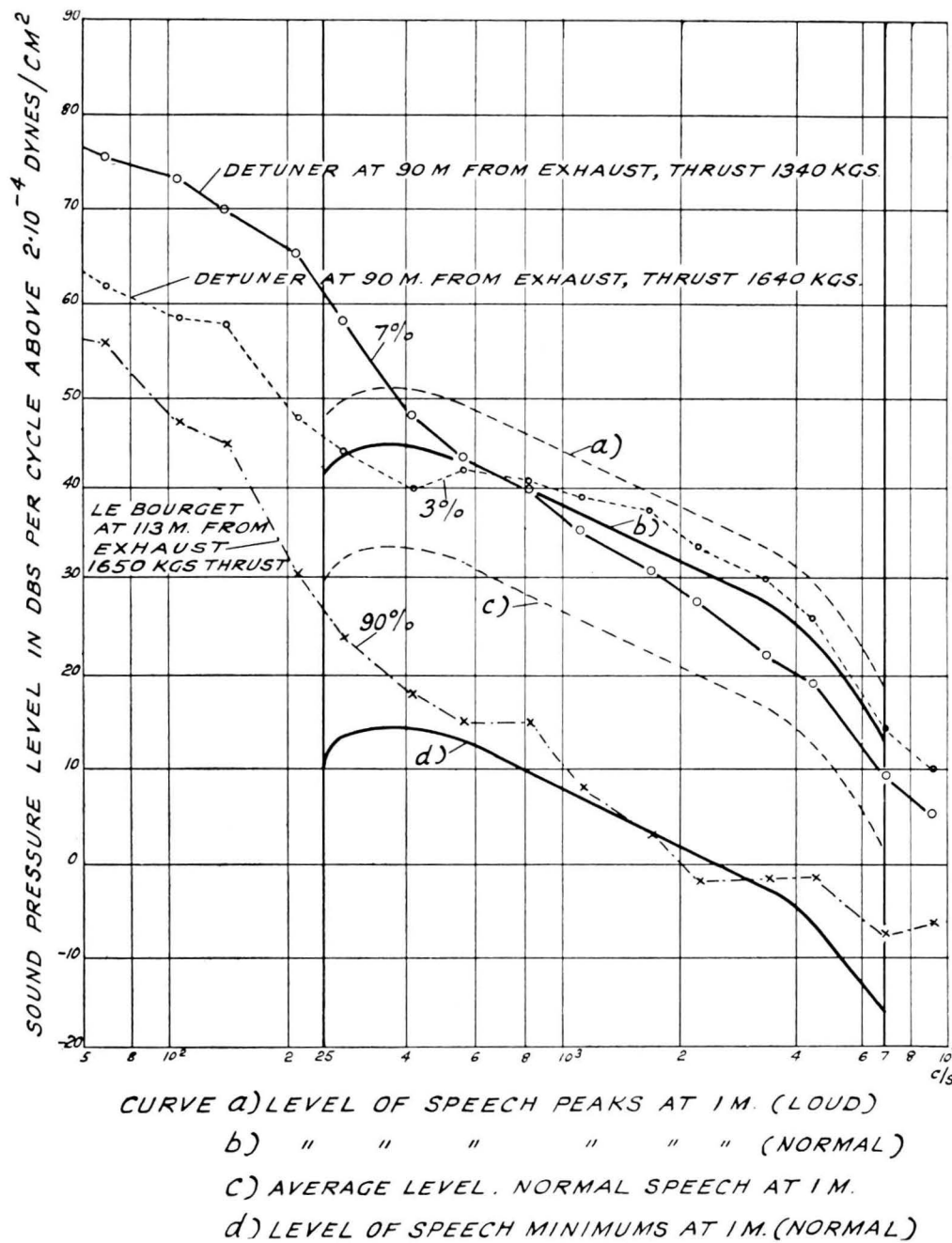


Fig. 5.—Articulation Index for noise levels outside jet test houses at 100 m. from exhaust, engine running at 1,340/1,650 kg. thrust
 Reference level: 'normal' speech at 1 m. = 55 db. above $2 \cdot 10^{-4}$ dynes/cm².
 Le Bourget at 113 m. from exhaust = 90 per cent at 1,650 kg.
 Test house with detuner at 90 m. from exhaust = 3 per cent at 1,340/1,640 kg.

silencing installation may lead to different interpretations.

As regards the chosen points of reference, one may particularly define the attenuation of the noise from a test house as follows:

- the difference at a given point between the intensity of the noise without silencing installation and with silencing installation, the jet engine being placed in a test house in each case.
- The difference at a given point between the intensity with the engine running in the open and without a silencing installation and at the same distance with a silencing installation. (This latter definition is the more complete, seeing that it takes into consideration the influence of the engine room itself on the noise emitted from the engine.)
- The difference between a given point in the engine room or the mean value in the engine room and a given point outside the test house.*
- The difference between the intensity at the entrance to the exhaust tunnel and at its exit.

The measurements which were only made after the completion of the installation are in accordance with third definition. At the same time, the calculated results or measurements made in this way can only be approximate in view of the fact that no measurement is possible immediately at the intake to the exhaust tunnel.

It is possible to estimate the intensity at the entrance to the exhaust tunnel from the measurements made at different positions in the engine room and under different running conditions.

* The sound field in the engine room is non-isotropic and non-homogeneous.

The precision of these calculations can only be verified by the order of magnitude of the variations from the mean calculated value.

It is evident that definition (b) will give, other things being equal, a less favourable result than the other methods owing to the fact that the intensity of the noise of the jet engine is increased when this is running in an enclosed chamber even if this chamber is lined with absorbent material.

Consequently, the results indicated below are in accordance with definitions (c) and (d).

The noise intensities were measured by means of different objective noise meters, fitted with either electro-dynamic or piezo-electric microphones and the spectra analysed with octave filters (50 to 12,800 c/s and 375 to 9,600 c/s) or with a narrow band analyser (50 to 10,000 c/s) in order to obtain reliable mean values.

The precision of the measurements depends on the calibration of the noise meters and the stability of the noise.

From the acoustic point of view, the microphones are subject to a variation according to frequency which may be evaluated at ± 3 db. As indicated above, the noise inside the engine room is unstable at certain frequencies with a fluctuation of the order of ± 3 to 4 db.

For certain measurements, fluctuations which were evidently due to the dynamic characteristics of the apparatus occurred of from ± 1 to ± 4 db. according to the frequency.

The mean values were in each case determined for each apparatus with an accuracy of the order of 1 db.

The measurements in decibels or in db./Octave

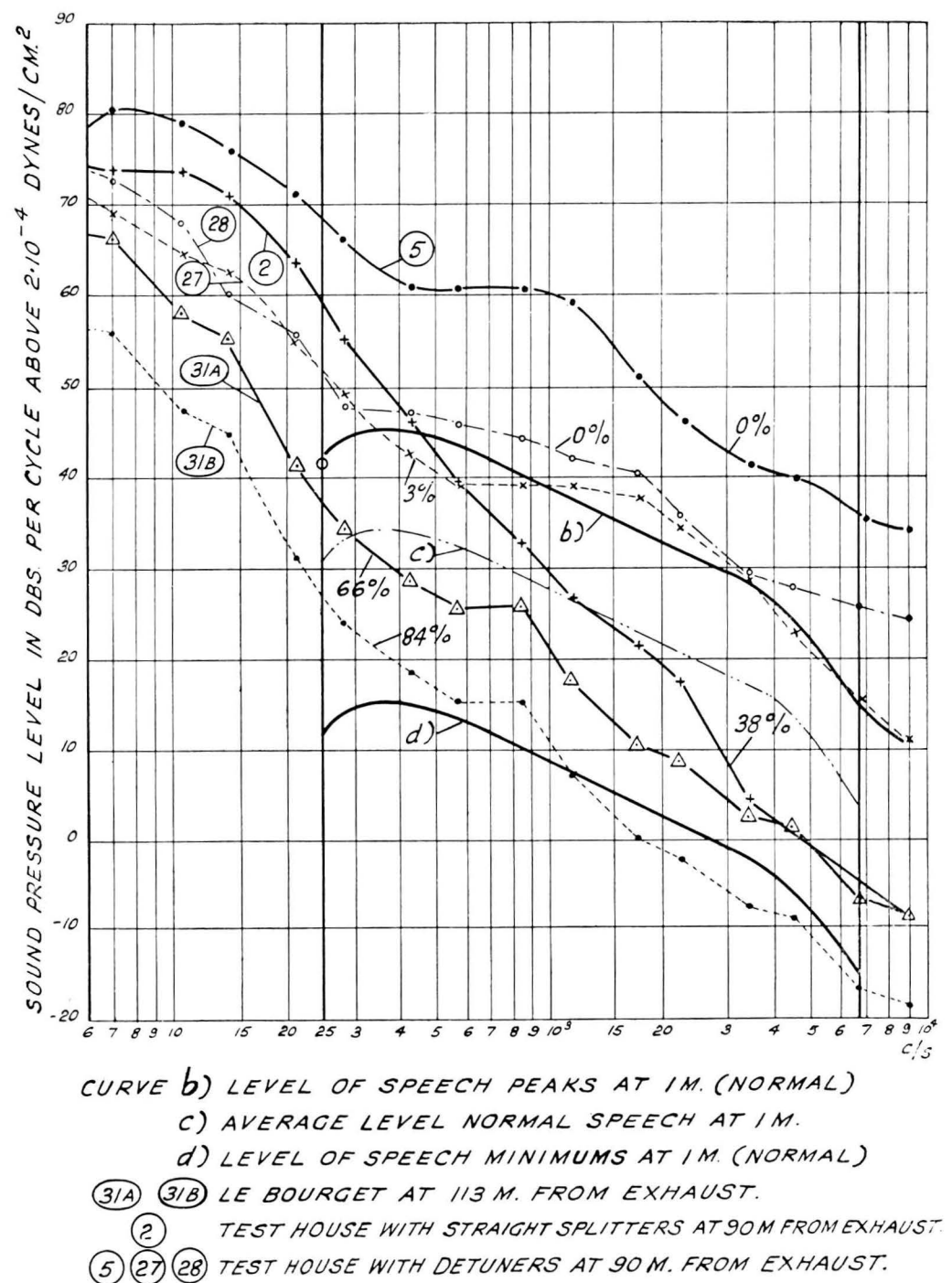


Fig. 6.—Articulation Index for noise levels outside jet test houses at 100 m. from exhaust, engine running at 2,000/2,270 kg. thrust
 Reference level: 'normal' speech at 1 m. = 55 db. above $2 \cdot 10^{-4}$ dynes/cm².
 Le Bourget at 113 m. from exhaust = 66 per cent at 2,000/2,200 kg.
 Le Bourget at 113 m. from exhaust with modified nozzle = 84 per cent
 Test house with straight splitters at 90 m. = 38 per cent at 2,270 kg.
 Test house with detuner at 90 m. = 0 per cent to 3 per cent at 2,270 kg.

were supplemented by measurements in phons with standard '70' and '40' weighting networks.

The results expressed in phons have been corrected after the curves of Barstow, but the subjective sound levels are only given as a general indication, the determination of these values being still subject to considerable differences of opinion.

A discussion of this question has been given in a recent paper by M. Baron, on 'The Objective Measurements of Noise'.

The measurements inside the engine room were made at different points and particularly on the axis of the intake and to the right of the exhaust as well as in the centre of the engine room itself (FIG. 7).

The noise levels outside, as also the spectra, were taken at the entrance to the air intake, at the outlet of the exhaust both on top and at ground level, and at a number of points situated at the side of the test house in the marshalling yard and on the axis of the exhaust.

The comparison of the results measured with the different noise meters has made it possible to estimate the mean values of the sound reduction; the errors do not exceed the errors characteristic of each apparatus.

As is to be expected, appreciable fluctuations in the intensity of the noise immediately at the outlet of the exhaust, that is up to a distance of 5 ft. occurs, but these fluctuations disappear at a distance of 30 yd. This phenomenon is in accordance with the observations we have made on earlier silencing installations which we have carried out and also on the unsilenced test house in America.

The results are given on the attached graphs and also summarized in TABLES I and II.

Articulation Index for normal voice (55 db. at 3 ft.

At 113 m. (120 yd.) from exhaust:
 Thrust: 1,650 lb. I=90 per cent (11.1.49)
 2,200 lb. I=66 per cent
 2,000 lb. I=84 per cent (17.3.49)

Propagation at a distance

For those readers who are not familiar with the measurement of noise in decibels, and the interpretation of noise spectra, it may be interesting to note that the mean attenuation obtained by the silencing installation, relative to positions immediately at the entrance to the silencing installation, corresponds to the attenuation of a solid brick wall of 22 in. thickness.

To the side of the test house, on the marshall yard, the overall noise level is approximately 76.5 phons at 50 ft. from the entrance to the air intake with an Index of Articulation of the order of 68 per cent which corresponds to an average of 80 per cent of separate words understood (the reference level being that of normal speaking at 55 db. at 3 ft. distance).

According to the American measurements, speech with a R.M.S. voice level of 69 db. may be easily understood at 3 ft. distance with an index of 60 per cent.

66 ft. behind this latter point, the overall noise level dropped to 56 phons.

The subsequent propagation of the noise along the axis of the exhaust duct follows very closely the theoretical values calculated on the basis that the attenuation equals $20 \log R/R_0$ where R_0 = the radius of the surface area from which the noise is emitted

R = the distance of the point under consideration from the outlet of the exhaust.

At a distance of 220 yd. approximately from the exhaust the noise with the engine running with a thrust of 4,400 lb. drops at least to 55 phons and is masked by the ambient noise of the surroundings.

On account of the very strong attenuation of the high frequency notes amounting to some 70 db. the predominant frequency in the residual noise is below 100 c/s.

The noise level in the yard of the test houses close to the soundproof doors of the engine room is of the order of 78 to 83 phons, with a predominating frequency between 50 to 100 c/s.

It is interesting to note that the noise level in an office situated approximately 60 ft. from the door to the engine room is reduced to 40 phons. The noise from the engine is practically inaudible.

COMPARISON OF RESULTS WITH THOSE OBTAINED ON TEST HOUSES USING DETUNERS AND TEST HOUSES WITH STRAIGHT SPLITTERS

Graphs are attached showing the noise spectra for the residual noise from test houses using different systems of silencing and these values have all been corrected to the same distance of approximately 110 yd. and under approximately the same running conditions for the engine.

The comparison of these results is summarized in the following table where are indicated the overall noise level in phons, the surface index, the distance index and the index of articulation (see TABLE III).

CONCLUSIONS

The cooling effect on the gases obtained by entraining fresh air corresponds to the estimates based on tests for air flow made on models and on full-sized splitters with bends. The temperature is reduced to approximately 200 deg. C. with

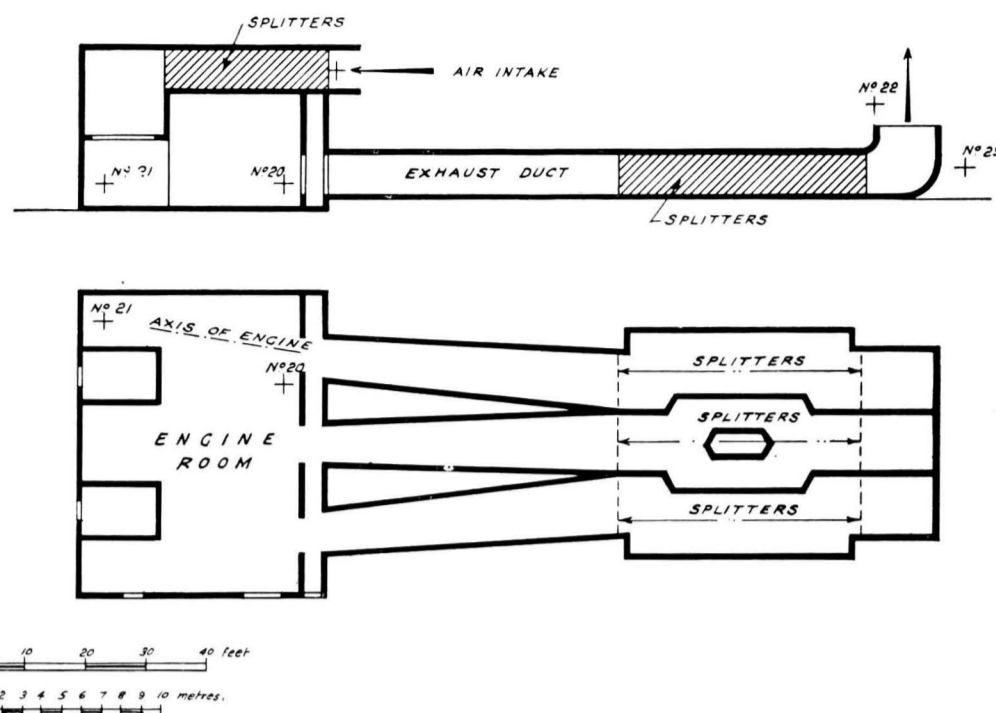


Fig. 7.—Silencing installation of test houses at Le Bourget

TABLE I—ATTENUATION IN DECIBELS/OCTAVE

FREQUENCY BANDS	50 to 100	100 to 200	200 to 400	400 to 800	800 to 1,600	1,600 to 3,200	3,200 to 6,400	6,400
EXHAUST								
(a) Engine Room/Outlet from Exhaust Stack	24	42	56	62	68	72	80	72
(b) Entrance to Exhaust Duct/Outlet from Exhaust Stack	22	36	52	59	62	64.5	74	70.5
Mean Values	±2.25	±0.25	±0.75	±0.25	±1.25	±1.0	±0	±1.5
AIR INTAKE								
Engine Room/Entrance to Air Intake	17.5	33.5	43.5	53.5	55.0	68.5	73	75
Mean Values	±3.5	±1.5	±1.5	±1.5	±2.25	±2.0	±3.0	±1.5

TABLE II—RESIDUAL NOISE LEVELS WITH ENGINE RUNNING AT 2,000 kgs. THRUST

	decibels	phons	
at 30 m. from centre of Exhaust Stack	82.5	78	frequency < 100 ~
at 108 m. " " "	68.5	53.58	" < 100 ~
at 230 m. " " "	61.5	40	" < 50 ~
at 310 m. " " "	55	40	" < 50 ~
In the Marshalling Yard at 17 m. from Air Intake	80.5	76.5	" < 100 ~
In the Test House Office at 26 m. from Test House with doors and windows shut	48.5	40	" < 100 ~

TABLE III

	Overall Noise Level at 90/110 m. PHONS	Surface Index	Distance Index	Articulation Index, normal voice at 55 db. at 1 m.
TEST HOUSE AT LE BOURGET	80	1.0	1.0	> 66.5%
Engine running at 2,200 kgs. thrust	68	1.0	1.0	> 90%
Engine running at 1,650 kgs. thrust	87 to 98	31.5 to 58	1.8 to 7.6	< 7%
TEST HOUSES WITH DETUNERS				38%
TEST HOUSES WITH STRAIGHT SPLITTERS	91	8	2.85	

a weight of fresh air entrained equal to approximately double the weight of the exhaust gases.

Recent research has shown that it should be possible to improve this result, and thus cope with higher gas temperatures.

Since the development of jet engines is likely to lead to gas temperatures of 1,800 deg. to 2,000 deg. centigrade with afterburning it may be considered questionable whether the method of silencing test houses by means of tunnels containing splitters, the only method satisfactory from the acoustic point of view, may still be practicable.

This problem may be solved by making further modifications to the system, such as the injection of water which, while lowering the temperature in the installation, at the same time increases the acoustic efficiency up to 10 db. for the whole spectrum.

The development of engines with greater powers will naturally necessitate an increase in the cross section of the intake and outlet ducts, but an extrapolation is not difficult.

Even if the cost of the test-house installations with splitters with bends is higher than for one with detuners of which the acoustic results will

leave something to be desired, the methods used at Le Bourget present the operator of the test houses with an incomparable advantage in regard to the location of the test-house in inhabited areas. This advantage may well lead to appreciable economies on transport of the engines and the general organization of the test house installation with the factory producing the engines.

We have shown that it is possible to render the noise from a jet engine giving 4,850 lb. thrust, practically inaudible at a distance of 275 to 330 yd. from the exhaust. It is evident, but may nevertheless be useful, to emphasize again that the successful construction of a test-house installation can only result if all the aspects of the problem are considered together on the lines described above. The period of trial and error already passed in the case of test houses for piston engines as far back as 1939, has now also been passed for test houses for jet engines.

The successful results obtained at the test house installation for jet engines at Le Bourget, built in co-operation with M. M. Peru of S.O.C.E.M.A. indicate the progress achieved in French methods since 1939, methods which are equally applicable in other countries.

An American Gas Turbine of Low Power

A Unit Developed Experimentally by the Boeing Airplane Company for Study and Investigation

By H. W. Perry

A LOW-POWER gas-turbine engine developed by the Boeing Airplane Company and the reasons for its evolution were described by S. D. Hage, chief of the company's propulsion development unit, at the annual meeting of the Society of Automotive Engineers in Detroit last January. When the U.S. Air Forces invited proposals late in 1943 for a medium bomber driven by high-speed turbo-jet engines, the development of gas turbines was in such an early stage that not enough practical information was available from manufacturers to meet the needs for designing an aircraft to take maximum advantage of this type of power-plant, so Boeing decided to make a thorough study of the new engine type, developing one of small size to keep the cost of research as low as possible.

This work resulted in 1947 in a turbo-jet engine of simple design believed to be the smallest of the type ever built. It is 29 in. long, without tail pipe, 22 in. in diameter, has a frontal area of 2.2 sq. ft., weighs 85 lb. and develops 150 lb. thrust at 36,000 r.p.m. This engine, designated the Model 500, is adaptable to aircraft, target planes or missiles. Another model (502) is a propeller turbine engine having a secondary free-power turbine, reduction gears and an airscrew shaft. Most of the specifications of dimensions and construction of the two models are the same, but the propeller turbine is 42 in. in length, weighs approximately 150 lb. without accessories, develops 118 to 219 equivalent horse-power at 2,050 to 2,750 airscrew shaft r.p.m. at sea level.

Both engines have a single-stage centrifugal compressor, dual constant-pressure combustion chambers and a turbine which drives the com-

pressor. The compressor is a two-piece aluminium-alloy casing with an integral diffuser and has two tangential outlets and vaned elbows connecting with the combustion chambers. It encloses a two-piece aluminium-alloy impeller unit composed of a 22-blade inducer section attached to the front of the main 22-blade impeller. The compression ratio is 3:1 and the air mass flow is 3.25 lb./sec. at 36,000 r.p.m.

The combustion chambers, which are independent of each other and not interconnected, are made of stainless steel tubing and are of straight-through-flow type. Inside each chamber is a perforated flame tube of stainless steel having a fuel injection nozzle projecting into the centre of the front portion of the flame tube for downstream injection.

The Model 500 (the turbo-jet) has a single-stage and the Model 502 (the turbo-prop) a two-stage turbine. Both turbines are of the axial-flow type 7.28 in. in diameter and consist of stainless steel diaphragms with 27 inserted nozzle guide vanes and rotor disks of special alloy steel with 64 welded solid blades. At the turbine speed of 36,000 r.p.m. the gas temperature is 1,500 deg. F. before the turbine and 1,250 deg. after it. Gas from the turbine of the turbo-jet exhausts through an outer stainless steel casing and fixed inner cone. That of the turbo-prop exhausts into an annular manifold having two outlets.

Fuel is fed into the combustion chambers through a single manifold system at a pressure of 400 lb./sq. in. by a Boeing governor-type fuel pump.

A wet sump system, with pressure feed to the main bearings at 50 lb./sq. in. by a gear-type

pump, provides lubrication in the turbo-jet. The turbo-prop employs a dry sump system with the same type of feed Pump and also a gear-type scavenge pump. Each system is equipped with a high-pressure oil filter.

The turbo-jet is started by a compressed-air starter, but a direct-drive electric starter is used on the turbo-prop. Both engines have two ignition coils and two igniter plugs.

In addition to the compressor-driving turbine, which also drives the accessories, the turbo-prop has a power output turbine rated at a speed of 24,000 r.p.m. and reduction gearing that gives the power output shaft a rated speed of 2,500 r.p.m. Speed of the primary stage is regulated entirely by the fuel flow, while that of the secondary, or power-output, stage is regulated independently by the load and can be varied from stall to maximum safe speed.

The engine is said to start very easily and consistently. After the start is initiated the engine can accelerate from an idling speed of about 10,000 r.p.m. to the full speed of 36,000 r.p.m. in 5 sec. and it develops its rated power in 15 sec.

Rated specific fuel consumption will vary between 1.5 and 1.0 lb./b.hp./hr. depending on the power rating and the degree of refinement of the engine components. Oil consumption is at a rate of 0.5 lb./hr. at cruising speed. AN-F-34 Army-Navy grade of fuel is burned, and the lubricating oil has a viscosity of 60 S.U. sec.

Some important performance characteristics of the gas turbine are compared with those of reciprocating petrol or diesel engines in FIG. 5, where the dotted lines represent two types of extreme load—a grade load and an air-friction load. The solid brake-horse-power curves show that the turbine engine develops considerably more excess power for acceleration than the reciprocating engine for either type of load. The torque curves show that, whereas the torque of the reciprocating engine drops rapidly at low engine speed to zero when the engine stalls, the stalled torque of the gas turbine is double the torque at rated speed, which indicates that the gas turbine engine cannot be stalled.

Curves of specific fuel consumption (SFC) are drawn in solid lines for consumption at full power at any speed and in broken lines for consumption

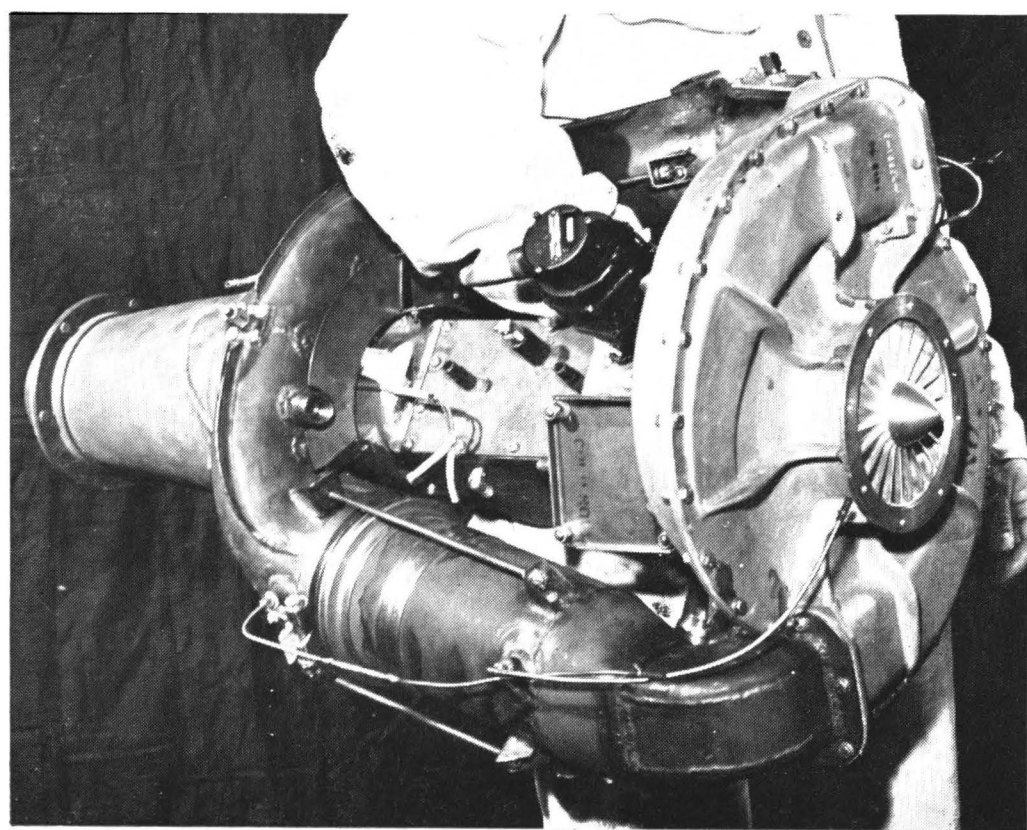


Fig. 1.—The Boeing Model 500 turbo-jet engine developed as a research project weighs only 85 lb. and develops 150 lb. thrust. The overall diameter is 22 in. and the length, without tail pipe, 29 in. The turbine speed is 36,000 r.p.m.

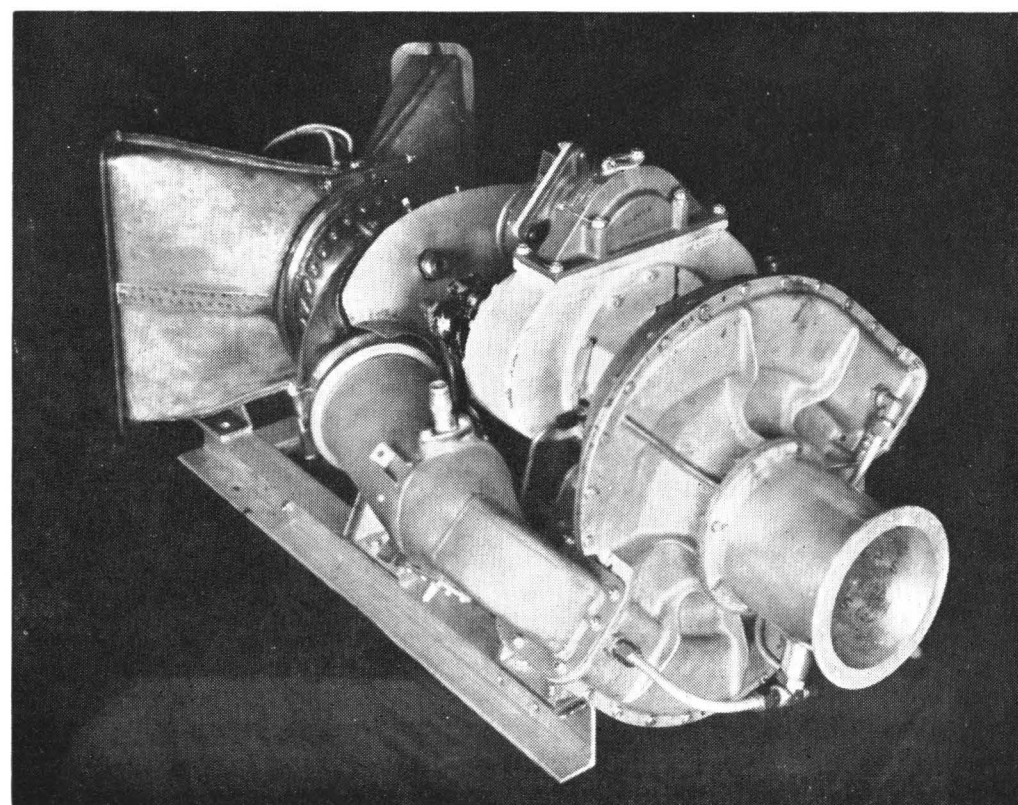
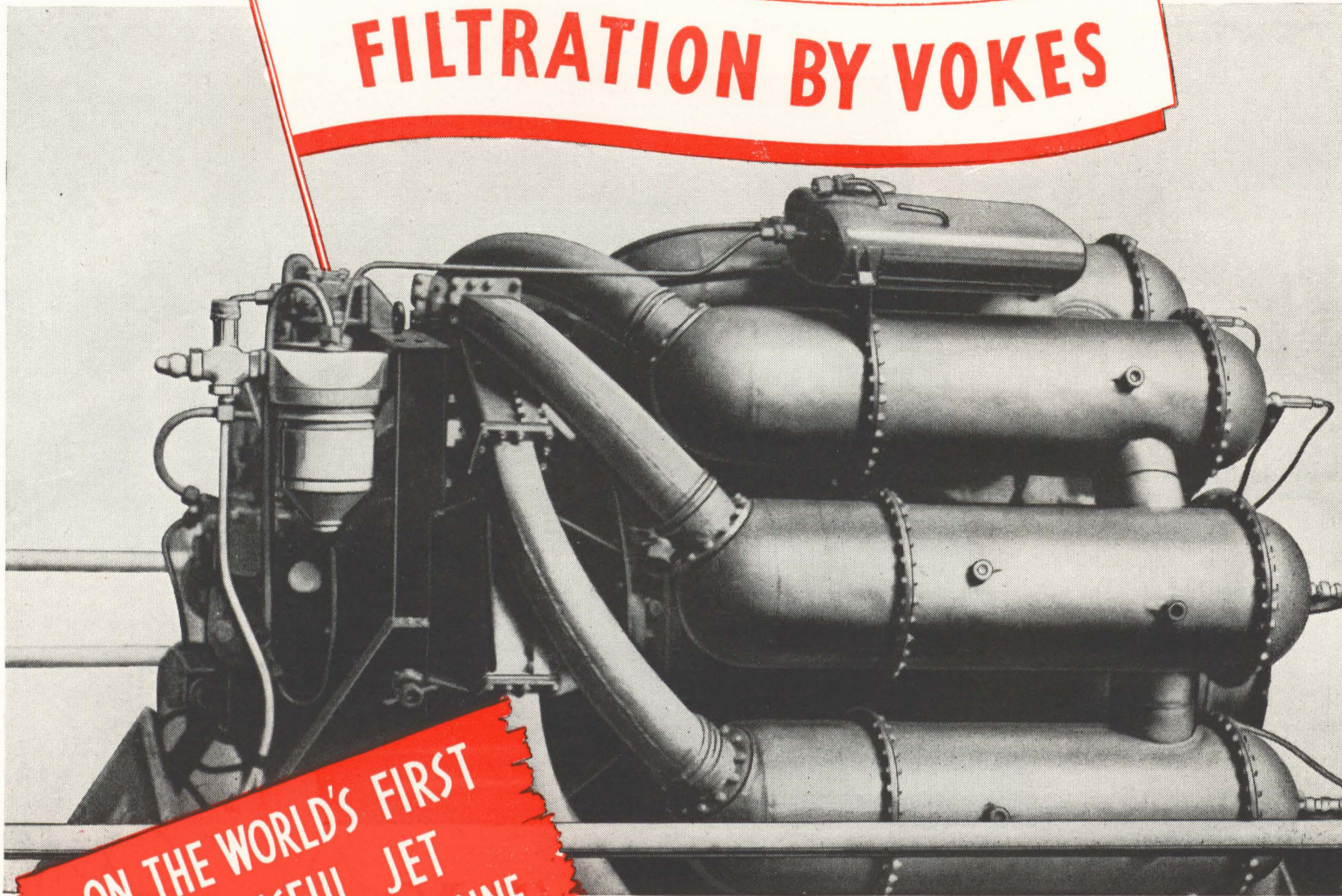


Fig. 2.—Compressor end of the Model 502 turbo-prop engine, which has a secondary airscrew-driving turbine rated at 24,000 r.p.m. and reduction gears that give a rated tailshaft speed of 2,500 r.p.m.

FILTRATION BY VOKES



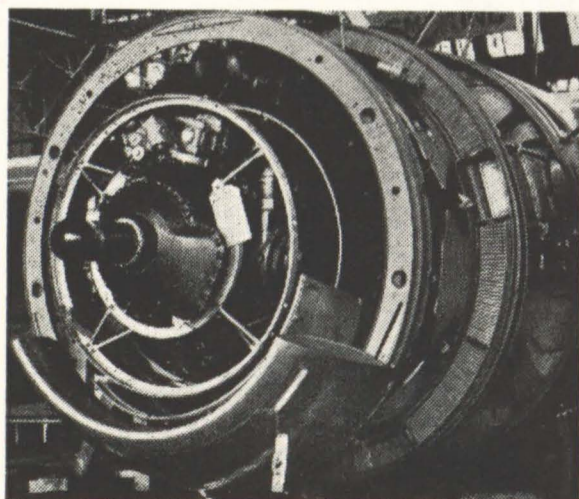
ON THE WORLD'S FIRST
SUCCESSFUL JET
PROPULSION AERO ENGINE

IN THE FOREFRONT OF THE WORLD'S AIRCRAFT FILTRATION DEVELOPMENTS

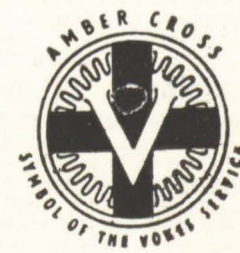
This first Whittle Gas Turbine Jet Engine is now a 'museum piece' . . . indeed when photographed above it was on loan from the South Kensington Science Museum. When considering present day VOKES' filtration in aircraft applications, it is interesting to recall that the VOKES E72 High Pressure Fuel Filter was featured on this engine which carried out the world's first successful gas turbine flight on 15th May, 1941. Today VOKES' filters bring their 99.9% efficiency rating to a wide variety of applications . . . to hydraulic lines . . . to air intake . . . to cabin pressurisation and silencing plant . . . to the ventilation of test bed houses.

It is by examples such as this that the VOKES claim is demonstrated—Pioneers of Scientific Filtration.

Illustration below shows circular air intake filter as fitted to the Airspeed Ambassador.



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SUBLIMITY

Never does friction's fretful pain,

Curb carefree 'horses' such as these,

YOUR horses' power may likewise gain,

By wider use of FBC's

FBC
TRADE MARK
ball and roller bearings

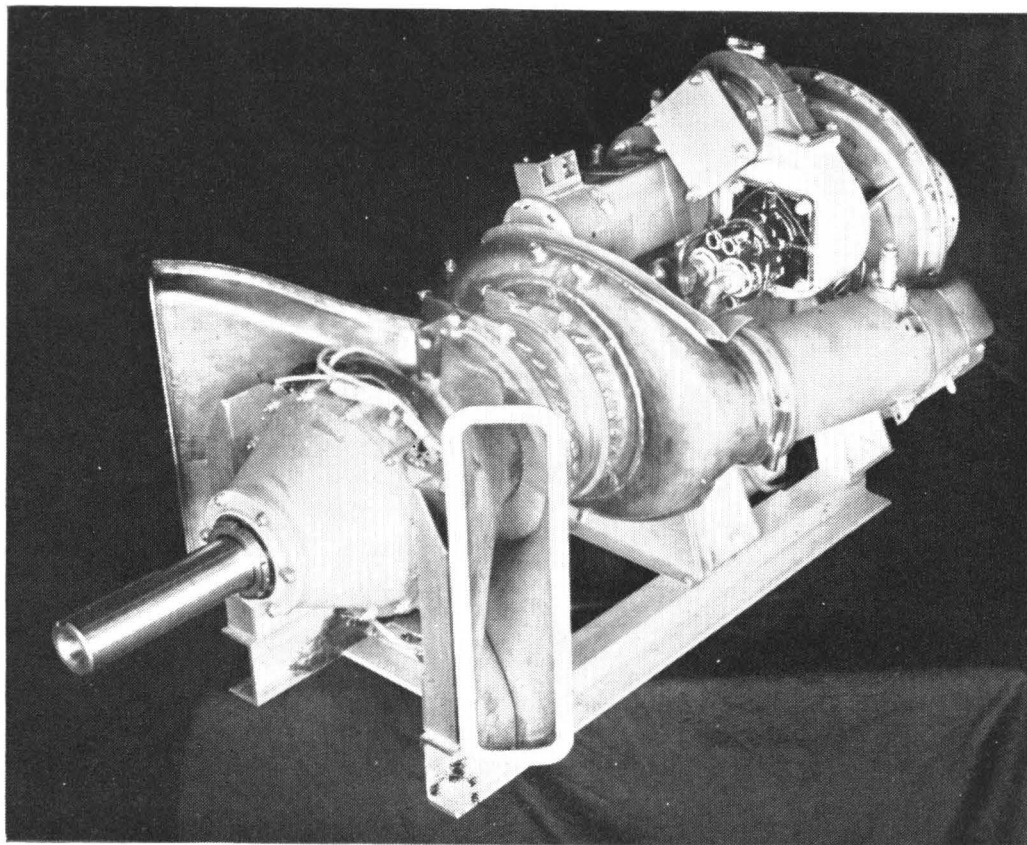


Fig. 3.—Turbine-and-driveshaft end of the Model 502

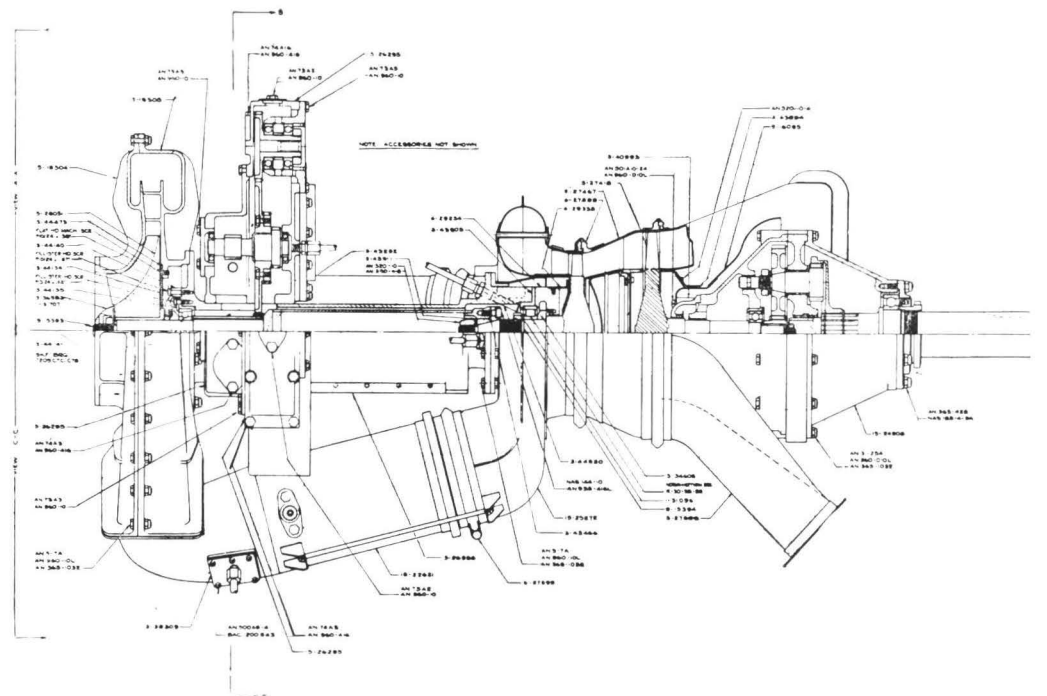


Fig. 4.—Drawing of the Model 502, showing a vertical axial section in the upper half and a longitudinal outline of the lower half

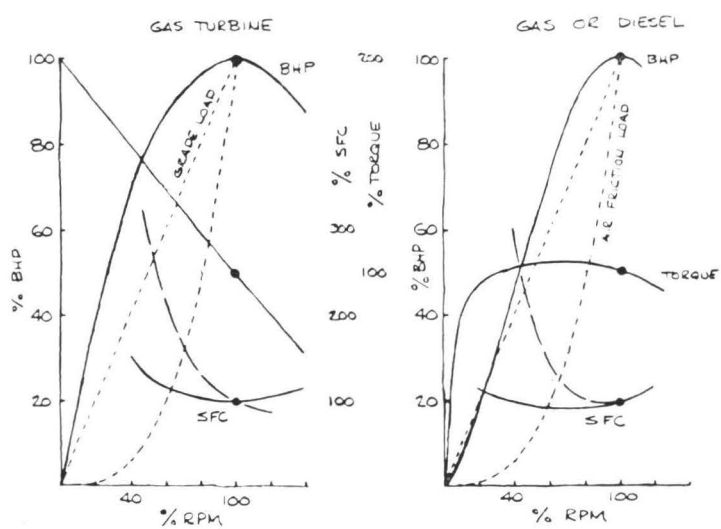


Fig. 5.—Comparison curves of some important performance characteristics of the Boeing gas turbine and those of a comparable petrol or diesel engine

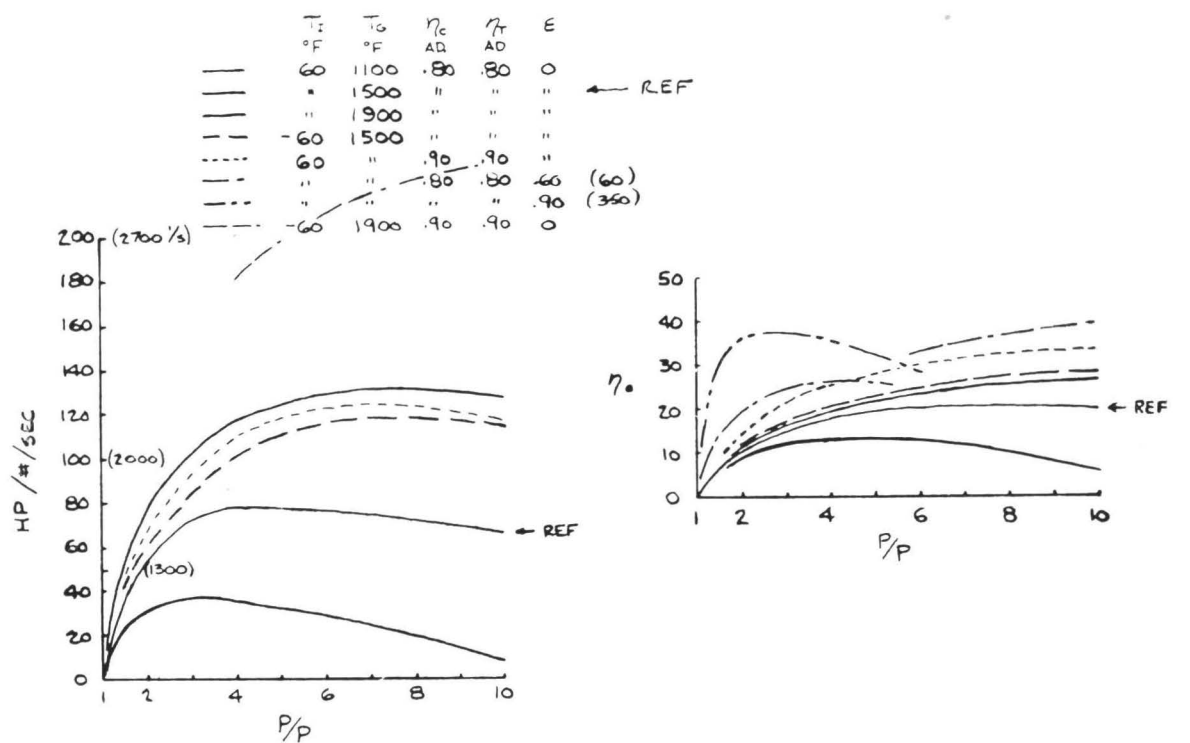


Fig. 6.—Horse-power per pound per second and thermal efficiency of the engine plotted against various temperatures, component efficiencies and effectiveness of a thermal regenerator

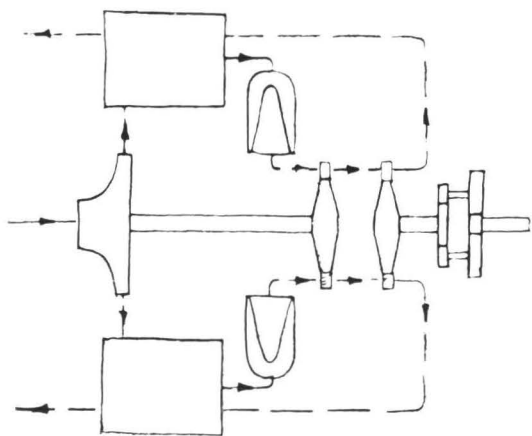


Fig. 7.—Diagram of Model 502 with a free-power turbine and regenerative heat exchangers giving a 3:1 pressure ratio

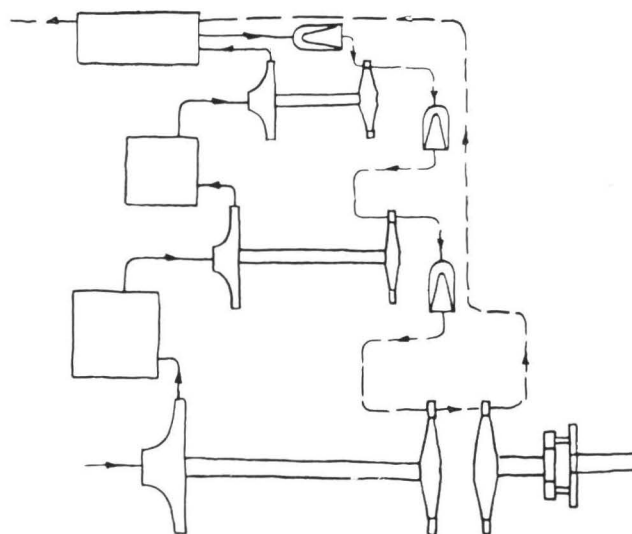


Fig. 9.—Diagram of a three-shaft simple rotor, intercooling, heat regeneration, 27:1 pressure ratio and free-power turbine

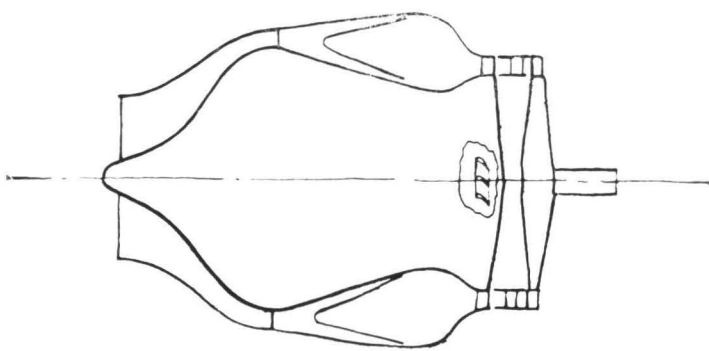


Fig. 8.—Section of a compressor-burner-nozzle rotor with a free-power turbine

at air-friction or cubic load. They reveal that the best economy point of the turbo-prop for any power is in the cubic load curve. It is pointed out that this is important because the air-friction load is characteristic of most transportation power sources and it indicates that this type of engine without any complicating load-varying devices, is excellently suited to propulsion of land, water and air vehicles. However, a gas turbine engine

which does not have a free-power turbine is not very suitable for general applications; a direct-connected machine will stall under load at about 40 per cent of its rated speed.

Some offsetting disadvantages of a small gas turbine of the type described also were discussed by Mr Hage. One is that air requirement is very high, resulting in excessive air-friction losses in the intake and exhaust and in compressor inlet noise. No good silencing solution has been found, owing to the high rate of air flow and the need to keep the pressure drop very low. Another unsolved factor is the high rate of fuel consumption when idling. This is roughly 20 per cent of consumption at full power. Cost of development of an engine of this type also is high because many new problems that must be solved arise, in addition to the usual mechanical problems encountered in developing any new engine.

The Boeing engines are not in commercial production and the probable cost of manufacture on a quantity basis is unknown. They were developed for the specific purpose of acquiring knowledge of dimensions, power/weight ratio and performance characteristics of gas turbine powerplants and so that airframes could be designed that would have the best flight properties when full-size engines of the type were installed.

Although the small research gas turbine was
(Concluded on p. 263)

The Development of Turbine Engines in France

An Account of Some of the Experimental Work Carried Out by the Research Departments of the Société Rateau at La Courneuve*

IN the years preceding the last World War, before it was concerned with the problem of the gas turbine, the Société Rateau dealt, with some success, with the very important problem of blower equipment for marine boilers. This is a problem having marked analogies with that of the supercharging of aero-engines. It is, however, more spectacular owing to the incomparably greater power involved and more particularly because the size of the engines is of the same order as, or greater than, that of the gas turbine. This made possible a close study of all the problems presented by the latter type of power unit.

This problem also had the advantage of permitting the development of axial compressors which were used industrially for the first time on that occasion. It was due to the recognition of the advantages of this new type of compressor that it was preferred to the centrifugal type for the first gas turbine engines produced. In this respect the similarity of construction between the turbo-blowers, for example, used in the boiler heating systems of such warships as the *Richelieu* and the *Jean-Bart*, shown in FIG. 2, and the gas turbine in FIG. 8, cannot be over emphasized.

Thus the Société Rateau had already produced about a hundred gas turbines of this type (approx. 4,000 h.p.) for the French Navy when the necessity became evident in 1938 for replacing the classical aero-engine-airscrew combination by engines giving greater speed. In conjunction with M. Anxionnaz, patents for jet-propulsion gas turbines were obtained and the production of these units was proposed to the French Air Ministry.

The design of a prototype was started in secret in September 1940, in spite of enemy occupation. For the direction of this work the Société Rateau invited the technical co-operation of Monsieur Riffard, who produced the design of a twin-engined aircraft shown in FIG. 3, which was, however, never built; its purity of line is evident and it has marked similarity with the Gloster Meteor, which broke the world speed record some years later in England.

* Translated by Lionel Mote, F.I.L., A.M. Inst. Pet., from the Bulletin Technique Rateau, No. 170, 1948 No. 2, pp. 4-27.

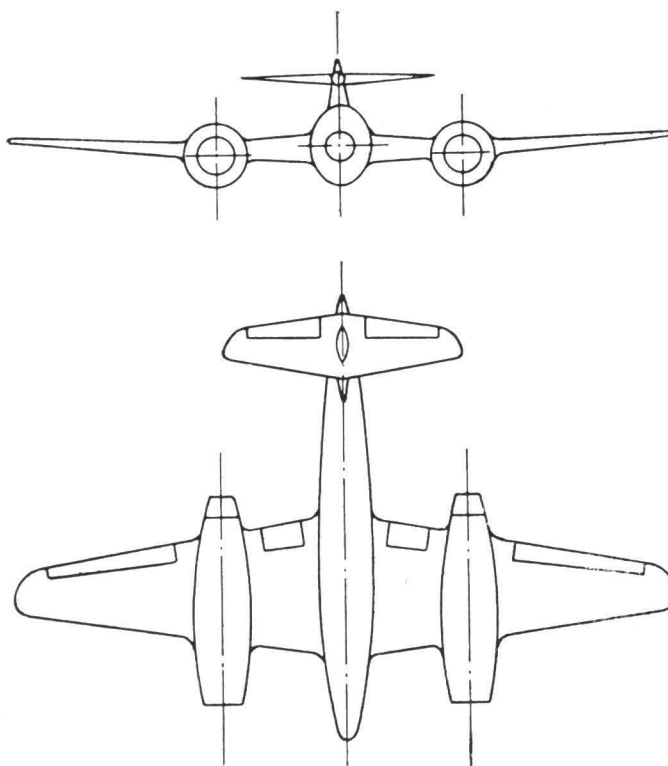


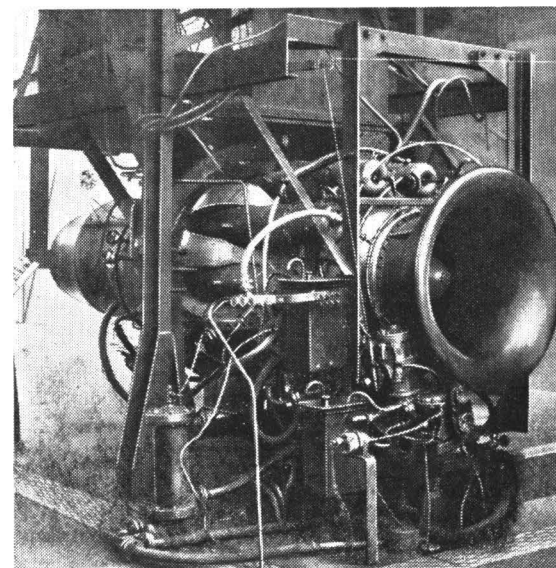
Fig. 3.—Aircraft designed by M. Riffard in 1940 which was to be fitted with the S.R.A. I turbo-jet

Later, at the instigation of the Services Techniques de l'Aéronautique, the Société Nationale de Constructions Aéronautiques du Sud-Ouest recommenced work on the design of the aircraft and decided in favour of a single-engined machine.

The working conditions in the French industry during the Occupation did not, of course, allow the jet propulsion unit to be built. As far as possible, however, preparations were made for its construction. All the necessary preliminary development, and machining drawings, as well as wind-tunnel and high-temperature research, were completed and the principal equipment collected.

After the Liberation the construction was pressed forward as actively as possible, and in September 1946 the first engine was installed in the test-bed.

This engine—known as the S.R.A. I—is of the divided flow type. It includes a 16-stage axial compressor, in which 4 low-pressure stages supply dilution air, representing 40 per cent of the air



Experimental engine test rig

delivered. The remainder of the air passes through the 12 high-pressure stages which raise the pressure ratio to 4 : 1. Leaving the compressor, the air enters the outer casing of nine combustion chambers arranged in barrel formation about the compressor. Part of this air passes to the front of the combustion chambers and enters the flame tubes at the injectors. Holes provided upstream of the combustion zone admit secondary air to reduce the gas temperatures to a value suitable for the preservation of the turbine blades.

The gas flow then passes through the fixed and moving 2-stage turbine blades. At the exit, the dilution air is mixed with the expanded gas and the whole is ejected at high velocity through the jet-pipe.

In FIG. 18, which illustrates the rotating components of the unit, a noteworthy feature is the short distance between the turbine and the compressor, resulting from the arrangement of the combustion chambers. The shaft is hollow throughout its length. It is supported by two ball bearings; the first before the compressor is fitted outside the shaft, while the second after the turbine is fitted inside the shaft, so as not to oppose its expansion.

The skeleton of the engine is of welded thin sheet steel, strengthened by three perforated sheet-steel beams supporting the bearings. This design made possible a particularly rigid monobloc construction. The turbine disks and blades are of special high temperature steel, of the type used for the gas turbines used to drive the blower equipment for 'Sural' boilers, i.e. steel of the 18/8 type with the addition of 3 to 4 per cent tungsten, which was the best steel of its kind available at that period.

Since then, the Société Rateau has developed a new high-temperature alloy 'ASR', which is one

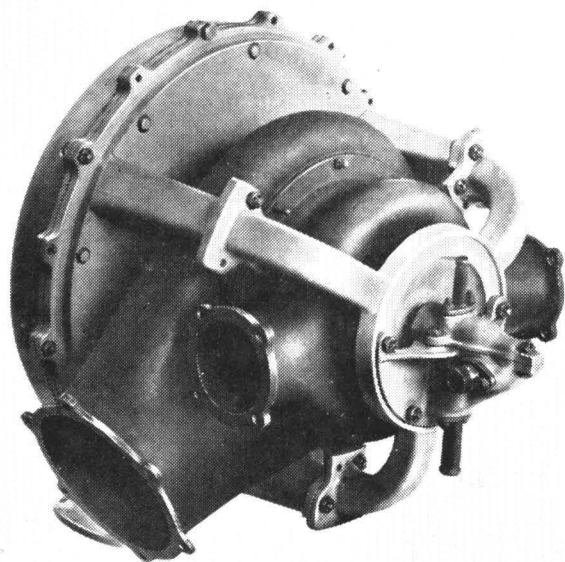
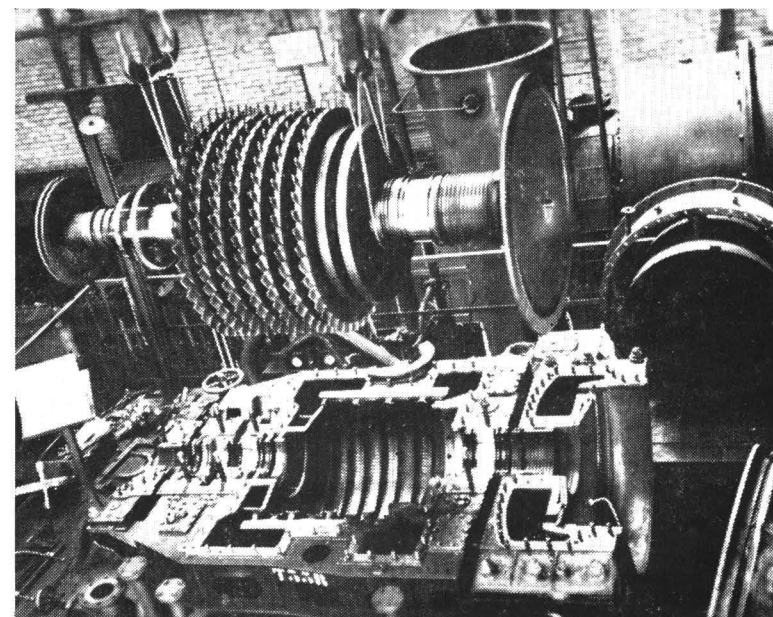


Fig. 1. (left)—Turbo-compressor for 300 h.p. engine used in 1917

Fig. 2. (right)—Steam raising turbo-blower assembly



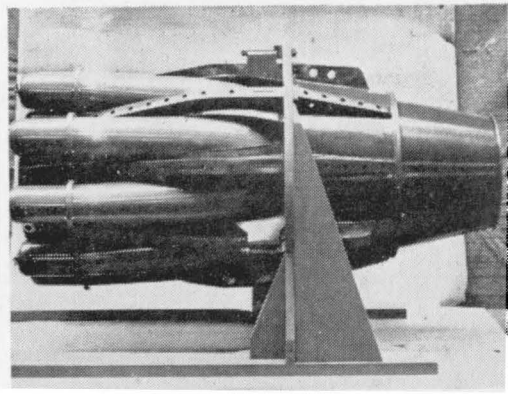


Fig. 4.—Mock-up of turbo-jet produced in 1940

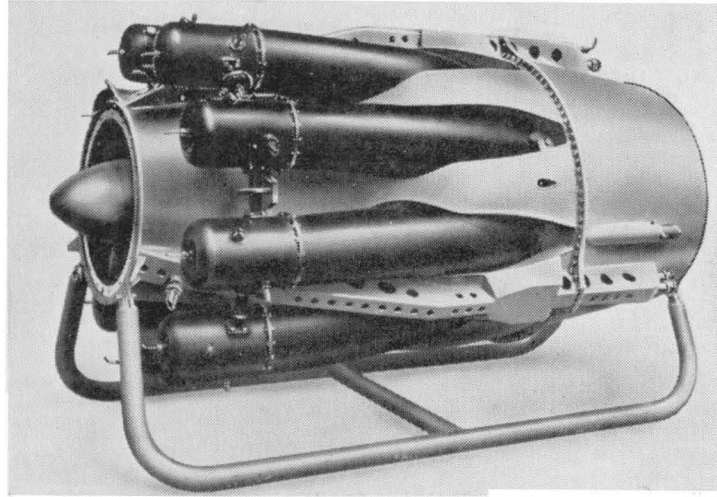


Fig. 5.—External view of the S.R.A. I turbo-jet

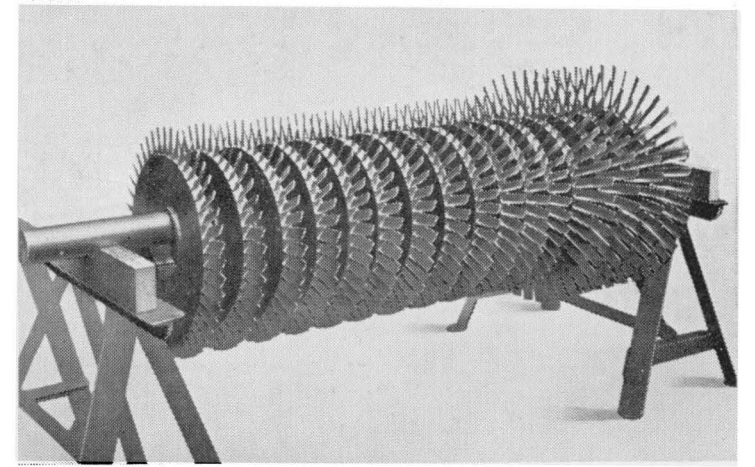


Fig. 6.—Impellers of compressor

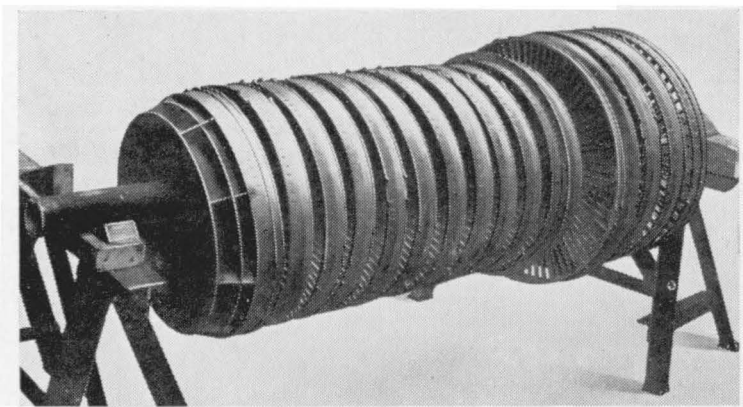
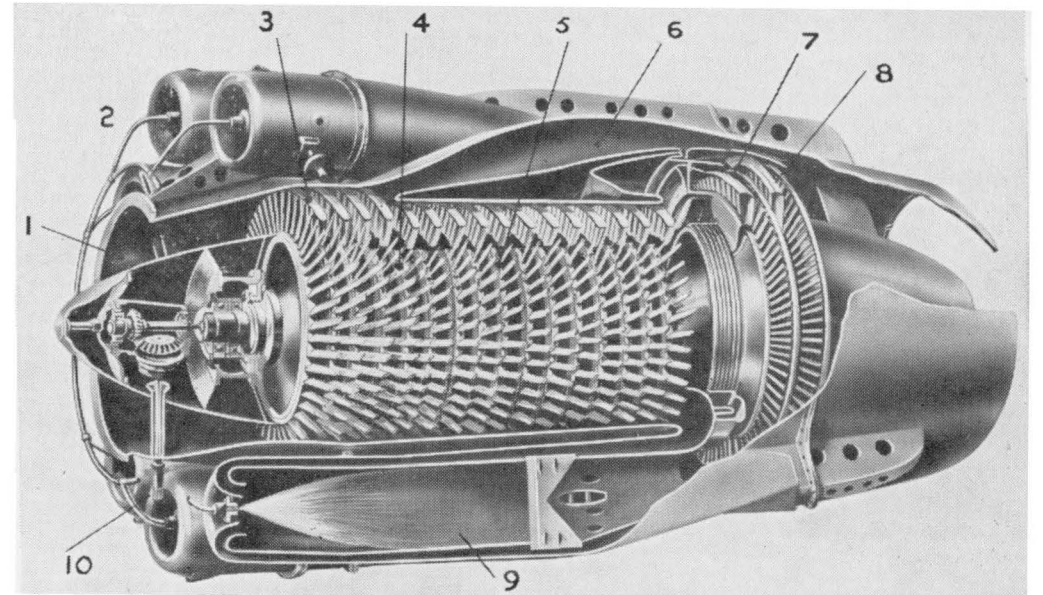


Fig. 7.—Guide-vane assemblies of compressor

Fig. 8.—Cross-section of the S.R.A. I turbo-jet



- | | |
|-------------------------|---------------------------|
| 1. Air inlet | 7 & 8. Nozzle guide-vanes |
| 2. Fuel entry | 9. Gas exit |
| 3. Guide vanes | 10. First turbine stage |
| 4. Low-pressure stages | 11. Second turbine stage |
| 5. High-pressure stages | 12. Combustion chamber |
| 6. Dilution air duct | 13. Auxiliary drive |

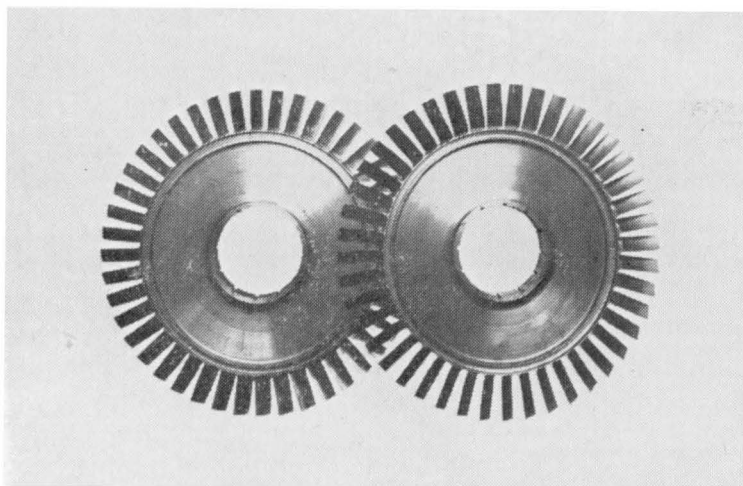


Fig. 9.—GT565 axial compressor impellers

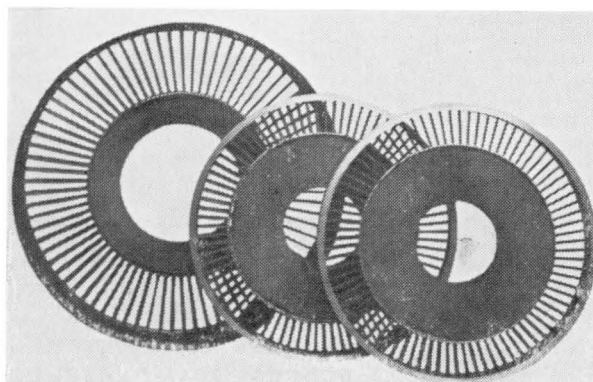


Fig. 10.—GT565 axial compressor guide vanes

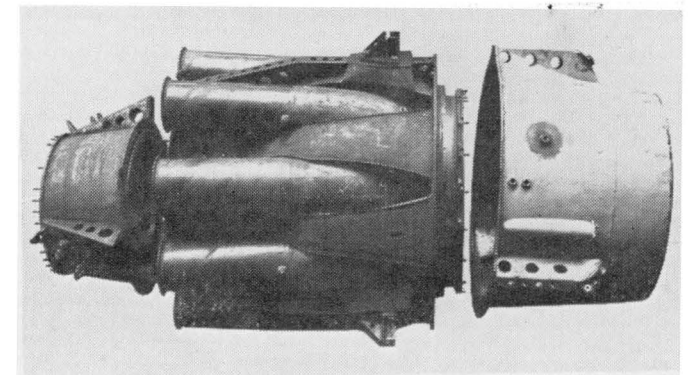


Fig. 11.—The various fixed components of the GT565 turbo-jet

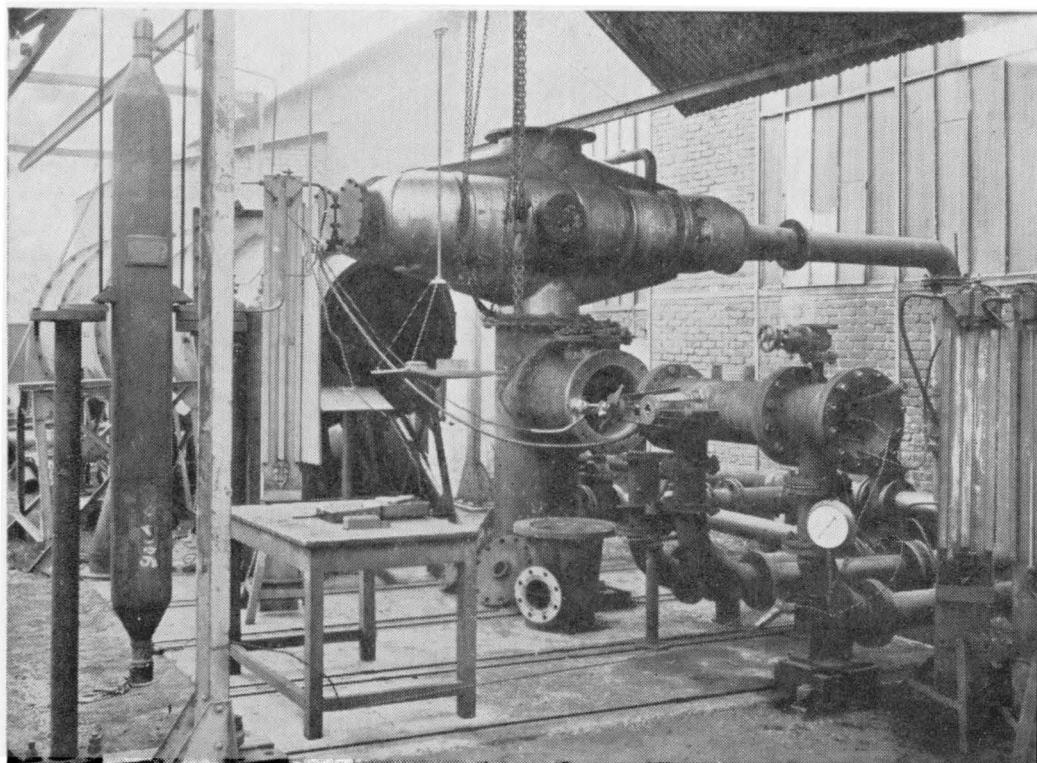


Fig. 12.—Burner test rig

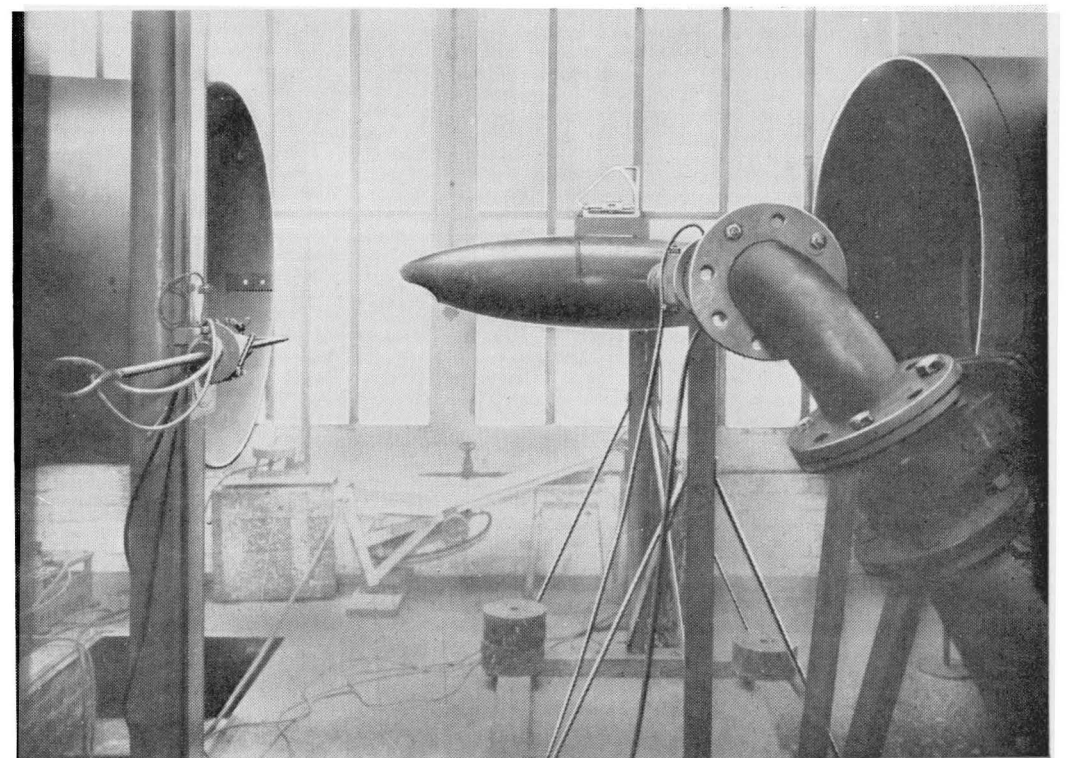


Fig. 13.—Wind-tunnel tests of fuselage model (for SO 6000 aircraft)

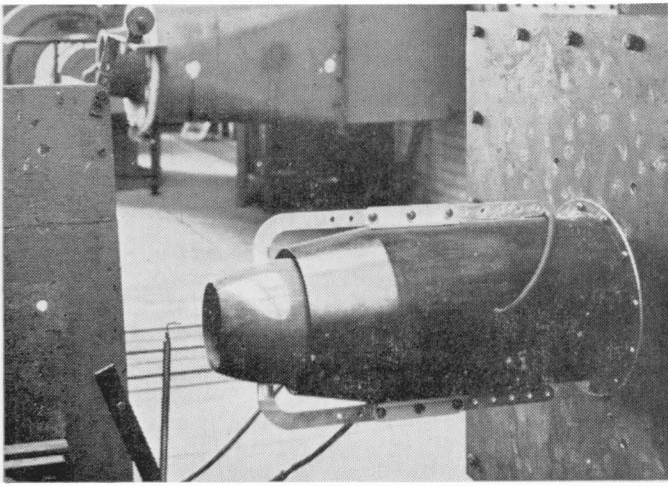


Fig. 14.—Wind-tunnel tests of tail-pipe nozzle

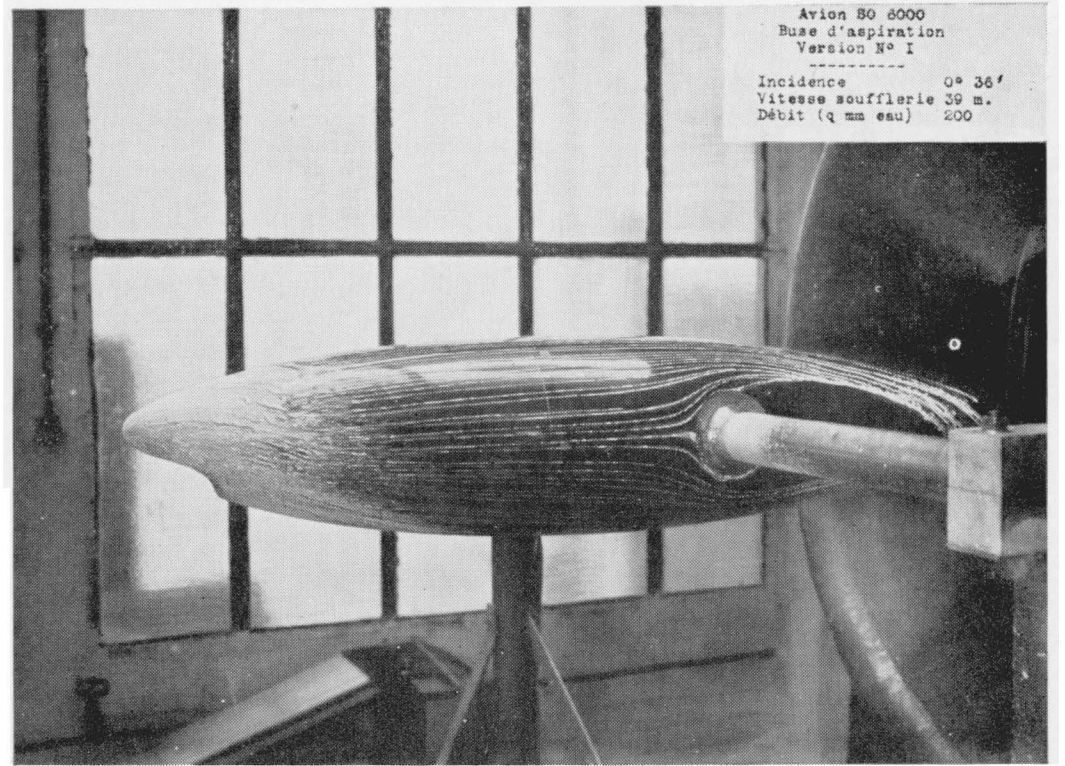


Fig. 15.—Wind-tunnel test of streamlining of fuselage model (for SO 6000 aircraft)

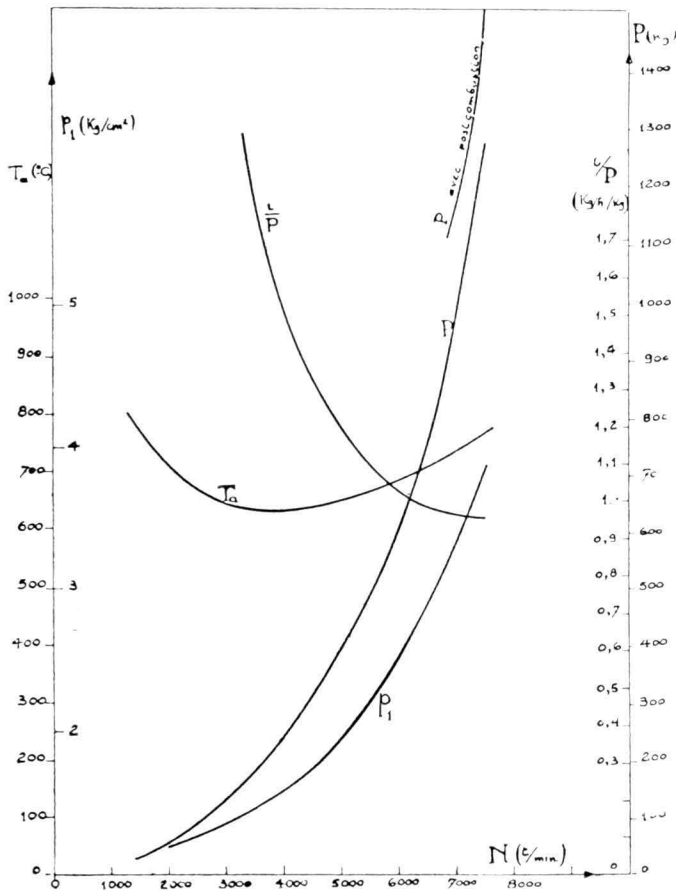


Fig. 16.—Results of bench tests of S.R.A. I turbo-jet at atmospheric temperature of 15 deg. C. and normal pressure 1 min. = r.p.m.; avec post-combustion = with after-burning

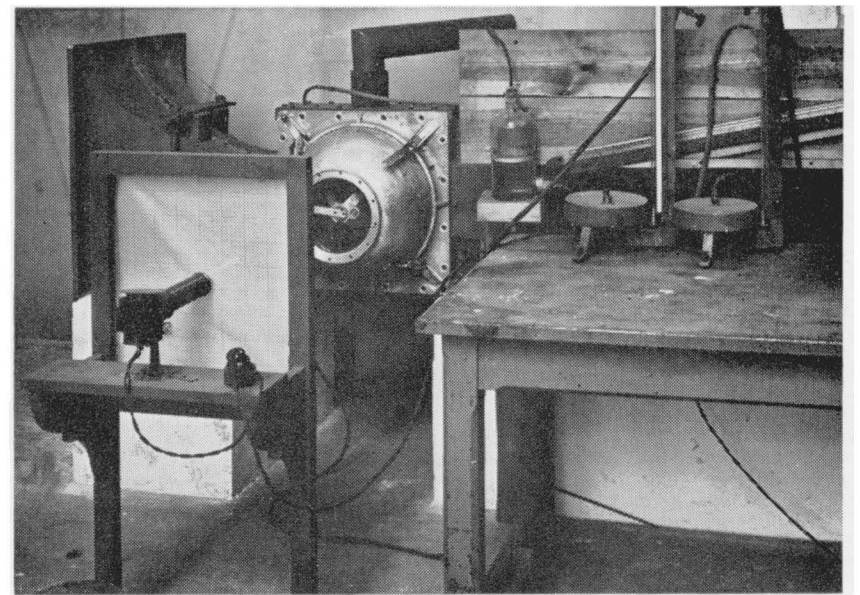


Fig. 17.—Test rig for nozzle tests in supersonic wind tunnel

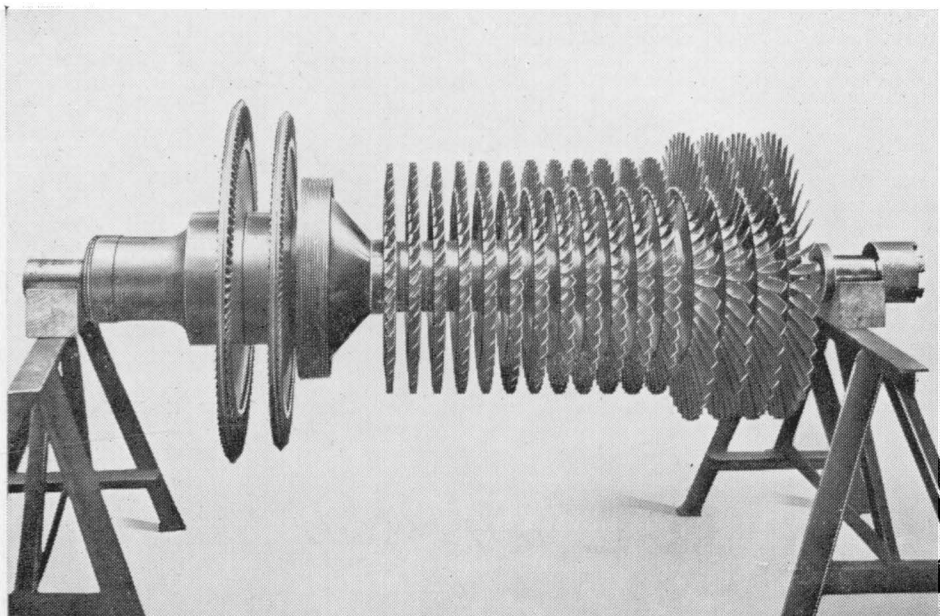


Fig. 18.—Rotating assembly of turbo-jet. From left to right: turbine disks, 12 stages high-pressure compressor, 4 stages low-pressure compressor

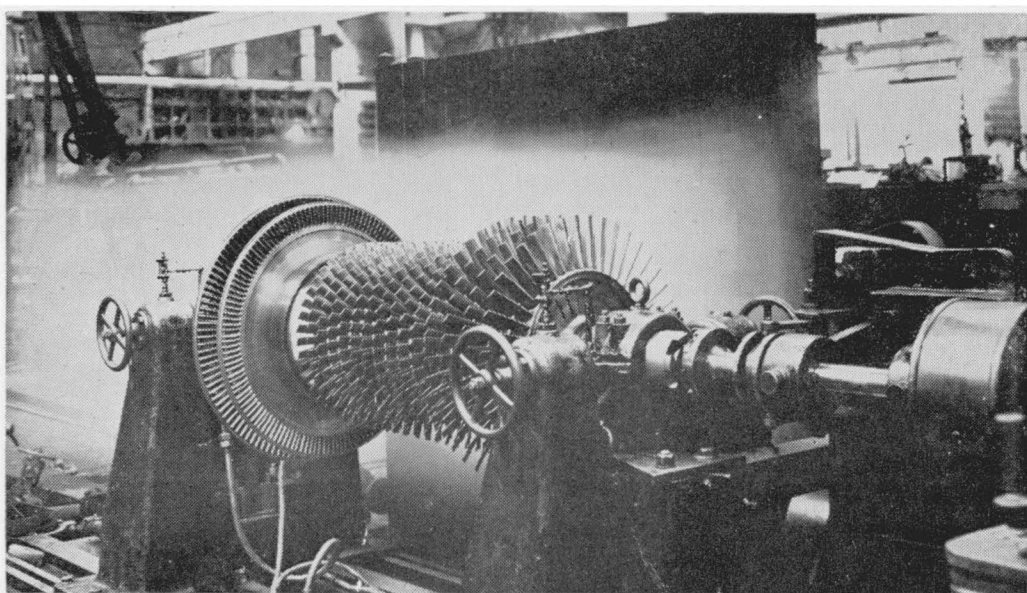


Fig. 19.—Rotating assembly in dynamic balancing machine

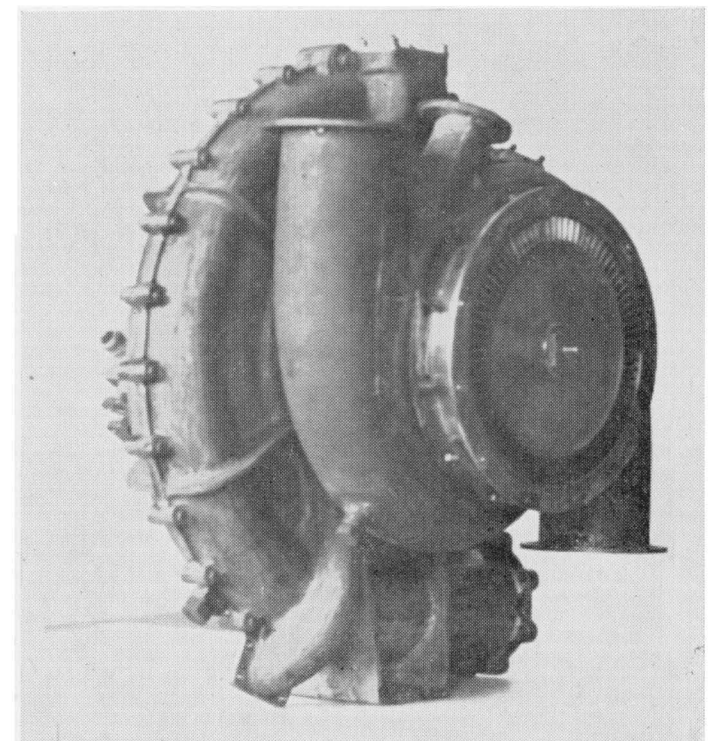


Fig. 20.—Turbo-supercharger designed for Hispano Suiza 12 Y

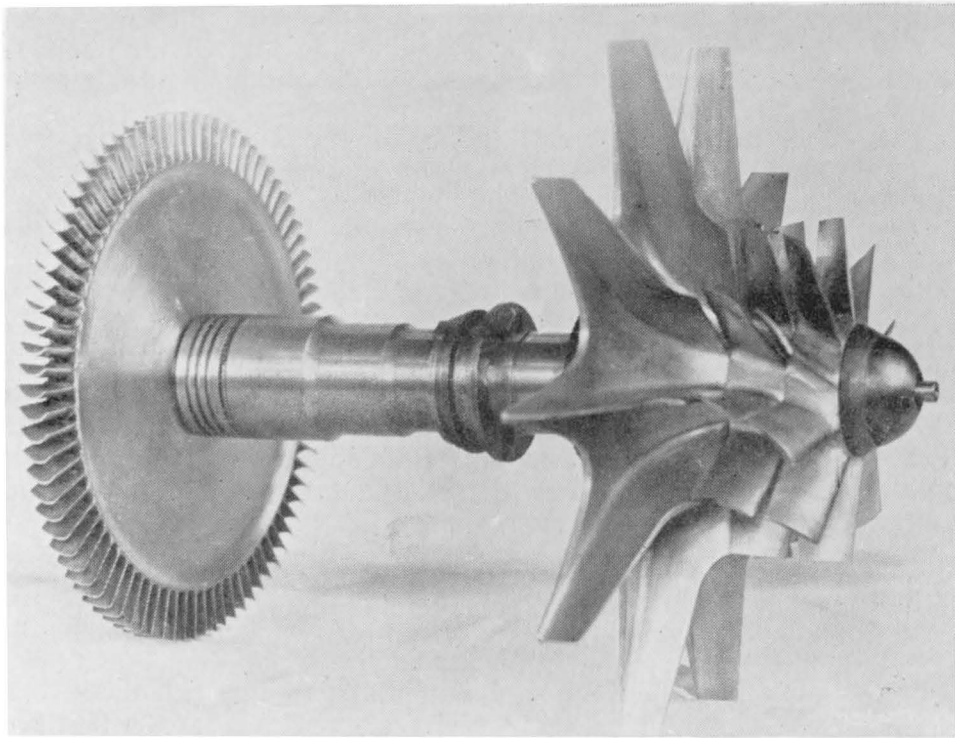


Fig. 21.—Rotor and impeller designed for Hispano Suiza 12 Y

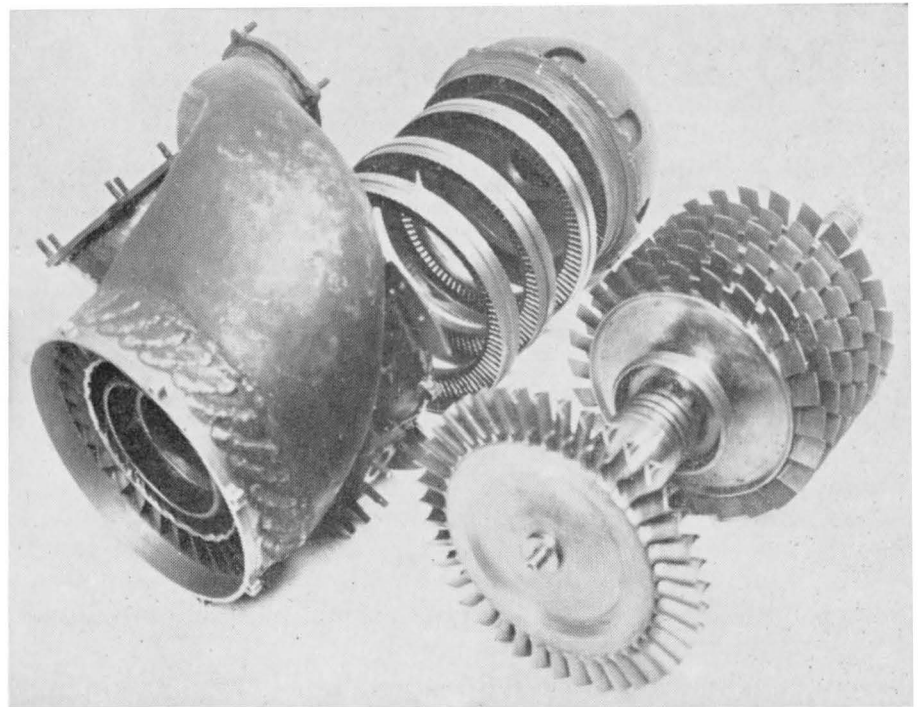


Fig. 22.—Axial compressor turbo-supercharger for aero-engine. The smallest axial compressor built by the Société Rateau. (Diameter 180 mm.)

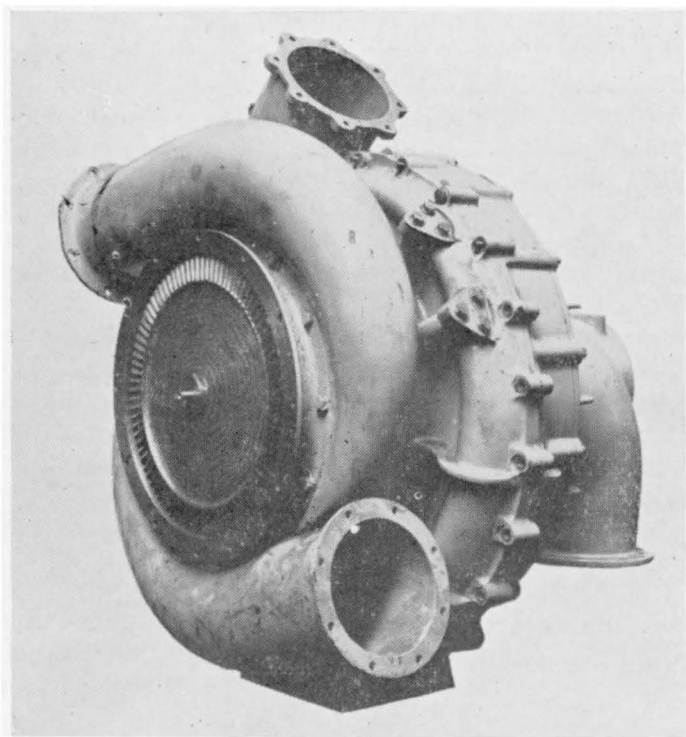
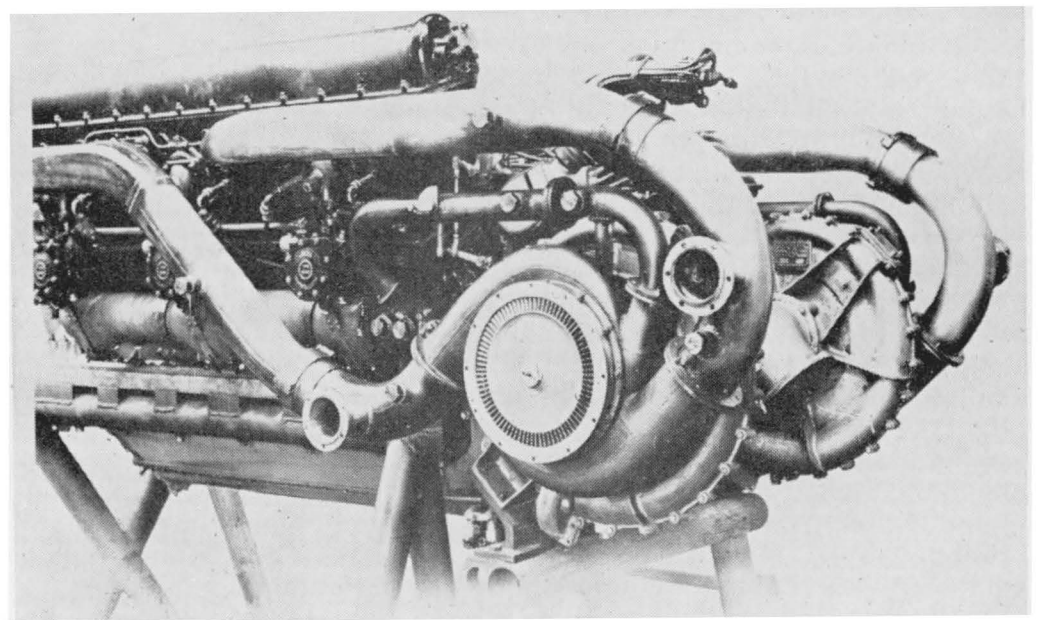


Fig. 23.—Two-stage centrifugal turbo-supercharger for Hispano Suiza engine

Fig. 24.—Installation of turbo-supercharger on Hispano Suiza 12 Y engine



of the best alloys of this type at present known, and future models will naturally make the best use of this material.

For installation in the aircraft, the fuel and oil pumps and auxiliary equipment are mounted at the side of the engine, the drive being provided before the compressor as shown in the cross-sectional diagram.

The S.R.A. 1 jet propulsion unit differs in its basic principles from other types by the use of low-pressure air for dilution. It is this arrangement which has made it possible for the fuel consumption of the first engine tested to reach the extremely low figure of 1 kg./h./kg. thrust, a value less than, or at most equal to, that of the best foreign productions.

The main characteristics of this unit are:

External diameter	1.23 m.
Total weight, in operating condition	1,000 kg.
Maximum speed	7,500 r.p.m.
Total pressure ratio	4 : 1
Air mass flow aspirated	28 kg./s.
Dilution air mass flow	11 kg./s.

The characteristics obtained in static thrust tests with this engine, at an atmospheric temperature of 15 deg. and at normal pressure, are shown in FIG. 16.

The continuous lines relate to the characteristics for normal operation and the broken line to those under overload conditions using after-burning to the full extent permissible.

If these results are compared with those of the best engines at present known, the least cautious user would begin by comparing the thrust-weight ratio with the value usually now obtained which is, at the most, about 3. Here it must be stated that this was a first model not specially developed to give maximum saving in weight. At the time when it was designed, without any knowledge of the efforts being made in several countries with this type of engine, it was deemed much more important to secure suitable and reliable operation than the maximum possible saving in weight. At that time the problem was, in fact, to convince Government officials and flying personnel of the possibilities and advantages of this new method of propulsion and any set-back would have compromised the whole project. It was for this reason that every effort was made, during design and production, to ensure complete reliability. The results obtained have clearly shown that the safety factors of the various parts were too generous for the final version of an aero-engine, which provides the possibility of considerable reduction in weight for future models.

Finally, the arrangement of the dilution air system resulted in an increase in weight, which otherwise would have been considerably less. This represents the price paid for the improvement in the fuel consumption.

In this respect the experience gained from the tests with this prototype was extremely useful, with regard to the advantages of dilution, as well as from many other aspects.

Moreover, it should be remembered that the

engine was designed between 1940 and 1942; that is to say that the progress made since then, in both aerodynamics and metallurgy, now makes it possible to visualize an incomparably better performance.

(To be continued)

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The Elementary Theory of Stressed-Skin Construction

Two Further Instalments of a Series on the Stressing of Modern Aeroplane Structures

By W. S. Hemp, M.A.

PART V. THE CALCULATION OF DEFLEXIONS

5.1 Applications

AIRCRAFT wings, tail planes, fuselages and control surfaces have to satisfy certain mandatory requirements of stiffness. These requirements are designed to ensure the absence of aero-elastic troubles. They all take the form of a minimum specified limit to a stiffness, calculated or measured under the application of a definite force and constraint system. A 'stiffness' may be defined as the ratio of a force to its 'corresponding' displacement (see 5.2) and so the calculation of stiffnesses reduces itself to a 'deflection problem' (1.1 (2)).

Calculations of deflexions are often necessary to ensure sufficient clearance to allow the safe functioning of moving parts and other installations. Distortion of the structure under load may destroy the proper alignment of the bearings of a shaft and so prevent its rotation. Deflexion of the wing and undercarriage during landing may cause the propeller to dig into the runway. Distortion of the wing may bring the tip into the cone of fire of a gun turret. These and similar examples, which might be quoted, all show the importance of deflexion calculations in aircraft design.

A further application is afforded by the need to calculate 'natural modes of vibration'. These are required for the calculation of flutter speeds and for the assessment of the response of the aeroplane to rapidly applied forces, such as are induced in landing or by hitting a gust. The calculation of such modes is based upon the following principles:

- (a) The inertia force per unit mass is equal to the product of the deflexion and the square of the angular frequency.
- (b) The total inertia force and couple are zero for the aircraft as a whole.
- (c) The deflexions are determinate only in relative value and so the deflexion at a reference point may be taken as unity.
- (d) The inertia forces of any particular mode do no work when taken through the deflexions of any other mode.

A procedure which may be followed in a calculation can be briefly defined as follows. A fundamental mode is guessed in such a way that (b) and (c) are satisfied. The corresponding inertia forces follow by (a) except for a common arbitrary multiplier. Using these forces, the deflected shape assumed by the aeroplane under their action is calculated. The arbitrary 'constants of integration' corresponding to rigid body motion are determined by (b) and a first approximation to the frequency is given by (c). The process is then repeated until successive steps give results in close agreement. For the overtones arbitrary amounts of previously calculated modes are added to the guessed mode and their proportions determined so that the conditions of (d) are satisfied. The procedure used for the fundamental may then be applied. It will be noted that the determination of the deflexions of the aeroplane structure under known forces forms an essential step in these calculations.

5.2 General Theorems

There are a number of general theorems which are of considerable use in the calculation of deflexions. For the sake of completeness we shall enunciate them here giving necessary explanations, but no proofs.

In our description of methods in Part I we followed, in the case of the two methods considered, rather different procedures. In the 'Fundamental Method' of 1.2 we relied upon immediate physical principles such as the conception of strain, Hooke's Law and the conditions of equilibrium. In the 'Castigliano Method' of 1.3 we based ourselves upon a rather sophisticated theorem of stationary or minimum strain energy (1.3 (4)). Now the procedure of the Fundamental Method may equally well be expressed in this latter form of a 'Variational Principle'. The theorem for the Fundamental Method corresponding to Castigliano's Principle of Least Work is that general theorem of Mechanics known as the 'Principle of Minimum Potential Energy'. This may be enunciated as follows:

'The total potential energy, including both strain energy and the potential energy of external forces, of a structure or elastic body is smaller for the correct displacement pattern, than for any other displacement pattern which satisfies the imposed kinematical conditions.'

The contrast with the Castigliano Theorem should be noticed. In this last we are concerned with possible stress distributions, which must satisfy the conditions of equilibrium; consistency of displacement is automatically ensured. In the Principle of Minimum Potential Energy, however, we are concerned with possible deflexion patterns, which must satisfy the conditions of continuity and kinematics; the conditions of equilibrium are automatically satisfied. One can perceive a certain 'duality' in these theorems, but it should be emphasized that the Principle of Minimum Potential Energy is much more general than the Castigliano Principle, applying not only to systems obeying Hooke's Law, but to 'conservative' systems in general. It can be applied successfully to problems involving 'large deflexions' such as the consideration of post-buckled states of plates and shells (1.4).

A second theorem of great value is that known as 'Castigliano's First Theorem'. This may be enunciated as follows:

'The partial differential coefficient of the total strain energy stored in a structure with respect to one of the external forces acting upon the structure is equal to the displacement corresponding to this force.'

This theorem is applicable only to bodies which obey Hooke's Law. For such a body the strain energy stored under the application of external forces can be expressed as a quadratic function of these forces. The notion of a deflexion 'corresponding to a force' is best introduced by stating that the work done by an applied force, when the body or structure undergoes a small virtual increment of displacement, is equal to the product of

the force and the increment of the 'corresponding displacement'. This definition is complementary to that used in Mechanics, where the force would be termed the 'Generalized Force' corresponding to the displacement involved.

The third and last theorem with which we shall deal is the 'Reciprocal Theorem'. In its general form it may be stated as follows:

'The work done by a first set of forces applied to a structure, taken over the displacements due to a second set of forces, is equal to the work done by the second set of forces taken over the displacements due to the first set.'

This theorem is applicable only to structures obeying Hooke's Law. For such a structure the applied forces are linear functions of their corresponding displacements. A special case of our theorem then shows that the coefficients of these equations form a symmetrical array (matrix). The Reciprocal Theorem of Maxwell given in most text-books on Structures is another special case of our theorem.

5.3 Methods

Various methods are available for the calculation of deflexions. We limit ourselves here to three, founded respectively upon 1.2 and the first two theorems of 5.2.

The 'Fundamental Method' of 1.2 is essentially a method of deflexion analysis. A beginning is made with deflexion patterns (1.2 (1)) and the final equations (1.2 (6)) are equations for the determination of these patterns. The determination of stresses is really incidental. This method is very powerful and has the merit of physical clarity, which is not possessed in the same measure by the minimum energy methods. In view of the detailed description given in 1.2 we shall not, however, deal further with this method here.

A method fully equivalent to that of the 'Fundamental Method' can be developed using the Principle of Minimum Potential Energy (5.2). Here one begins with either a perfectly general displacement pattern or with an approximate, but practically adequate, pattern and then calculates the strain energy stored in the body or structure and the virtual work done by any external forces during a small change in the displacement pattern. This last term represents the decrease of potential energy of the external force system. Expressing that the total potential energy is stationary we equate this virtual work to the corresponding increment of strain energy and hence obtain an equation which is linear in the differentials of the parameters or functions, which determine the displacement pattern. These differentials being quite arbitrary, one obtains a series of ordinary equations by equating their coefficients to zero. This method is of great service in the case where the 'exact' equations derived from the Fundamental Method are too difficult to solve by the usual mathematical processes. Adopting an approximate assumption about displacements or a perfectly general representation, as for example by means of a Fourier series, one can resolve any deflexion problem. The use of Fourier series is particularly convenient in this connexion because, thanks to their orthogonal properties, the formulae for the strain energy reduce to sums of squares of the coefficients of these series with consequent simplification in the resulting equations.

In the special case where the structure is deformed by prescribed displacements at certain points, the Principle of Minimum Potential Energy reduces to a Principle of Minimum Strain Energy since the external forces which produce the displacements do no work when the displacement pattern is varied consistently with the imposed conditions. It follows that, if constraints are imposed upon the structure and the original

unconstrained displacement pattern can no longer be realized, the strain energy stored in the constrained state is greater than in the unconstrained state and so greater forces are needed to produce the prescribed displacements. The introduction of constraints therefore makes the structure stiffer and the use of an approximate displacement pattern will overestimate the stiffnesses, since the restriction of displacement possibilities implied by the approximation is tantamount to the introduction of constraints.

A great deal of aircraft structural analysis is based upon Castigliano methods (1.3) or even upon purely static considerations supplemented by a number of special assumptions about stress distribution (cf. Part III), and so methods of calculating deflexions founded upon this type of analysis are clearly very desirable. In a case where the stress distribution due to each of a given set of applied loads is known even approximately, an estimate of the deflexions corresponding to these loads can be given using Castigliano's First Theorem (5.2). The strain energy in the structure is calculated from the known stress distribution as a function of the applied loads, which must of course be introduced symbolically into the equations concerned. Numerical values of these forces may be inserted after the differentiations have been performed. The calculation of deflexions at places where no external forces are acting can be accomplished by the introduction of suitable fictitious forces, which should be set equal to zero after the differentiation of the strain energy has been carried out.

The use of Castigliano's First Theorem combined with an approximate estimate of stress distribution leads to an *overestimate* of the deflexion due to a given force; i.e. an underestimate of the stiffness. This is because the strain energy of an approximate stress distribution, which is statically correct, is greater than the true strain energy (1.3 (4)) and so for a given force, since the strain energy equals one-half the force times the displacement, the corresponding displacement will be too large.

5.4 Examples

The methods outlined in 5.3 are well illustrated by the various processes which have been devised for the analysis of the deflexions of beams. The usual theory, which is founded upon a differential equation expressing the proportionality of bending moment and curvature, is a good illustration of the fundamental method. The power and generality of the method is established in all the text-books on Strength of Materials and Engineering Structures. The use of 'harmonic analysis' is also well treated in the literature, both for problems of statics and dynamics. The second application usually forms the corner-stone of that pinnacle of civil engineering—'The theory of moving loads on bridges.' The simplest example of all is afforded by the analysis of the deflexions of a uniform beam simply supported at each end, by the use of a series of sines of multiples of π times a non-dimensional co-ordinate. The sum of such a series, and also of that obtained by double differentiation, vanishes at each end of the beam and so satisfies the boundary conditions. The strain energy is then expressed as a sum of terms involving squares of the coefficients of the series representing the deflexions. It can be shown that this means that each of these coefficients can be calculated directly from the external forces, by means of the minimum potential energy theorem or otherwise, without the intervention of any of the other co-ordinates. Each equation derived contains only one of our unknowns and so is very easily solved. The use of Castigliano's First Theorem for the analysis of beam deflexions is also very well known and need be only mentioned here.

The ordinary theory of beams is incomplete in that it takes no account of shear stresses in its deflexion calculations (1.2 (4)). For many purposes this omission is of no practical importance,

but in the calculation of natural modes of vibration particularly for the overtones, where the lengths of bending (distances between nodes) approach the section dimensions in order of magnitude, it is very necessary to allow for it. An approximate method of allowing for this effect may be constructed using Castigliano's First Theorem and a shear stress distribution deduced by differentiating the direct stresses in a longitudinal direction and integrating the result over partial sections of the beam to obtain mean values of the shear stresses (cf. 3.1 Corollary III). The strain energy of both direct and shear stresses can then be calculated as a function of the external forces and the deflexions obtained using the Castigliano Theorem.

An example of the influence of constraints upon stiffness is afforded by the different values of wing torsional stiffness obtained by applying symmetric or anti-symmetric torques to corresponding sections of port and starboard wings. The stiffness is greatest in the symmetric case. The reason for this has already been given in 4.3. Another example is afforded by the neglect of shear flexibility in ordinary beam theory discussed in the previous paragraph. The assumption of that theory which imposes the requirement that plane sections normal to the axis of the beam remain plane and normal to the deformed axis after bending is a clear case of kinematic constraint and leads to an overestimate of stiffness.

As a last example let us consider the calculation of the stiffness of a fuselage under a symmetric tail load. This illustrates very well the simple and rather crude methods which can often be applied to obtain a rough estimate of the deflexions of aircraft components. The applied loads can be separated into symmetric and anti-symmetric parts. If the fuselage has a vertical plane of symmetry, the deflexions due to each of these parts may be obtained by independent calculations. The symmetric loads will clearly produce bending in the plane of symmetry and the corresponding deflexions may be calculated using the ordinary theory of beams. The anti-symmetric loads will produce twisting only and the corresponding rotations may be calculated using the Batho Theory of Torsion. If the fuselage has a doubly symmetric section the axis of twist lies at the intersection of the planes of symmetry. If this is not the case further calculation is necessary (cf. 5.5 below) in all strictness, but for rough calculations a good guess is often sufficient.

5.5 Wing Deflexions

We have seen earlier (3.6) that in the case of a two-spar wing of uniform section, it is possible to define an axis, termed the flexural axis, by means of which separation of bending and torsion is made possible. This conclusion can be extended to the case of a slightly tapered or swept-back wing for which the ratio of the second moments of area of the two spars is appreciably constant. For this case the flexural axis is defined as the locus of points, which divide the interspar spacing inversely as the second moments of area of the two spars. This is a straight line, when the spars themselves are straight, and may therefore be used as a reference axis for the calculation of bending moments and torques. When the bending moments and shears are calculated as described in 3.7 it will be found, so long as the flexural axis is used as datum, that the moments of these quantities about the datum add up to zero, and so the Batho torque may be calculated directly from the moments of the external forces about the datum (cf. 3.7 (6)). If all the external forces be applied on the flexural axis there is no Batho torque and no twist, since, if shear deflexions be neglected, the spars, which carry bending moments everywhere proportional to their rigidities (3.7 (2)) will have equal deflexions. It follows from the Reciprocal Theorem that the flexural axis is also the 'axis of twist' and so the rotations due to the Batho Torque can be located. The calculation of the deflexion of our wing under given forces is

thus resolved into two parts. Calculating the bending moments by taking moments about lines at right angles to our flexural axis and applying the simple beam theory we find the normal deflexion of the flexural axis. Calculating the torques about our flexural axis and using the Batho theory we find the rotation of wing sections about the flexural axis.

The situation is by no means as simple for the case where the ratio of spar second moments of area varies appreciably along the span. Here as previously it is possible to locate the external forces, when distributed over the whole span, in such a way as to make the Batho Torque zero everywhere and so to achieve a state of affairs in which, when shear deflexions are neglected, the wing is simply bent without twisting. However, the appropriate fore and aft locations of the forces do *not* lie on a straight line and so it is not possible to invoke the Reciprocal Theorem and determine the axis of twist. For this case there is a 'Flexural Centre' on each cross-section, which is the point for which applied loads produce no twist at the section, but may well produce twist elsewhere. There is, however, no Flexural Axis in this case. Just as previously, we can calculate a bending deflexion from the bending moment and a rotation from the Batho torque, but we have no means of locating these rotations in the fore and aft direction and so determining the complete deflexion picture.

The difficulties encountered in the previous paragraph may be resolved by dividing the wing into a number of segments in each of which the ratio of spar second moments of area may be treated as constant. Each segment will have its own 'flexural axis' and the relative deflexions of its ends may be calculated by the method previously described. The several segments may then be 'pieced together' and the complete deflexion pattern for the wing as a whole built up. For this last step it is essential to refer the deflexions of the segments to a common wing datum and care must be taken to resolve the twists and bending rotations into the axes of the common wing datum before summation, as well as to calculate these quantities using the bending moments and torques appropriate to the 'local' flexural axis.

An alternative method may be constructed by making use of an approximate stress distribution determined by the methods of 3.7. Applied normal loads and torques are introduced symbolically at each rib station along the wing datum. The bending moments and Batho torques are calculated and an expression for the total strain energy obtained as a function of these applied forces. Application of Castigliano's First Theorem (5.2) will then yield formulae for the deflexions and rotations corresponding to the applied forces which should now be given their concrete values. A similar method might well be applied to the case of a stressed skin wing in which the bending loads are carried by stringers, using the stress distribution calculated by the methods of 3.5 as a basis. A beginning could be made with the case of a uniform section and a flexural axis determined by minimizing the strain energy of the shear stresses and computing the line of action of their resultant which would clearly give the case of pure bending. The results could then be applied to a series of segments of the wing on the approximate supposition that the geometry of the structure remained unchanged along each segment. The complete deflexion pattern could then be built up by successive 'addition' of the deflexions of each segment in the manner suggested above for the two-spar wing.

PART VI. PROBLEMS OF ELASTIC STABILITY

6.1 Struts

THE application of the Energy Method of 1.4 (2B) to the determination of the buckling load of a strut is quite a straightforward

process. One begins with either a quite general assumption, such as an expansion in a Fourier series, regarding the possible lateral deflexion pattern, or perhaps with an approximate estimate of the expected buckling form. This assumption must be supplemented by a further assumption with regard to possible longitudinal displacement. A satisfactory procedure for dealing with this last deflexion component is to determine it in such a manner that the longitudinal direct strain at the neutral axis of the strut is unchanged by the lateral bowing. This is clearly a sound procedure for the case of a strut loaded by given compressive forces at its ends and it may be shown that only a practically insignificant error results when the derived formulae are applied to a case in which the overall compressive strain is given. If the centre line of the strut is unextended it follows that the ends of the strut must move towards one another when bowing occurs. The amount of this movement is given by the integral of one-half the square of the bowing slope taken over the length of the strut. During bowing the compressive forces at the ends of the strut will thus do work. To obtain the critical load we equate this work to the strain energy stored in the strut due to its bending and so obtain that value of the compressive load which produces a state of neutral equilibrium for the type of 'perturbing displacement' assumed (i.e. buckling or bowing displacement). If our choice of lateral displacement involves a number of unknown parameters, these must now be chosen so as to make the critical compressive load as small as possible, thus obtaining the practical buckling load. The Energy Method is particularly valuable in dealing with cases in which the stiffness of the strut or the compressive load carried vary along the length.

The usual calculation of the buckling load of a strut proceeds by the method of 1.4 (2A). Here the strut is bent and the possibility of equilibrium in the bent form investigated. Thanks to the bending, the compressive load produces an offset bending moment at any section of the strut. This is related to the curvature by the well-known formula and a homogeneous differential equation results. This equation possesses non-vanishing solutions, which satisfy the end conditions, for only a discrete series of values of the end load. The smallest of these is the practical buckling load. Calculations of this type may be generalized to include the effects of initial lack of straightness, which is always present in a practical strut. It is usual to analyse the eccentricity 'harmonically' using the sequence of buckling modes corresponding to the critical loads calculated by the methods of the present paragraph. It is found that the first term of this series is of paramount importance and calculation shows that the amplitude of this component of the initial eccentricity, which corresponds to the lowest or practical mode of buckling, grows as the critical load is approached according to a multiplying factor equal to the ratio of the compressive load carried to the difference between the smallest critical load and this compressive load. The amplitude of the bowing thus goes to infinity along a hyperbolic curve as the critical load is approached. If the amplitude of the bowing be plotted against that amplitude divided by the corresponding compressive load a straight line will result, whose slope is equal to the first critical load. This method of analysing experimental results is due to Sir R. Southwell and is called 'Southwell plotting'. It gives the 'critical load' even though the strut fails at a lower load due to its initial eccentricity.

The formulae derived by the methods outlined above break down if the compressive stress at the critical load exceeds the elastic limit of the material from which the strut is made. Consider a strut compressed beyond the limits of proportionality and elasticity of the material. We can represent its state of stress and strain by a point P on the compressive stress-strain curve for the said material. Impose a small bending deflexion upon the strut. Assume that the developed direct strains

vary linearly as in beam theory. The net result will be to cause a small increment of compressive strain upon one side of the strut and a small decrement upon the other, with a linear variation in between. The relation between stress and strain for small increments in the neighbourhood of the point P on the stress-strain curve is determined by the local slope, or 'tangent modulus' as it is often called. The relation for small decrements will, however, be determined by the full modulus. It results therefore that the relation between bending moment and curvature at any section of the strut will depend upon two moduli in much the same way as the bending stiffness of reinforced concrete depends upon the moduli of the two materials involved. On this foundation one can build the so-called 'Double Modulus' theory, but this suffers from the practical difficulty that different formulae have to be developed for each strut section considered. A compromise, which works quite well, is to assume that the tangent modulus gives the relation between stress and strain for small increments and decrements in the neighbourhood of P . The elastic properties of the section are then homogeneous and it is easily seen that the relation between bending moment and curvature differs from that which applies in the elastic case, by the substitution of the tangent modulus for the full Young's modulus. It follows that the critical load for the strut is given by the appropriate 'Euler' formula with the tangent modulus written instead of Young's modulus. In applying this formula one must be careful to adjust the tangent modulus to correspond to the compressive stress determined by the critical load. This may be done by trial and error or otherwise, using plots of stress divided by tangent modulus against stress for the appropriate material.

6.2 Flexural Buckling of Stringers

Consider a panel of stringers and skin loaded by compressive forces parallel to the stringers and supported at least against lateral movement at the loaded ends. To calculate the critical load for such a panel we impose a common flexural displacement upon the stringers in a direction at right angles to the skin and proceed as previously in the case of the isolated strut (6.1). Since the skin is rigidly attached to the stringers it must play its part in resisting the bending and if unbuckled will play a part corresponding to its full area. The case is different, however, if the skin has buckled between the stringers at a lower load, in the manner of a supported plate (see 6.4 below). In this case the bent stringer will impose a certain strain and corresponding stress at the line of attachment to the skin, but the load induced in the skin will not correspond to this stress multiplied by the skin area of section (cf. 3.3). We must distinguish between overall strain and load carried in the skin or expressed in other terms; we have on the one hand, a stress at the 'edge' of the skin panels where they meet the stringers, which is called the 'edge stress', and on the other an 'average stress' in the skin equal to the load carried by the skin divided by the area of the skin cross-section. The relation between the average stress and the edge stress for a plate buckled in compression has been determined by theory and experiment (see 6.5) and will be assumed known here. Returning to the buckling problem we see that the imposed bending will induce a load in the skin equal to the increment of average stress multiplied by the skin area. This is equal to the differential coefficient of average stress with respect to the edge stress multiplied by the increment of edge stress and the area of the skin. This last expression contains the increment of edge stress as a factor and so falls into line with the calculation of load induced in elementary areas of the stringer due to the imposed bending. It follows that stringer and skin can be treated together by means of the usual beam theory so long as the skin area is reduced by the factor d (average stress)/ d (edge stress). The procedure for the calculation of the buckling load for flexural buckling

of a stringer-skin combination for which the skin is already buckled is now clear. We take a stringer and a width of skin equal to the stringer pitch multiplied by the value of d (average stress)/ d (edge stress) corresponding to the final critical stringer stress. (Since this is not yet known a guess must be made here.) The second moment of area for an axis through the centre of area and parallel to the skin is then found in the usual way and the buckling load computed using the Euler formula. This can be translated into a stringer stress using the known relation between average and edge stress in the skin and assuming that the stringer carries load according to the edge stress and its actual section area (cf. 3.3). This edge or stringer stress should be compared with that used to determine the 'effective' width of skin and if necessary a correction and subsequent calculation made. The process is quite rapidly convergent. The important distinction between the effective width of skin to be used in calculations of flexural instability and that used to determine the load carried by a stringer-skin combination (3.3) was first made by H. L. Cox.

In using the Euler formula in the calculation sketched above one has to substitute an appropriate pin-ended length. In the case of flat or nearly flat panels such as occur on the surfaces of stressed skin wings the pin-ended length of the stringers may be taken equal to the rib pitch. The stringers will be supported at the ribs and will buckle alternatively outwards and inwards in successive rib bays. This rule tends to be less correct for fuselages of large curvature, which like all curved plates and shells show a decided tendency towards 'inward' buckling. However, as no *conclusive* evidence on this point is known to the present writer, no attempt will be made here to give a definite design rule. It is to be hoped that this long outstanding problem will receive more attention from aircraft structural engineers in the future. In the case of large fuselages it is possible that the rings provided may have insufficient flexural stiffness to enforce buckling of the stringers between them. The rings as well as the stringers will then participate in the buckling and a 'General Instability' will ensue. In this case the 'pin-ended' length of the stringers may well be much greater than the ring pitch.

The correctness of a design of stringers and skin is usually checked by a panel test. Most panel tests are carried out with the panels tested 'flat-ended' in a testing machine. If the testing machine is of sufficient rigidity this condition of test corresponds to the ideal condition of 'both ends fixed' and so for the panel test the pin-ended length will equal one-half the panel length. Panels used for checking designs should therefore be tested with a length equal to twice the pin-ended length of the stringers in the aircraft structure.

6.3 Torsional Instability

The possible modes of buckling of aircraft structures are legion. A mode of buckling to which all 'open' section stringers are prone is 'torsional instability'. Whereas in flexural instability the stringer section moves as a whole in a direction at right angles to the skin, in torsional instability the section rotates as a whole about an appropriate axis. Thanks to the extreme rigidity of the skin in its own plane, which prevents sideways movements of the riveted flange of the stringer, this axis will lie in the plane of the skin. The rigidity of the stringer web in its own plane tends to bring the axis into the plane of the web. If this limiting case is realized and the axis of twist lies at the intersection of web and skin, we may well speak of a 'pure' torsional instability. On the other hand if the axis lies a long way from the stringer, the stringer deflexions will be indistinguishable from those occurring in flexural instability. In between these two extremes we have a continuous series of mixed flexural-torsional instabilities. This 'coupling' between flexure and torsion which is always present, even though it be

practically negligible, is an example of the fact that the 'standard' modes of buckling are never independent and that the boundaries between them are very blurred.

The calculation of torsional instability stresses may well be performed using the Energy Method (1.4 (2B)). The various kinds of strain energy involved may be enumerated as follows:

- (1) Energy of Torsional Shear Stresses. Any section when twisted will resist torsion by a system of shear stress calculated in accordance with the classical theory of St Venant. Formulae for the corresponding stiffnesses are well known and so the appropriate energy can be calculated in terms of the stringer twist.
- (2) Energy of Differential Bending Stresses. Open sections carrying a variable torque derive an appreciable part of their stiffness from differential bending. In the case of a Z-section the two flanges bend in opposite directions and provide a torque by means of their equal but opposed shears. The web carries a uniform direct stress and the flanges must carry, besides bending stresses, appropriate balancing direct stresses, which, without inducing a net end load, enable continuity of direct strain to be maintained at the corners. The energy of all these direct (and bending) stresses constitutes the energy of the differential bending. The absolute magnitude of this energy is determined by the curvatures induced in the plane of the flanges by the deflexions corresponding to the rotation. This second energy term is thus a function of the stringer twist.
- (3) Energy of the Restraining Action imposed by the Skin. If the stringer rotates about an axis in the plane of the skin, the skin will resist this action by bending as plates between the stringers. The energy stored by this effect is usually calculated by formulae derived by assuming that the skin acts as a series of independent beams between the stringers. While one would be hard pressed to suggest an effective alternative, it must be confessed that this assumption is very dubious particularly for short wavelengths and for the case where the skin is already buckled. This last case represents another unsolved problem, which has, however, great interest, since, as experiments have shown, the stiffness of the skin increases with buckling, presumably due to the dimpling or corrugating effect of the buckles.

The sum of the three types of strain energy corresponding to an arbitrary rotation of the stringers must be equated to the work done by the compressive end loads acting at the ends. This work can be calculated in a manner analogous to that outlined for the strut (6.1). To obtain a critical load a suitable form of twist must be substituted in the resulting formula. It is sufficiently general in this as in other cases to use a simple sine wave of arbitrary wavelength, which is determined by making the critical load a minimum. A further assumption must be made about the behaviour of adjacent stringers. Inspection of relative stiffnesses would suggest alternate directions of rotation as that most likely to give the minimum buckling stress. However, on test, panels nearly always fail with the stringers rotating in the same sense. This phenomenon is probably bound up with the corrugating effect of skin buckling mentioned above. The whole difficulty in the development of a proper theory of torsional instability lies in our inability to deal properly with the restraining action of the skin, especially when buckled.

6.4 Buckling of Plates

A theory of the buckling of plates can be developed by appropriate generalization of the theory outlined for struts (6.1). For an Energy Method we require expressions for the strain energy stored in a slightly bent plate and for the work done by

the external forces applied to the edges of the plate when the plate is bent without any extension of the surface midway between the faces. The system of external forces must be two dimensional but can be any system so long as they are in equilibrium. The small displacement used to test the stability of equilibrium is chosen so that there is no change in this two-dimensional system of stresses. This is analogous to the assumption made for the strut and is equally justified in practice. The nature of the assumed normal displacement of the plate varies with the conditions of support at the edge and with the nature of the initially applied forces. In the case of a rectangular plate with simply supported edges compressed parallel to one pair of sides, an appropriate assumption would be to take the normal deflection as sinusoidal with an arbitrary number of half waves in directions parallel to the edges of the plate. The use of a complete double sine series would actually give no greater generality but would provide a rigorous demonstration of the formula for buckling stress obtained. Equating the work done by the external forces to the strain energy stored we then find an expression for the critical stress which becomes a minimum, when a buckled form with one-half wave in a direction at right angles to the compression of a half wavelength as near to this as is possible in a direction parallel to the compressive forces is assumed. Other conditions of loading (e.g. shear) and support (e.g. clamped edges) require more complex assumptions (doubly infinite series) and are thus much more difficult to analyse in numerical terms. In all cases, however, the buckling stress is found to be proportional to Young's Modulus and the square of ratio of plate thickness to plate width, the remaining factor denoted by K depending upon the kinematical conditions at the edges, the type of external forces and the ratio of length to breadth of the plate.

The method which depends upon the examination of the possible realization of equilibrium in a slightly perturbed state (1.4 (2A)) is also easily applied to plates. It is assumed as before that the two-dimensional stress system is unchanged by the perturbation, but the conditions for its equilibrium must be written down in the deformed state and not in the initial state as is usual in equilibrium problems involving small deflexions. In particular the condition of equilibrium normal to the plate must be calculated and expressed in terms of the assumed normal displacement. The values of the applied forces which yield non-zero solutions of this last equation are the required critical loads.

The plates which occur in aircraft structures are never subjected to rigid kinematic conditions at their edges, although in certain extreme cases such assumptions yield close approximations to the truth. Plates are normally bound by stringers which exert elastic support at their points of juncture with the plates. Most stringers can be approximately represented as a series of coupled plates (e.g. Z-sections, top-hats, etc.) and so the problem of the buckling of plates bounded by stringers reduces itself to the analysis of the instability of a series of connected plates. The solution of this last problem can be fairly easily resolved under the following assumptions:

- (1) The stringer-skin combination is subject to compressive loading parallel to the stringers.
- (2) The 'corners' of the stringers and skin (i.e. points of intersection of flanges, webs and skin) are fixed in space. This is generally fairly true for 'initial' buckling.
- (3) The right angles at the corners of (2) are conserved.
- (4) The buckling mode is sinusoidal in the direction of the stringers.
- (5) Adjacent stringers have identical or alternating modes of deformation. Top-hats form an example of the first, while Z-sections behave in the second way.

The process of the calculation is then as follows.

The stringer-skin combination is separated into its individual plates. Thanks to (2) above, these plates are all simply supported at their edges. The mutual actions between them consist of distributed bending moments, which by (4) are sinusoidal in distribution along the plate lengths. The 'stiffness' of each plate under this type of applied force can be computed by plate theory and will depend upon the longitudinal compressive stress carried and the wavelength of the applied bending moments. Expressing that the bending moments are in equilibrium and the rotation angles are equal at each line of juncture of the plates (see (3)) we obtain, using the stiffness values mentioned above, a set of equations whose eliminant gives a relation between compressive stress and wavelength for which the assumed deformations are possible. Choosing the wavelength to make the compressive stress a minimum, we find the required critical stress.

The theory of plate buckling may also be applied to the approximate calculation of stresses at which 'local instability' of the stringers develops. Local instability is a form of buckling in which the cross-section deforms in its own plane without overall movement. The web of a Z-section or the sides and top of a top-hat may well be treated as plates with simply supported edges, the factor K (above) being taken as 3.62. The free flange of a Z or Channel can be treated as a plate with one free edge and the other edge having support somewhere between simple support and full clamping. An empirical value of K equal to 0.58 can be used in this case. These rules are liable to be inaccurate in extreme cases. For example, in the case of a thin stringer and a thickish skin, the skin may well tend to clamp the end of the web nearest the riveted flange. Problems of this last type, and indeed all problems of local instability, which refer to cases where *no other previous mode* of buckling has occurred, are really covered by the calculations of the buckling of stringer-skin combinations outlined above. It is difficult to draw a rigid distinction between 'skin buckling between stringers' and 'local instability' since they are really inseparable—the one always involving the other to a greater or lesser extent. However, the problem of local instability which occurs after skin buckling and becomes a 'secondary' mode of buckling is really beyond the power of existing theory to resolve.

6.5 Post-Buckled States

It is not possible in an elementary account of the subject of stressed skin construction to do more than refer briefly to the existence of the problems of post-buckled states. All kinds of buckling are of course not catastrophic. Skin buckling between stringers may occur at very low stresses and yet the structure will carry stresses equal to several times these buckling stresses without failure. In fact most aeroplane skins are designed to behave in this manner. It follows that a knowledge of the behaviour of skins after buckling, i.e. a knowledge of their post-buckled state, is an important element of aircraft structural analysis. The need for this knowledge has been referred to several times already. In 3.3 we needed a compressive load-edge strain relation to compute the effective area of a buckled skin. In 6.2 we used the differential coefficient of this functional relation to calculate the flexural instability stress of stringers. In 6.3 we deplored the absence of knowledge on stiffness of buckled skins under bending moments applied at the edges. Post-buckled problems are problems of the 'large' deflexions of plates. Mathematically speaking they are non-linear problems and as a consequence are of extreme difficulty. Certain cases of compression and shear have been worked out, the Wagner Tension Field Theory being an example of the latter, but much more work is urgently required. Since the theoretical calculations are so difficult, it would seem profitable to encourage experimental investigations.

The Determination of Redundant Constraints in Beams

A Simple Statement, with Proofs, of Formulae for the Three Principal Cases

By F. E. S. Manton, B.Sc., A.C.G.I.

Summary

IN what follows $n-2$ equations have been obtained, valid for all kind of beams having n rigid level supports, and which are either:

- A. Simply supported.
- B. Rigidly built in at one end with zero slope.
- C. Rigidly built in at both ends with zero slope.

Together with two, three or four additional equations in case A, B, or C respectively.

Three examples, one for each case A, B and C, have been worked out to illustrate the method.

The formulae used in these cases have been obtained from more general ones for beams with non-level elastic supports, and elastic fixing moments at non-zero initial slope, the proof of which is given, together with one example of the general case.

Notation

V = total vertical resultant of applied loads, positive downwards
 m_x = bending moment at x due to applied loads (not including constraints)

$$\bar{m}_x = \int m_x dx; \bar{\bar{m}}_x = \int \int m_x dx dx$$

T_n = total moment of applied loads about point of application of P_n
 EI = stiffness of beam

The $n-2$ Equations

$$\sum_{i=1}^{r-1} \left\{ P_i(a_{r-1} + a_r + a_{r+1}) \right\} + P_r \frac{(d_r)^2}{D_r} - 3M_1 - \Phi_r = 0 \dots \dots \dots (1)$$

from $r=2$ to $r=n-1$

where $\Phi_r = \frac{\Omega_r - \Omega_{r-1}}{D_r} = \frac{\Delta\Omega_{r-1}}{D_r}$

$$\Omega_r = \frac{\omega_{r+1} - \omega_r}{d_r} = \frac{\Delta\omega_r}{d_r}$$

$$\omega_r = 6 \int_0^{l_r} \int m_x dx dx = 6 \left[\bar{m}_x \right]_0^{l_r}$$

$$v_n = 6 \int_0^{l_n} m_x dx \quad 6 \left[\bar{m}_x \right]_0^{l_n} = 6\bar{\bar{m}}_n$$

which are obtained from difference Table I.

TABLE I

r	ω_r	$\Delta\omega_r$	v_n *	$v_n - \Omega_{n-1}$ *	$\Gamma_n = \frac{v_n - \Omega_{n-1}}{d_{n-1}}$
n			Ω_r	$\Delta\Omega_{r-1}$	Φ_r
n-1			Ω_{n-1}		
—					
2					
1			Ω_1		

* Required for cantilevers only.

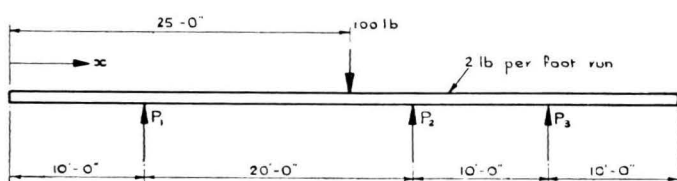


Fig. 2—Example A

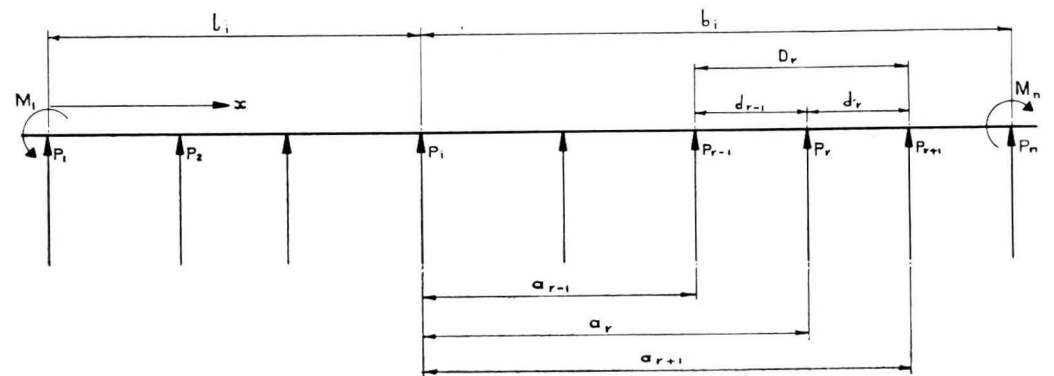


Fig. 1—Notation

A. Simply supported

Obtain $P_2, P_3 \dots \dots \dots P_{n-1}$ in terms of P_1 from (1), when $M_1=0$

$$\text{Obtain } P_1 \text{ from } \sum_{i=1}^{i=n-1} (P_i b_i) - T_n = 0 \dots \dots \dots (2(a))$$

$$\text{Obtain } P_n \text{ from } \sum_{i=1}^{i=n} (P_i) - V = 0 \dots \dots \dots (3)$$

B. One End Fixed (Cantilever)

Obtain $P_2, P_3 \dots \dots \dots P_{n-1}$ in terms of P_1 from (1), when $M_1=0$

$$\text{Obtain } P_1 \text{ from } \sum_{i=1}^{i=n-1} \left\{ P_i(3b_i - b_{n-1}) \right\} - \Gamma_n = 0 \dots \dots \dots (4)$$

$$\text{Obtain } P_n \text{ from } \dots \dots \dots (3)$$

$$\text{Obtain } M_n \text{ from } \sum_{i=1}^{i=n-1} (P_i b_i) - T_n + M_n = 0 \dots \dots \dots (2(b))$$

C. Built-in at Both Ends

Obtain $P_2, P_3 \dots \dots \dots P_n$ in terms of P_1 and 3 M_1 from (1)

$$\text{where } 3 M_1 = P_1 d_1 - \frac{\Omega_1}{d_1} \dots \dots \dots (5)$$

$$\text{Obtain } P_1 \text{ from } \sum_{i=1}^{i=n-1} 3P_i b_i^2 - 2b_1(3M_1) + v_n = 0 \dots \dots \dots (6)$$

$$\text{Obtain } P_n \text{ from } \dots \dots \dots (3)$$

$$\text{Obtain } M_n \text{ from } \sum_{i=1}^{i=n-1} (P_i b_i) - T_n + M_n - M_1 = 0 \dots \dots \dots (2(c))$$

Example A

$$6m_x = 6x^2 + 600(x-25) \text{ ignore bracket when negative}$$

$$6\bar{m}_x = \frac{x^4}{2} + 100(x-25)^3 \text{ ,, ,, ,, ,,}$$

TABLE II

r	ω_r	$\Delta\omega_r$	Ω_r	$\Delta\Omega_{r-1}$	Φ_r
3	1,280,000 + 337,500 = 1,617,500	1,200,000	120,000	99,375	3312.5
2	405,000 + 12,500 = 417,500	412,500	20,625		
1					

$$50P_1 + 3.33P_2 - 3312.5 = 0 \dots (1) \quad \therefore P_2 = 993.75 - 15P_1$$

$$30P_1 + 10P_2 = 3000 \dots \dots \dots (2(a))$$

$$3P_1 + 993.75 - 15P_1 = 300 \quad \therefore P_1 = 57.98 \text{ lb.}$$

$$P_2 = 300 - 173.94 \quad \therefore P_2 = 126.06 \text{ lb.}$$

$$P_1 + P_2 + P_3 = 200 \dots \dots \dots (3) \quad \therefore P_3 = 15.96 \text{ lb.}$$

Example B

$$6m_x = 3x^2 + 6(x-5)^2 \text{ ignore bracket when negative}$$

$$6\bar{m}_x = x^3 + 2(x-5)^3 \text{ ,, ,, ,, ,,}$$

$$6\bar{\bar{m}}_x = \frac{x^4}{4} + \frac{(x-5)^4}{2} \text{ ,, ,, ,, ,,}$$

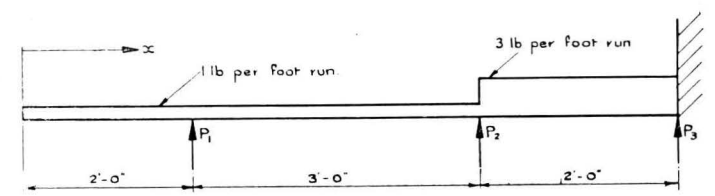


Fig. 3—Example B

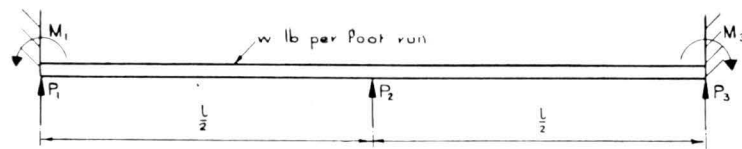


Fig. 4—Example C

TABLE III

r	ω_r	$\Delta\omega_r$	359	133	66.5
3	$600 + 8$	608	Ω_r	$\Delta\Omega_{r-1}$	Φ_r
2	156	452	226	175	35
1	4	152	51		

$$8P_1 + 8P_2 - 35 = 0 \dots\dots\dots (1) \quad \therefore P_2 = 43.75 - 10P_1$$

$$13P_1 + 4P_2 - 66.5 = 0 \dots\dots\dots (2)$$

$$3 \cdot 25P_1 + 43.75 - 10P_1 - 16 \cdot 63 = 0 \quad \therefore P_1 = \frac{27 \cdot 12}{6 \cdot 75} = 4.02 \text{ lb.}$$

$$\therefore P_2 = 43.75 - 40 \cdot 2 = 3.55 \text{ lb.}$$

$$P_1 + P_2 + P_3 = 11 \dots\dots\dots (3) \quad \therefore P_3 = 11 - 7.57 = 3.43 \text{ lb.}$$

Example C

$$6m_x = 3wx^2$$

$$6\bar{m}_x = wx^3; \nu_n = wl^3$$

$$6_x\bar{m} = \frac{wx^4}{4}$$

TABLE IV

r	ω_r	$\Delta\omega_r$	Ω_r	$\Delta\Omega_{r-1}$	Φ_r
3	$\frac{wl^4}{4}$				
2	$\frac{wl^4}{64}$	$\frac{15wl^4}{64}$	$\frac{15wl^3}{32}$	$\frac{7wl^3}{16}$	$\frac{7wl^2}{16}$
1	0	$\frac{wl^4}{64}$	$\frac{wl^3}{32}$		

$$P_1 \frac{3}{2}l + P_2 \frac{l}{4} - 3M_1 - \frac{7}{16}wl^2 = 0 \quad (1) \quad \therefore P_2 = \frac{7}{4}wl + 12 \frac{M_1}{l} - 6P_1$$

$$3M_1 = P_2 \frac{l}{2} - \frac{wl^2}{16} \dots\dots\dots (5) \quad \therefore P_2 = \frac{7}{4}wl + 2P_1 - w \frac{l}{4} - 6P_1 = \frac{3}{2}wl - 4P_1$$

$$3P_1l^2 + \frac{3}{4}P_2l^2 - P_1l + \frac{wl^3}{8} - wl^3 = 0 \quad (6)$$

$$3P_1l + \frac{9}{8}wl^2 - 3P_1l - P_1l + \frac{wl^2}{8} - wl^2 = 0 \quad \therefore P_1 = \frac{1}{4}wl$$

$$P_2 = \frac{1}{2}wl$$

$$P_1 + P_2 + P_3 = wl \dots\dots\dots (3) \quad \therefore P_3 = \frac{1}{4}wl$$

$$M_1 = \frac{wl^2}{24} - \frac{wl^2}{48} \quad M_1 = \frac{wl^2}{48} = M_3$$

PROOF OF FORMULAE

Additional Symbols Required

- y_r = distance below reference of application of constraint P_r (when $P_r=0$)
- k_r = stiffness of constraint P_r
- α_1 } = slope at constraints M_1 & M_n in opposite direction to the direction of the constraints as shown in FIG. 1 (when M_1 & $M_n=0$)
- α_n }
- s_1 } = stiffness of constraints M_1 & M_n
- s_n }
- M_x = total bending moment at x (due to loads and constraints)
- λ_1 & λ_2 = Lagrange undetermined coefficients
- U = strain energy

Vertical balance equation $\sum_{i=1}^{i=n} (P_i) - V = 0 \dots\dots\dots$ I

Moment about line of P_n $\sum_{i=1}^{i=n-1} (P_i b_i) - T_n + M_n - M_1 = 0 \dots\dots\dots$ II

from Castigliano's theorem and from I & II $\frac{\partial U}{\partial P_r} + \frac{\lambda_1}{EI} + \frac{b_r \lambda_2}{EI} = 0 \dots\dots\dots$ (1)

$$\therefore \sum_{i=1}^{i=n-1} \left\{ \int_{l_i}^{l_{i+1}} M_x \frac{\partial M_x}{\partial P_r} dx \right\} + EI(y_r + k_r P_r) + \lambda_1 + b_r \lambda_2 = 0 \dots\dots\dots (2)$$

from $r=1$ to $r=n$

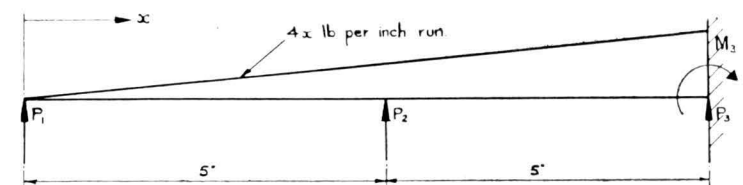


Fig. 5—Final example

where $M_x = m_x + M_1 - \sum_{i=1}^{i=n-1} P_i(x-l_i)$ (3) ignore bracket when negative.

from (3) $\frac{\partial^3 M_x}{\partial P_r \partial x^2}$ and all higher derivatives with respect to x are zero
 \therefore integrating (2) by parts

$$\sum_{i=1}^{i=n-1} \left[\frac{\partial M_x}{\partial P_r} \int M_x dx \right]_{l_i}^{l_{i+1}} - \sum_{i=1}^{i=n-1} \left[\frac{\partial^2 M}{\partial P_r \partial x} \int \int M_x dx dx \right]_{l_i}^{l_{i+1}} + EI(y_r + k_r P_r) + \lambda_1 + b_r \lambda_2 = 0 \dots\dots\dots (4)$$

as $\int M_x dx = \bar{m}_x + M_1 x - \sum_{i=1}^{i=n-1} P_i \frac{(x-l_i)^2}{2} \dots\dots\dots$ (5)

and $\int \int M_x dx dx = \bar{\bar{m}}_x + M_1 \frac{x^2}{2} - \sum_{i=1}^{i=n-1} P_i \frac{(x-l_i)^3}{6} \dots\dots\dots$ (6)

are continuous functions of x

and $\frac{\partial M_x}{\partial P_r} = 0$ or $-(x-l_r)$ between 0 & l_r and l_r & l_n resp.

$\frac{\partial^2 M_x}{\partial P_r \partial x} = 0$ or -1 between 0 & l_r and l_r & l_n resp.

(4) simplifies to $\int_{l_r}^{l_n} \int M_x dx dx - b \int_0^{l_n} M_x dx \dots\dots\dots$ (7)

and substituting from (5) and (6) in (7) and simplifying

$$\sum_{i=1}^{i=r} P_i b_r^2 (3b_i - b_r) + \sum_{i=r+1}^{i=n-1} P_i b_i^2 (3b_r - b_i) - 6 \left\{ b_r (\bar{m}_n + M_1 l_n) - \left(\bar{\bar{m}}_n + M_1 \frac{l_n^2}{2} \right) + \left(\bar{m}_r + M_1 \frac{l_r^2}{2} \right) - EI(y_r + k_r P_r) - \lambda_1 - b_r \lambda_2 \right\} = 0 \dots\dots\dots (8)$$

from $r=1$ to $r=n$
 subtracting r^{th} equation from $r+1^{\text{th}}$ equation, dividing by $(b_{r+1} - b_r)$ again
 subtracting the r^{th} equation from the $r+1^{\text{th}}$ equation, and simplifying by
 putting $r=r-1$; $b_{r+1} - b_{r+2} = d_{r+1}$, and $b_i - b_r = a_r$ we get

$$\sum_{i=1}^{i=r-1} \left\{ P_i (a_{r-1} + a_r + a_{r+1}) \right\} + P_r \frac{(d_r)^2}{D_r} + 6EI \left(\frac{k_{r+1} P_{r+1}}{D_r d_r} - \frac{k_r P_r}{d_r d_{r-1}} + \frac{k_{r-1} P_{r-1}}{D_r d_{r-1}} \right) - 3M_1 - \Phi_r = 0 \quad (9)$$

from $r=2$ to $r=n-1$

for Φ_r see above, but with $\omega_r = 6\bar{m}_r - 6EI y_r$ in the general case.

Equations (9) are $n-2$ in number, and valid for all manner of loading and all kinds of constraints. These have to be used in conjunction with two, three or four additional equations, such as to make the number of equations equal to the number of unknowns in the three different cases as follows:

A. Simply supported

Equation (9) with $M_1=0$, and balance equations I & II with $M_1=M_n=0$

B. Built-in One End (Cantilever)

Equation (9) with $M_1=0$, and balance equations I & II with $M_1=0$ and one more equation derived as follows:
 From Castigliano's theorem and equation II

$$\frac{\partial U}{\partial M_n} + \alpha_n + s_n M_n + \frac{\lambda_2}{EI} = 0 \dots\dots\dots (10)$$

from (2) & (3) $\frac{\partial U}{\partial M_n} = 0 \therefore \lambda_2 = -EI(\alpha_n + s_n M_n) \dots\dots\dots$ (11)

from (8) putting $r=n$
 $EI(y_n + k_n P_n) + \lambda_1 = 0 \therefore \lambda_1 = -EI(y_n + k_n P_n) \dots\dots\dots$ (12)
 substituting (10) & (11) in (8), putting $r=n-1$, and dividing by $(b_{n-1})^2$,

we get

$$\sum_{i=1}^{i=n-1} \left\{ P_i(3b_i - b_{n-1}) \right\} - \frac{6EI}{b_{n-1}} (\alpha_n + s_n M_n) - \frac{6EI}{(b_{n-1})^2} (k_n P_n - k_{n-1} P_{n-1}) - \Gamma_n = 0 \quad (13)$$

C. Built-in at Both Ends

Equation (9), and balance equations I & II, and two more equations derived as follows:

From Castigliano's theorem and equation II

$$\frac{\partial U}{\partial M_1} + \alpha_1 + s_1 M_1 - \frac{\lambda_2}{EI} = 0 \quad (14)$$

$$\int_0^{l_n} M_x \frac{\partial M_x}{\partial M_1} dx + EI(\alpha_1 + s_1 M_1) - \lambda_2 = 0 \quad (15)$$

from (3) $\frac{\partial M_x}{\partial M_1} = 1$, and substituting for λ_2 from (11)

$$\int_0^{l_n} M_x dx + EI(\alpha_1 + \alpha_n) + EI(s_1 M_1 + s_n M_n) = 0 \quad (16)$$

substituting from (5) when $x = l_n = b_1$ we get

$$\sum_{i=1}^{i=n-1} (3P_i b_i^2) - 6M_1 b_1 - 6\bar{m}_n - 6EI(\alpha_1 + \alpha_n) - 6EI(s_1 M_1 + s_n M_n) = 0 \quad (17)$$

from (8) subtracting r^{th} equation from $r+1^{\text{th}}$ equation, dividing by $(b_{r+1} - b_r)$, putting $r=1$, and substituting for λ_2 from (11)

$$\sum_{i=1}^{i=n-1} (3P_i b_i^2) - P_i(b_1 - b_2)^2 - 6 \left\{ (m_n + M_1 b_1) + \frac{(\bar{m}_2 - EI y_2 - EI k_2 P_2 + \frac{1}{2} M_1 l_2^2)}{b_2 - b_1} - \frac{(\bar{m}_1 - EI y_1 - EI k_1 P_1 + \frac{1}{2} M_1 l_1^2)}{b_2 - b_1} + EI(\alpha_n + s_n M_n) \right\} = 0 \quad (18)$$

subtracting (18) from (17), putting $b_2 - b_1 = -d_1$, and simplifying

$$P_1 d_1 - \frac{6EI}{d_1} (\alpha_1 + s_1 M_1) - \frac{6EI}{(d_1)^2} (k_1 P_1 - k_2 P_2) - 3M_1 - \frac{\Omega_1}{d_1} = 0 \quad (19)$$

SUMMARY OF EQUATIONS

Required for all beams

$$\sum_{i=1}^{i=r-1} \left\{ P_i(a_{r-1} + a_r + a_{r+1}) \right\} + P_r \frac{d_r^2}{D_r} + 6EI \left(\frac{k_{r+1} P_{r+1}}{D_r d_r} - \frac{k_r P_r}{d_r d_{r-1}} + \frac{k_{r-1} P_{r-1}}{D_r d_{r-1}} \right) - 3M_1 - \Phi_r = 0$$

from $r=2$ to $r=n-1$

$$\sum_{i=1}^{i=n} (P_i) - V = 0$$

$$\sum_{i=1}^{i=n-1} (P_i b_i) - T_n + M_n - M_1 = 0$$

Required for cantilever

$$\sum_{i=1}^{i=n-1} \left\{ P_i(3b_i - b_{n-1}) \right\} - \frac{6EI}{b_{n-1}} (\alpha_n + s_n M_n) - \frac{6EI}{(b_{n-1})^2} (k_n P_n - k_{n-1} P_{n-1}) - \Gamma_n = 0$$

Required for beams built-in at both ends

$$\sum_{i=1}^{i=n-1} (3P_i b_i^2) - 6M_1 b_1 - \nu_n - 6EI(\alpha_1 + \alpha_n) - 6EI(s_1 M_1 + s_n M_n) = 0$$

$$P_1 d_1 - 3M_1 - \frac{6EI}{d_1} (\alpha_1 + s_1 M_1) - \frac{6EI}{d_1^2} (k_1 P_1 - k_2 P_2) - \frac{\Omega_1}{d_1} = 0$$

Example

$$y_1 = .02 \text{ in.}$$

$$k_1 = .0001 \text{ in./lb.}$$

$$k_2 = .0003 \text{ in./lb.}$$

$$EI = 30 \times 10^6 \text{ lb.-in.}^2$$

$$\alpha_3 = .2 \text{ radians}$$

$$s_3 = .00005 \text{ rad./lb.-in.}$$

$$y_2 = y_3 = k_3 = 0$$

$$6m_x = 4x^3$$

$$6\bar{m}_x = x^4$$

$$6\bar{m}_x - 6EI y_r = \frac{x^5}{5} - 18 \times 10^7 v_r$$

TABLE V

r	ω_r	$\Delta \omega_r$	10,000	6,125	1,225
3	20,000		Ω_r	$\Delta \Omega_{r-1}$	Φ_r
2	625	19,375	3,875	716,250	71,625
1	-3.6×10^6	3,600,625	720,125		

$$15P_1 + 2.5P_2 + 18 \times 10^7 \left(-\frac{.0003P_2}{25} + \frac{.0001P_1}{50} \right) + 71,625 = 0 \quad (9)$$

$$375P_1 - 2,157.5P_2 + 71,625 = 0 \quad \therefore P_2 = 33.3 + .174P_1$$

$$25P_1 + 10P_2 - \frac{18 \times 10^7}{5} (.2 + .00005M_3) - \frac{18 \times 10^7}{25} (-.0003P_2) - 1,225 = 0 \quad (13)$$

$$25P_1 + 2,170P_2 - 1,800M_3 - 7,201,225 = 0 \quad \therefore M_3 = .223P_1 - 3,960$$

$$10P_1 + 5P_2 - 666.7 + M_3 = 0 \quad \text{II}$$

$$10P_1 + 166.5 + .870P_1 - 666.7 + .2237P_1 - 3,960 = 0$$

$$\therefore 11.094P_1 = 4,460.2 \quad \therefore P_1 = 402.5 \text{ lb.}$$

$$P_2 = 33.3 + 70.1 \quad \therefore P_2 = 103.4 \text{ lb.}$$

$$P_1 + P_2 + P_3 = 200 \quad \text{I} \quad \therefore P_3 = -305.9 \text{ lb.}$$

$$M_3 = 90 - 3,960 \quad \therefore M_3 = -3,870 \text{ lb.-in.}$$

TRADE PUBLICATIONS RECEIVED

ME Perspective Drawing Instrument
[The Mollart Engineering Co. Ltd., Kingston By-Pass, Surbiton]

Dowty Miniature Undercarriage Indicator
[Dowty Equipment Ltd., Cheltenham]

Aircraft Stampings in Hiduminium
[High Duty Alloys Ltd., Slough]

Gyro Horizon Type H.L.3

The Sperry Gyrosyn Compass
[The Sperry Gyroscope Co. Ltd., Gt West Road, Brentford]

Avions et Moteurs Italiens
[Associazione Imprese Aeronautiche, Via Cerva 39, Milan, Italy]

Dryclean Air at Constant Pressure
[The Hymatic Engineering Co. Ltd., Redditch, Worcs.]

Dagenite Aircraft Batteries
[Peto & Radford, 50 Grosvenor Gardens, S.W.1]

Eclipse Instrument Vice
[Eclipse, Sheffield]

Masco Industrial Felts
[Mitchells, Ashworth, Stansfield & Co. Ltd., 23/24 Old Bailey, E.C.4]

Nordoil Synthetic Rubbers
[Northern Rubber Co. Ltd., Victoria Works, Retford]

Service to Aviation
Weybridge Fixed Pitch Propellers
[The Aircrew Co. Ltd., Weybridge, Surrey]

Condenser Tube Cleaning
[Kleen-E-Ze Brush Co. Ltd., Hanham, Bristol]

Morrisflex Double Acting Handpiece
[B. O. Morris Ltd., Clay Lane, Stoke, Coventry]

Tube-ability
[Reynolds Tube Co. Ltd., Hay Hall Works, Tyseley, Birmingham, 11]

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[The Mavitta Drafting Machines Ltd., Highlands Road, Shirley, Nr. Birmingham]

Mitia Carbide Tips and Tools Instruction Book
[Firth Brown Tools Ltd., 1 Bessemer Buildings, Carlisle Street, Sheffield]

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[The General Electric Co. Ltd., Magnet House, Kingsway, W.C.2]

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[Steel, Peech & Toyer Ltd., The Ickles, Sheffield]

For Your Information
[British Timber Ltd., Duston, Northampton]

Cylco Components for Aero Engines
Cylco Two-Ton Air Operated Toggle Press
[Cylinder Components Ltd., Lifford Lane, King's Norton, Birmingham]

The Wickman Mobile Demonstration Unit
[A. C. Wickman Ltd., Tile Hill, Coventry]

Fuel Injection Pumps Type H
[Injector Company A.B., Stockholm 20, Sweden]

Aero Research Technical Notes
Bulletin No. 76. The New House of Commons
[Aero Research Ltd., Duxford, Cambs.]

Jessop-Saville Special Alloy and Tool Steels
[William Jessop & Sons Ltd., Brightside Works, Sheffield, 1]

Mercury-in-Steel Thermometers. List T40
[Negretti & Zambra Ltd., 122 Regent Street, W.1]

Precision Hubs
[The David Brown Tool Co., Park Works, Huddersfield]

Airport Lighting Remote Control
[Standard Telephones & Cables Ltd., Oakleigh Road, New Southgate, N.11]

Aluminium Wire and Cable
[Aluminium Wire & Cable Co. Ltd., 10 Buckingham Place, S.W.1]

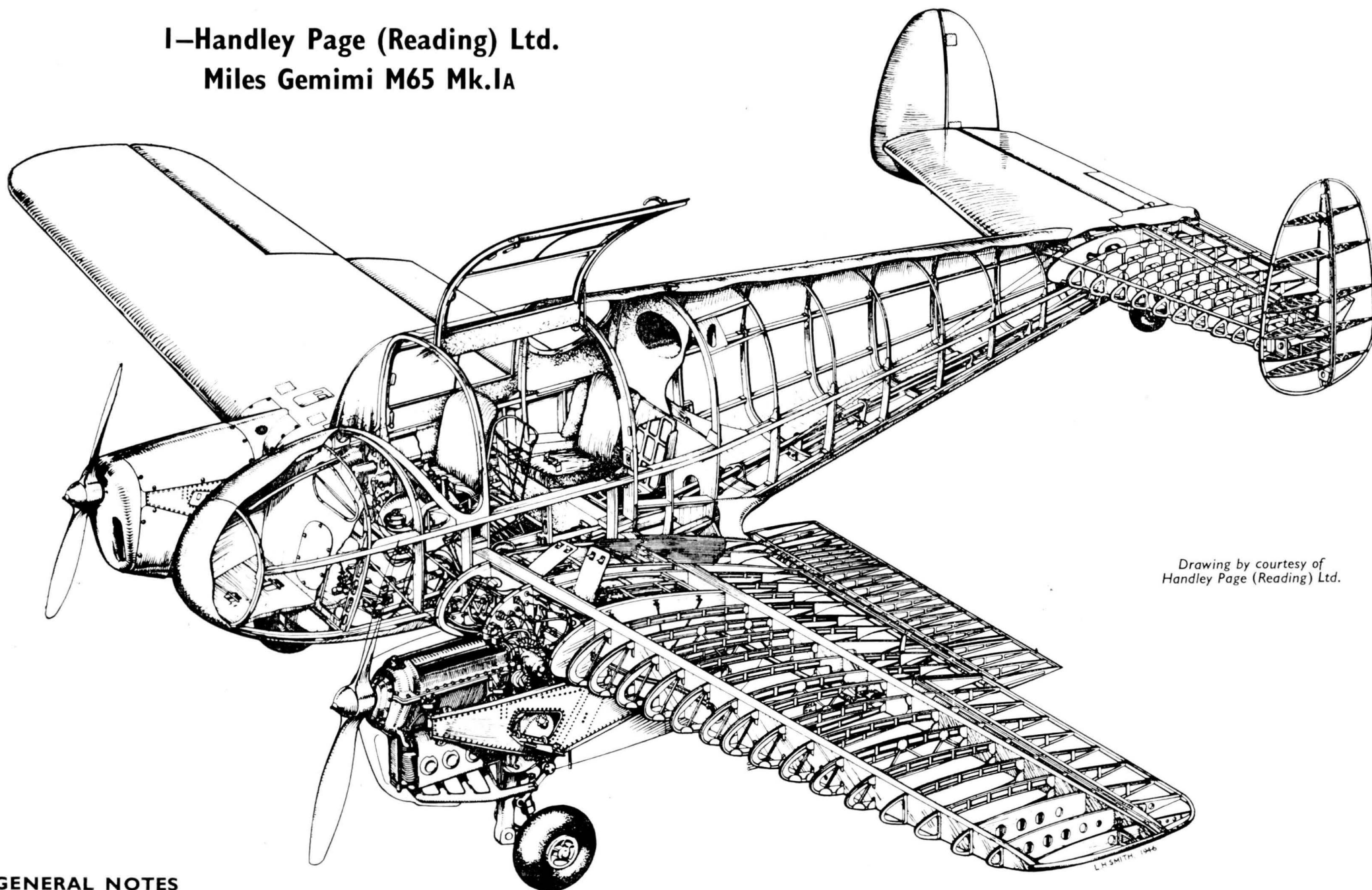
Ex-Panel-Ex Visible Filing System
[Henry Baker Ltd., Ludgate House, Ludgate Circus, E.C.4]

Hadley Industrial Sound Unit
Hadley Multicom
[Hadley Sound Equipment, 587-9 Bearwood Road, Smethwick]

Aircraft Engineering Reference Sheets

Prepared by
T. Tonkin

I—Handley Page (Reading) Ltd.
Miles Gemini M65 Mk.IA



Drawing by courtesy of
Handley Page (Reading) Ltd.

GENERAL NOTES

The Gemini is a four-seater wooden aeroplane designed for service on personal, club or taxi duties. Dual controls can be fitted and glider-towing equipment can also be installed. The data which follow are for the standard model, but various alternative installations and equipment are listed at the end.

PERFORMANCE

Note: The figures given are for an all-up weight of 3,000 lb. and standard propellers.

Take-off run to unstick in dry grass, still air	240 yards
Distance to clear 50 ft. runway	640 yards
Climb:	
Initial, sea level	650 ft./min.
To 5,000 ft.	10 mins.
To 10,000 ft.	28 mins.
Service ceiling	12,800 ft.
Absolute ceiling (two engines)	14,000 ft.
Speeds:	Knots m.p.h. (I.A.S.)
Max. permitted	174 200
Max. level	126 145
Cruising	117 135
Stalling speeds:	
Flaps up, engines off	42 48
Flaps up, engines at full throttle	30 34
Flaps down, engines off	35 40
Flaps down, engines at full throttle	26 30
Landing speed	48-52 55-60
Range, standard tanks	920 miles
Duration	8 hours

Limitations:

- (1) Flaps not to be extended at I.A.S. readings exceeding 80 m.p.h. (69 knots).
- (2) Main wheels not to be lowered at I.A.S. readings above 100 m.p.h. (87 knots).

LOADINGS

Tare weight (approx.) of standard model without radio	1,952 lb.
Maximum permitted all-up weight	3,000 lb.

Disposable load (including fuel and oil)	1,048 lb.
Wing loading	15.7 lb./sq. ft.
Power loading	15 lb./b.h.p.

POWER UNITS

Type	Blackburn Cirrus Minor II
Details	Four cylinder, inverted, in-line, direct geared, unsupercharged and air cooled.
Maximum b.h.p.	100 at 2,600 r.p.m. at sea level
Rated b.h.p.	88 to 92 at 2,300 r.p.m. at sea level

Limiting Conditions

	r.p.m.	cyl.	Temp. Deg. C.
Take-off (min.)	2,185	100	30
Takeoff (max.)	2,300	200	90
Climb (60 mins.)	2,300	200	90
Level flight, emergency (5 mins. max.)	2,600	200	90
Cruising (normal)	2,200/2,300	170	80

Fuel System

Fuel octane rating	73 minimum
Tanks (4) capacity	Inboard 18, Outboard 15, Total 66 imp. gals.

Consumptions (approx.)

	r.p.m.	gals./hr.
Max. take-off	2,300	7.0
Max. climb	2,300	6.0
Cruising, 80% power	2,300	6.0
Emergency max. (5 mins.)	2,600	7.5

Fuel pumps Engine driven Amal duplex type 120/505
Fuel pressure at carburettor inlet 0.5 lb./sq. in. (min.)
Carburettor Zenith downdraught 40FAIHB
Flame trap Amal 88/2850 or 88/1400

Oil System

Oil	Winter D.E.D. 2472A/O Summer D.E.D. 2472B/O Tropical D.E.D. 2472C/O
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Tanks (2) capacity of each	2.5	Air space	0.5
Total effective capacity = 5.0 imp. gals.			

Oil pressures:	
Normal at max. cruising	30-40 lb./sq. in.
Min. in emergency	25 lb./sq. in.

Consumptions of oil

Max. take-off	2
Climb	2
Cruising	0.4 to 2.0
Emergency max.	2.5

Ignition

Magnetos B.T.H. SG4-2 or SG4-5/6 screened

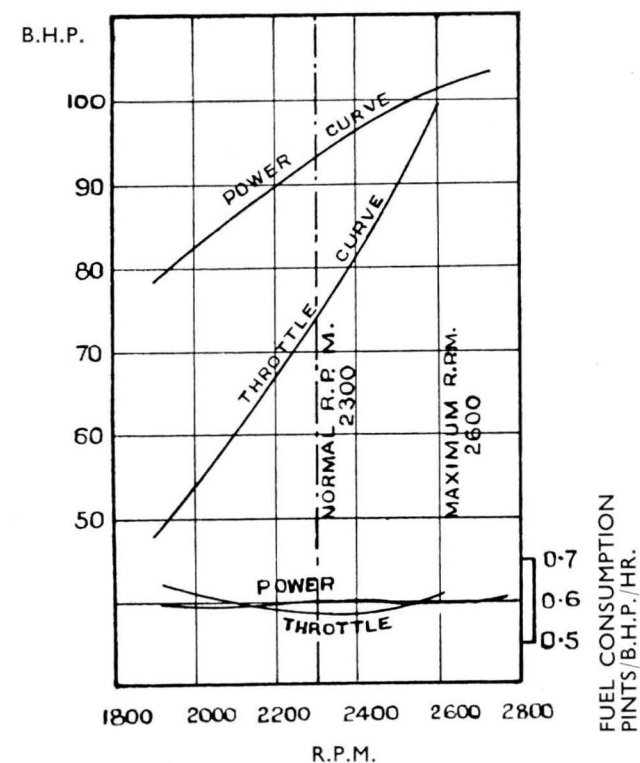


Fig. 1.—Power, throttle and consumption curves—Cirrus Minor II

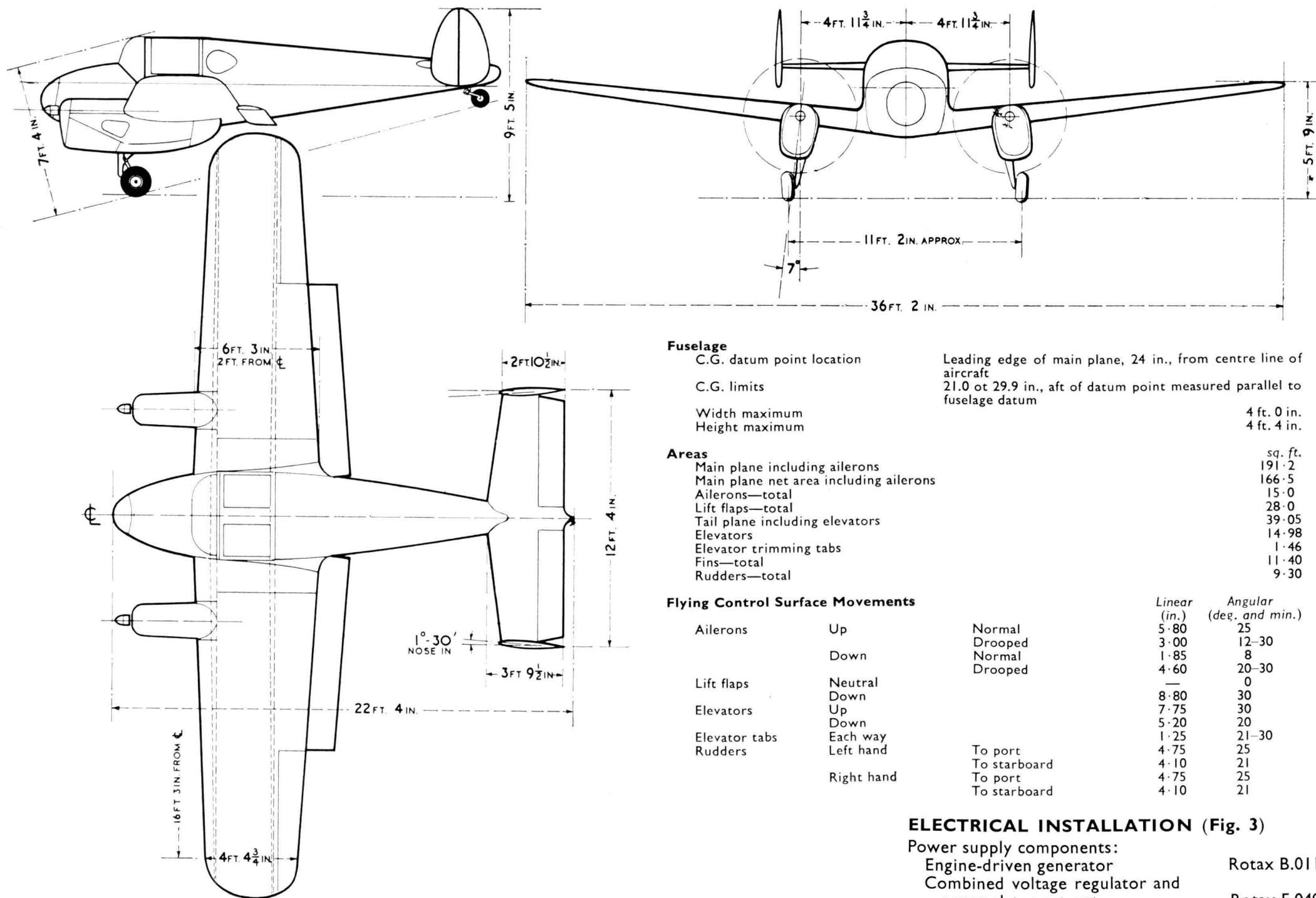


Fig. 2.—Fuel system diagram

1. Vertical vent pipes
2. Drain plugs
3. Starboard fuel cock control
4. Port fuel cock control
5. Filler necks
6. 'Cimatrol' plastic tanks
7. Amal Type 120 engine-driven pumps
- 8 and 9. Sheathed operating cables and pulleys
10. Starboard fuel cock
11. Induction manifold
12. Manifold drain
13. Fuel pump drain

Impulse starters B.T.H. L2C fitted to starboard magnetos
 Sparking plugs KLG RC5/4 or K42/I.R. Lodge RS9/1R.
 Supply Unscreened harness or Plessey type B.123 screened harness

Starters
 Electric motors Rotax N3EY
Engine Life to Overhaul 800 hours

Propellers
 Type Two blade, fixed pitch
 Rotation L.H.T. (anti-clockwise viewed from cabin)

Manufacturer	Drg. No.	Dia. (ft.)	Pitch (ft.)
Aircscrew Co.	Z.5435/1	5.50	4.65
	Z.5701	5.50	4.78
	Z.5702		
	Z.5704	5.50	5.06
Fairey (metal)	A.66619/X1	5.75	5.22
	A.66619/X4	5.75	4.93

AIRFRAME

Main Plane
 Aerofoil sections—root N.A.C.A. 23021
 tip N.A.C.A. 2412
 Incidence root $2^{\circ}+30'-15'$
 tip $1^{\circ}+30'-15'$
 Dihedral—measured 2 ft. outboard from C.L. on top face of front spar $3^{\circ}55'$
 Aspect ratio 6.85

Tail Unit
 Aerofoil section N.A.C.A. 0012
 Incidence $-2^{\circ}\pm 15'$ (with Mod. No. 317)
 $-1^{\circ}\pm 15'$ (pre Mod. No. 317)
 Nil

Alighting Gear
 Type **Main wheels** Separate, retractable, lever suspension
 Miles J.A.R.U. V.4093 oleo-pneumatic
Tail wheel Non-retractable
 Miles U.3801, oleo-pneumatic, fully castoring and self-centring

Shock-absorbers
 Fluid D.T.D.585
 D.T.D.44D
 Air pressure (no load) 400 lb./sq.in.

Wheels Dunlop A.H.8152
 Palmer 871B
 Dunlop A.H.2184/2
 Covers I.A.R.14 PA79 or PB79 T.A.14

Tubes
 6 in. x 6 1/2 in.
 I.A.3 P.A.80 T.A.3

Average air pressure, Wheels on ground, 25-30 lb./sq. in.
 35-40 lb./sq. in. pre Mod. 407
 30 lb./sq. in.
 35 lb./sq. in. with Mod. 407

Brakes
 Type Bendix, cable operated, internal expanding, No. A1959—5 7/8 in. x 1 1/4 in.

Fuselage

C.G. datum point location Leading edge of main plane, 24 in., from centre line of aircraft
 C.G. limits 21.0 or 29.9 in., aft of datum point measured parallel to fuselage datum
 Width maximum 4 ft. 0 in.
 Height maximum 4 ft. 4 in.

Areas

Area	sq. ft.
Main plane including ailerons	191.2
Main plane net area including ailerons	166.5
Ailerons—total	15.0
Lift flaps—total	28.0
Tail plane including elevators	39.05
Elevators	14.98
Elevator trimming tabs	1.46
Fins—total	11.40
Rudders—total	9.30

Flying Control Surface Movements

Control Surface	Movement	Normal	Linear (in.)	Angular (deg. and min.)
Ailerons	Up	Normal	5.80	25
	Down	Drooped	3.00	12-30
Lift flaps	Neutral	Normal	1.85	8
	Down	Drooped	4.60	20-30
Elevators	Up	Normal	8.80	30
	Down	Drooped	7.75	30
Elevator tabs	Each way	Normal	5.20	20
	Left hand	Drooped	1.25	21-30
Rudders	Left hand	To port	4.75	25
		To starboard	4.10	21
	Right hand	To port	4.75	25
		To starboard	4.10	21

ELECTRICAL INSTALLATION (Fig. 3)

Power supply components:
 Engine-driven generator Rotax B.0111
 Combined voltage regulator and accumulator cut-out Rotax F.0404
 Ammeter McMillan type
 Accumulators, two 12V, 25 Ahr. Exide 6FZ11-3
 Line voltage 24
 Wiring Majority of systems Two pole
 Certain circuits Earth return
 Cables Majority single core Unirubber
 Certain circuits Duvin
 Trivin
 Main wheel actuators Miles type E.J.1000

RADIO

Note: Various alternative installations can be supplied to special order. The Handley Page modification number/s relevant to the installation concerned is given hereunder.

Type	Modification numbers
Murphy V.H.F.	27, 339, 375, 417
S.T.R. 9-V.H.F.	154
Marconi-T.R.1196	270
H.F./R.T. radio type S.C.R.274N	355, 378
T.R.1464 radio	385
G.E.C. radio type AS/IB	397
Bendix radio:	
P.A.R.70 Receiver	398
P.A.T.40 M.F. Transmitter	415

INSTRUMENTS

Instrument	Manufacturer	Part No.
Airframe		
Air speed indicator	Smith	118 A.S.
Altimeter	Smith	81 A.M.
Artificial horizon (to special order)	Sperry	—
Clock	Smith	5 A.C.A.
Compass	Hughes	Mk. IIIA
Directional gyro (to special order)	Sperry	—
Elevator tab position indicator	Smith	—
Turn-and-bank indicator	Pullen	R.A.C.4
Engine		
R.p.m. indicators	Smith	82 R.V.
Fuel contents gauge (dual)	McMillan	—
Oil pressure gauge	Smith	282 P.G.
General		
Pitot head	Smith	118 A.S.

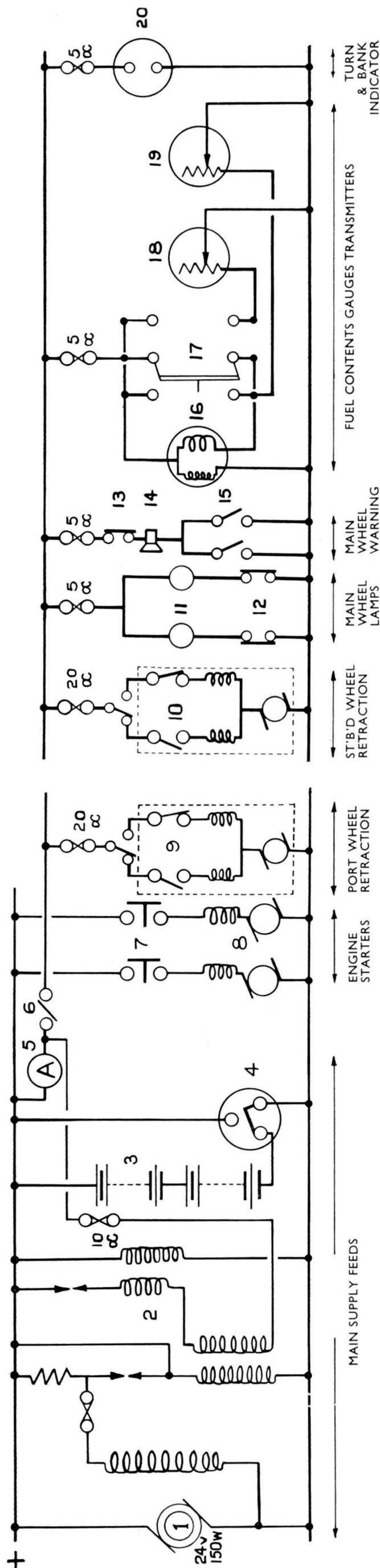


Fig. 3.—Electrical diagram

1. Generator—Rotax type
2. Combined Rotax regulator and accumulator cut-out
3. Exide accumulators
4. B.T.H. external supply socket
5. Ammeter
6. Master switch
7. Starter switches
8. Rotax starter motors
9. Miles actuators
10. Miles actuators
11. Indicator lamp assemblies
12. Inner main wheel micro switches
13. Throttle lever micro switch
14. Warning horn
15. Outer main wheel micro switches
16. Fuel contents gauge
17. Fuel contents gauge selector switch
18. Tank transmitters, inboard tanks only
19. Tank transmitters, inboard tanks only
20. Turn and bank indicator

MISCELLANEOUS

The following additional engine-driven accessories can be fitted to the Cirrus Minor engines:

- | | |
|--------------|------------------|
| Vacuum pumps | Pesco B3X Mk. II |
| | M.0104 or Rotax |
| Compressors | B.T.H. A.V./A. |
| | or |
| | Hymatic S.H.6/2 |
| Generators | Rotax B.0105 |
| | or |
| | Rotax B.1802 |

Possible combinations on any one engine are:

- Fuel pumps, starter, vacuum pump
- Fuel pumps, starter, compressor
- Fuel pumps, starter, generator

NOTES ON STRUCTURE, SYSTEMS AND INSTALLATIONS

Airframe

The Fuselage comprises a front cabin and rear monocoque assembly joined by bolts at five positions at the main plane rear spar. Four spruce longerons support the frames, certain of which are of fabricated construction others being routed from multi-ply. The forward portion of the cabin floor is of multi-ply, while the rear portion is fabricated from an assembly of longitudinal frames and lateral stringers, both portions being covered by ply panels on the upper and lower faces.

The metal nose fairing hinges upward, giving access to a luggage stowage. The rear end of the fuselage terminates in a detachable metal fairing that provides access to the tail wheel attachments and elevator torque shaft.

Main Plane. The continuous wooden main plane spars are of box construction, while the outboard nose ribs are routed from multi-ply and the inboard nose ribs and inter-spar ribs are made from laminated booms with diagonal braces. The fuel tank bay ribs have ply facings to their full depth while the nose ribs, and the spar area in the vicinity of the engine bay are fire-proofed with stainless steel sheet. Light alloy nacelle structures, each bolted to the under surface of the mainplane at six positions, terminate in a detachable rear end fairing giving access to the main wheel retraction mechanism. Splice-jointed ply panels cover the structure, with the exception of the leading edge and wing tip coverings, which are of pre-moulded ply.

The **Aileron** wooden spar has upper and lower booms with a single ply web only, the ribs and trailing edge member being fabricated from solid spruce; the aileron tip is formed by a laminated curved member. A mass balance weight is housed in a channel section cut-out in the bottom face of the spar lower boom, the weight being either a steel strip or square section tube filled with lead. The structure is ply covered.

The **Flaps** are similar in construction to the ailerons, with ply covering. A direct metal position indicator on the outboard end of the port flap projects through the wing.

The one-piece **Tail Plane** is of simple wooden construction, as can be seen from the cut-away drawing. The main spar is of box section at the centre, but outboard the booms are covered on one face only by a ply web. The rear attachment bolts pass through distance tubes held in wooden reinforcing blocks mounted between the spar booms, the fins being secured in a similar manner at the extremities of the spar.

Elevators, Fins and Rudders have their spar members covered on one face only with ply. All structures are covered by ply, including the elevator trimming tabs, the latter being secured to the elevators by butt-type hinges.

Undercarriage Main Wheel Units are shown diagrammatically in Fig. 4. They retract rearward into

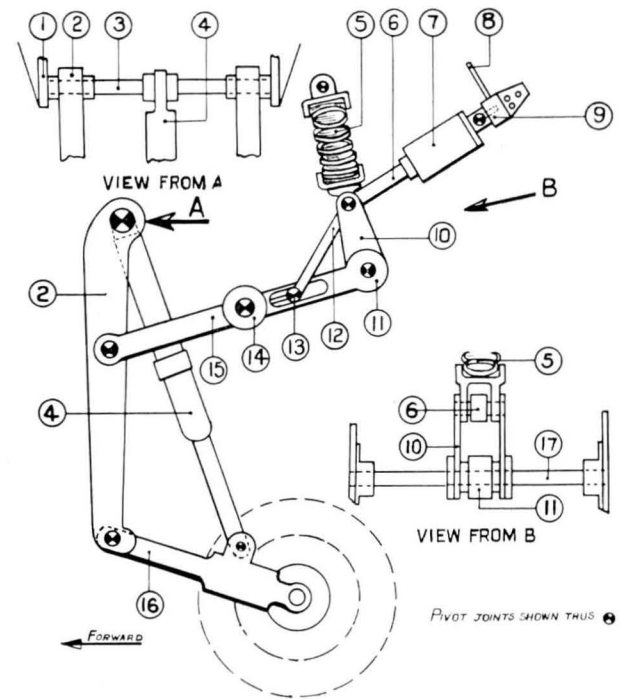


Fig. 4.—Diagram of main wheel unit

1. Nacelle structure
2. Main forks
3. Front cross shaft
4. Shock absorber
5. Compression spring
6. Actuator piston
7. Electric actuator
8. Lock release cable
9. Mechanical lock for emergency release
10. Pivot torque brackets connecting 6 to 12
11. Single upper folding stay
12. Control plunger operating rod
13. Down lock control plunger sliding in recess in upper folding stay
14. Down lock and knuckle joint
15. Lower forked folding stay
16. Lever arm
17. Rear cross shaft

the nacelles, being operated by an electric actuator, which, in conjunction with a strong compression spring retains the legs in the retracted position. Mechanical locks at the knuckle joints secure the legs in the lowered position. In an emergency the legs can be lowered by operating a cabin cable control which releases the rear end of the actuator from a mechanical lock in which it is normally held. This permits the legs to fall by gravity and lock down. Micro switches wired in series with a throttle switch give an electrically-controlled cabin indication of the main wheel position.

Retraction of piston 6 pivots 10 rearward causing 12 to pull 13 out of engagement with 14. Continued movement of 6 causes 13 to reach the upper end of the slot in 11 so that 11 is pulled to pivot upwards about 17. The lower stay 15 is also pulled thereby pivoting 2 and 16 rearward and upward about 3 thus retracting the assembly into the nacelle. Limit switches within 7 determine the stroke of piston 6. When retracted, the spring 5 presses on 10 (now pivoted forward) and so assists in retaining the units in the retracted position.

Main Wheel Shock Absorbers (Fig. 6) are of the oleo-pneumatic type, the fluid and air being completely isolated. Initial air pressure balances the static weight of the aircraft, further movement under load causing the piston, circular orifice flanges and flutter ring to move upward. There are eight holes in the flanges, but fluid passes through the holes in the lower flange only and is restricted, thereby absorbing the initial loads imposed on landing. Continued upward movement further compresses the air which, with the restricted fluid flow finally damps the shock. Relief of the imposed load causes the compressed air to force the piston and flutter ring downward, fluid passing, in the opposite direction, through the holes in the upper flange. The area of the holes controls the rate of fluid flow and therefore the rate of extension or compression of the strut.

The **Tail Wheel Shock Absorber** (Fig. 7) is also of the oleo-pneumatic type and embodies a self-centring mechanism and lever suspension. Shock absorption is effected by a conventional spring loaded flutter valve assembly. The self-centring mechanism consists of two rollers on the cylinder tube which contact a cam formation at the lower end of the attachment tube. Rotation of the cylinder, caused by deflexion of the wheel fork, results in the rollers following the cam face, thereby raising or lowering the cylinder relative to the attachment tube. This vertical movement is controlled by the strong centralizing spring which returns the cylinder and wheel fork to a fore-and-aft alignment.

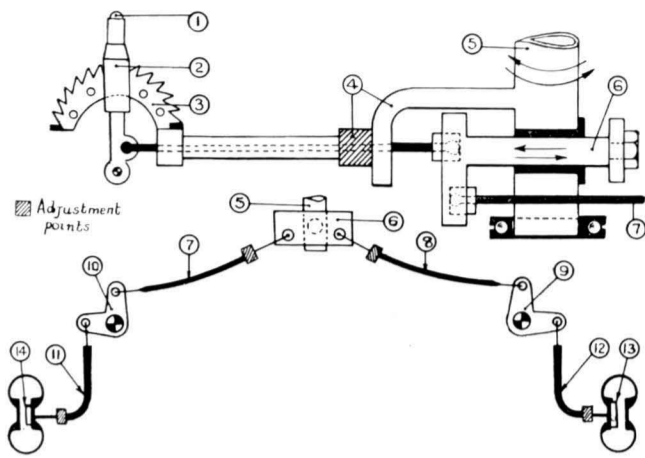


Fig. 5.—Brake system diagram

1. Parking plunger and pawl
2. Control lever
3. Quadrant ratchet
4. Bowden cables, control lever to differential and adjuster cable stop on differential—all in cabin
5. Rudder bar pillar extension
6. Sliding T-piece plunger
7. Bowden cable to port bell crank
8. Bowden cable to starboard bell crank
- 9 and 10. Starboard and port bell cranks on main plane front spar
- 11 and 12. Bowden cables, bell cranks to wheel units via nacelle and main wheel support member
- 13 and 14. Bendix brake units in wheels

The Brake System comprises an operating handle and ratchet assembly, embodying a spring-loaded plunger in the handle for parking purposes, a Bowden type cable run, a differential assembly at the base of the rudder bar pillar and a pair of conventional Bendix type wheel brake units. The system is shown diagrammatically below.

Flying Control Systems

Ailerons. The control column is linked to a torque tube mounted in bearings secured to the front and rear spars of the main plane. These bearings support the torque tube and control column, rotation of the torque tube being transmitted by the rocking lever, at the end of the torque tube and the control tubes to the differential lever. The differential lever actuates the aileron via the short operating tube and pivots about a bearing at the end of the flap interconnecting lever, the latter being secured to, but free to pivot about a bearing on the main plane.

The interconnexion of the aileron and flaps is a feature of the Gemini aircraft which allows the ailerons to be drooped by an amount proportional to the movement of the flaps. If so desired, the interconnexion can be removed by embodiment of Handley Page Mod. No. 223.

Flaps: Rotation of the handwheel sprocket causes the chain, passing under pulleys, to rotate the sprocket on the right and left hand threaded screw jack barrel. Threaded plungers in engagement with the barrel move the tubes in the main plane to pivot the link plate thereby actuating the lift flap through the adjustable operating tube. This movement is also transmitted by the tube between the link plate and aileron/flap interconnecting lever.

Elevators: Movement of the control column actuates a square section tube, which slides longitudinally within the torque shaft, so pushing or pulling the fuselage control tubes to rotate the cross-shaft which joins the elevators.

Rudders: The rudder bar is provided with parallel motion links and is adjustable for leg reach by a Bowden cable connected to a cabin control knob. Movement of the rudder bar is transmitted by the fuselage tubes to the vertical torque tube beneath the tail plane from which transverse tubes connect to the rudder actuating levers.

Elevator Trimming Tabs: Rotation of the handwheel sprocket is transmitted to a screw jack, similar

in principle to the flap jack, via a chain and cable run. From the ends of the screw jack barrels movement is transmitted by Bowden cables to the tabs, the system being completed by a balance cable between the tabs which is not in direct connexion with the screw jack.

Air Operated Instrument Systems

The pitot head, mounted under the port main plane, is connected by light alloy pressure and static tubes, which pass along the front face of the main plane front spar, to the air operated instruments on the panel. At the rear of the panel the pressure tube is connected by braided rubber hose to the A.S.I., the light alloy static tube being connected to a duralumin T-piece. The branches of this T-piece are connected to the static unions of the air-speed indicator and altimeter. Moisture drain traps are provided at the port root end of the main plane.

Engine

Fuel System: Each tank is mounted between the main plane spars and interspar ribs and is secured by fabric tapes, pins and bungee tensioning cords. There are three tapes, secured to the top of each tank by an adhesive compound, the ends of each tape passing through slots cut in the rib facings. Bungee cords are connected by kite cord, at each side of the tank, to the ends of the tapes, the three bungees converging to a common attachment plate, mounted on the lower booms of the adjacent tank ribs.

The plug type fuel cocks are mounted on brackets secured to the first port and starboard nose ribs, the cocks being actuated by a pulley and cable system from the co-axial rod and tube cabin control.

Pipes used in the system include wire wound flexible pipes and metal tubing.

Early installations were provided with electrical contents gauge transmitter units in the inboard tanks only, but later installations are fitted with transmitter units in all tanks. All earlier installations are being brought to the latest standard by the embodiment of Mod. No. 114.

Oil System: The aluminium oil tanks, secured by steel straps to the lower end of the fireproof bulkhead,

contain a perforated semi-circular oil return diffuser channel bolted to the front internal face of the tank. This channel directs hot return oil on to the internal supply pipe and also over the surface of the oil in the tank. The tank is provided with an external vent pipe and a drain plug.

From the tank a flexible supply pipe connects to the engine, the main return pipe being of light alloy. The system also embodies an Auto Klean filter in the pressure line and a metal and flexible pipe run to the cabin oil pressure gauge.

Engine Controls

Throttle: The inner lever in the cabin hand control box operates the throttle of the starboard engine via a vertically mounted adjustable ended rod which is connected to a bell crank situated on the forward face of the port side front spar adjacent to the first nose rib. A Teleflex cable connected to the bell crank passes across the fuselage, beneath the floor and along the forward face of fuselage frame 3, to enter the starboard side of the main plane leading edge. Continuing along the forward face of the starboard plane front spar via swivel joints, the cable connects to a bell crank lever mounted at the forward end of the engine nacelle from which an adjustable ended rod connects to the linkage of the starboard engine.

The outer lever in the cabin box controls the port engine throttle via a short run of adjustable ended rods and two bell cranks. A single friction adjuster is provided for the two cabin control levers and the throttle micro switch, associated with the main wheel retraction, is mounted adjacent to and contacts with the inboard bell crank lever on the starboard side.

Mixture: The engine mixture control levers are locked in the rich position.

Fuel Pump and Carburettor Priming: Bowden cables connected to the two cabin priming controls pass through each side of the lower portion of the cabin and along the forward face of the front spar to toggles on junction plates positioned on the spar face at the rear of the engine installation. Twin cables are connected to the toggles, one cable being linked to the fuel pump priming levers and the second to the carburettor tickler lever on each engine. The levers are spring loaded to ensure their return to the normal position.

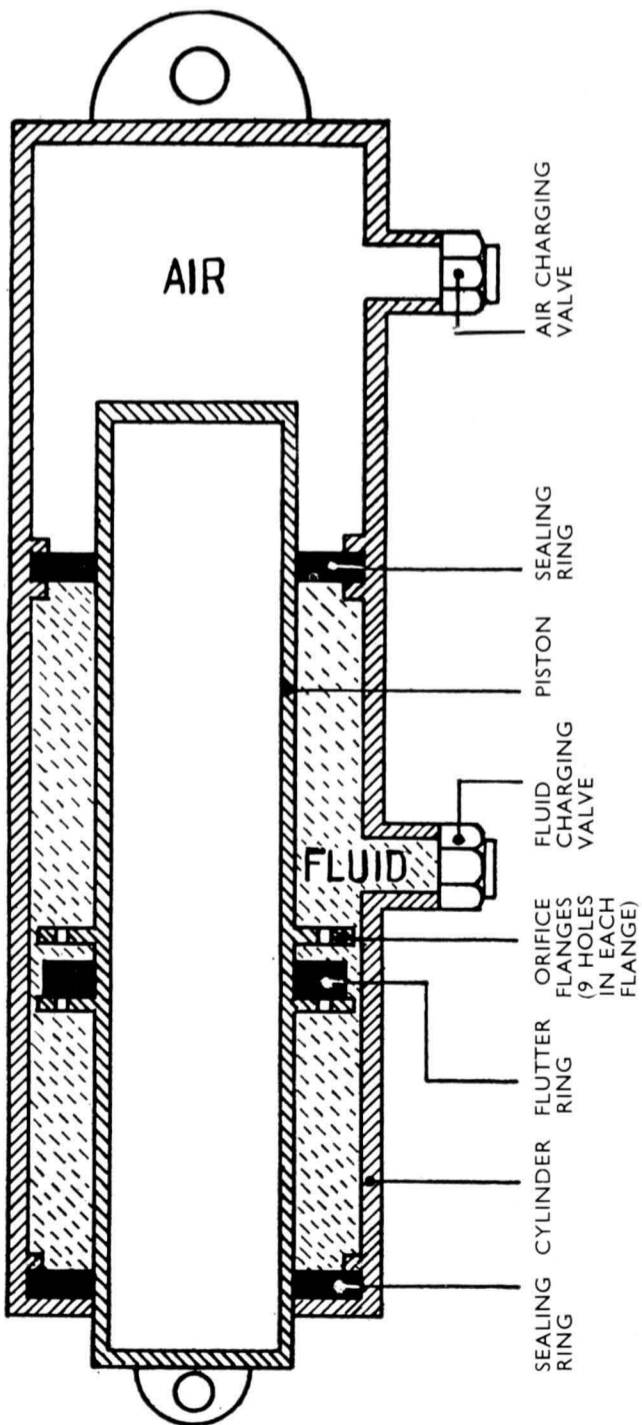


Fig. 6.—Main wheel shock absorber strut

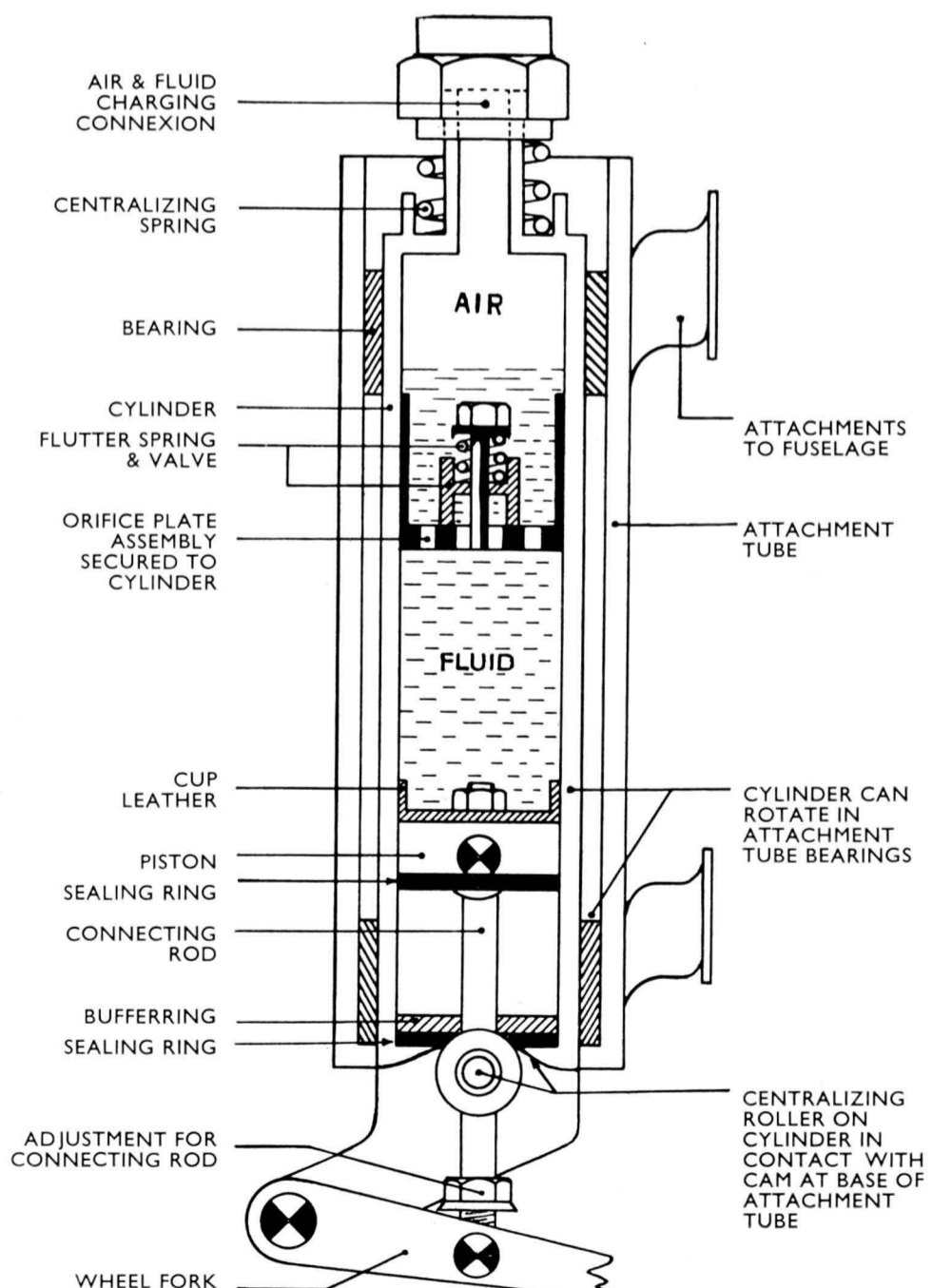
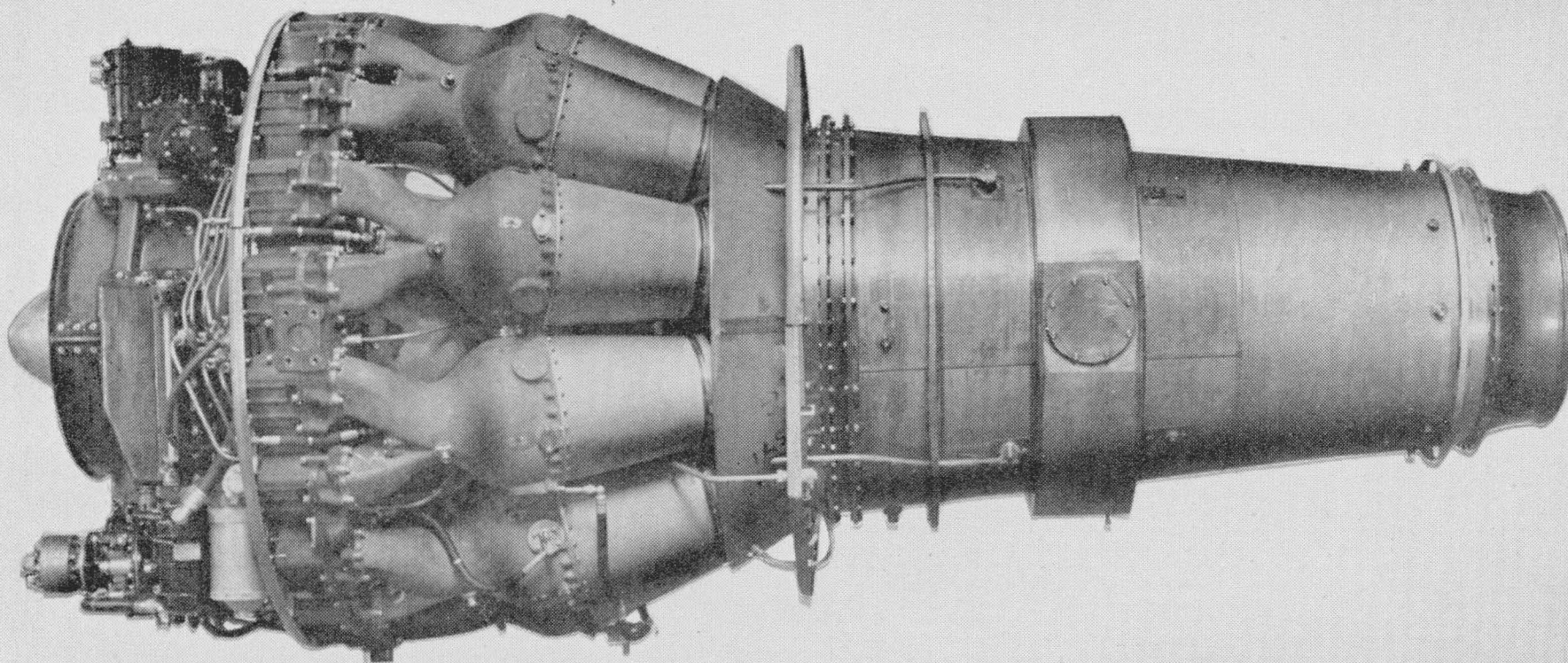


Fig. 7.—Diagram of tail-wheel shock-absorber

G H O S T

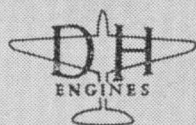
5,000 lb. static thrust



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The Library Shelf

Experimental Stress Analysis—Compressible Fluid

Curves—The Movement of Heat—Gas

Turbines—British Steels

Proceedings of the Society for Experimental Stress Analysis. Vol. VI, Nos. I and II. (Addison-Wesley Press, Kendall Square Building, Cambridge, Mass, U.S.A. \$6.0 each.)

The latest two sets of Proceedings of the above Society contain a useful variety of papers; there are five papers on photoelastic matters, nine on electrical resistance strain-gauge work, six on various aspects of dynamic or shock loading and ten on miscellaneous subjects. In each class the papers may be divided into two categories; those in which the main interest lies in the development of technique, and those in which technique *per se* takes second place and the chief interest lies in the problem to which the technique is applied. It is probably fitting that papers for a Society ostensibly devoted to 'experimental stress analysis' should have a preponderating number in the first category, and this indeed is what we find; for four out of the five papers on photoelastic matter deal essentially with technique, as do five out of six of the dynamic loading papers and seven (or eight) out of the ten miscellaneous papers. The exception is the set of papers on the use of the resistance strain-gauge, where only four out of nine are preoccupied with the development of technique. The inference is that strain-gauge technique is gradually becoming standardized, but that the techniques of photoelasticity and of dynamic load measurement are still in the process of active development. One cannot refrain from speculating whether, one of these days, when all current methods have been standardized, the Society, now so virile, may not die from lack of proper nourishment apart from an occasional morsel in the form of a miscellaneous paper; for papers whose main interest does not lie in the experimental technique employed belong by rights to the particular learned Society in whose field the problem presents itself.

To turn to a more detailed consideration of the set of papers collected in these two volumes, one notes that three of the papers concerned with photoelasticity describe new materials from which to make the experimental models. One of these materials called 'Fosterite' has the great advantage of not developing the 'time-stresses' to which present materials are addicted; it also enables a very satisfactory degree of accuracy to be obtained. The other material—Columbia Resin C.R.39—while not so useful for obtaining absolute values of stress gives a faithful picture of relative stresses in the test specimen. A fourth paper gives an admirable account of the building up of a new laboratory for photoelastic work and of the various factors that have to be weighed up in the process; the paper itself and the discussion that follows it should most certainly be read by anyone contemplating the setting up of such a laboratory.

Of the four papers on resistance strain-gauge work that are mainly concerned with technique, one deals with the merits of the direct coupled amplifier for measuring dynamic strain, and another describes an instrument for measuring the curvature of a sheet in three directions at any point on its surface, thus enabling the bending moment to be obtained and hence, with the aid of gauges on one side only (the other being inaccessible), the strain in the middle surface and the resultant stress. A third paper shows how, by sticking gauges to the thin walls of a small duralumin cylinder stressed only by its own inertia load

during acceleration, a compact accelerometer with a frequency range of 20-5,000 c.p.s. has been successfully made. The fourth paper presents some useful charts that enable any prospective user of resistance gauges to choose the type best suited to his purpose.

Of the five papers in which technique is not the primary interest, one describes an interesting experiment in which a successful attempt was made to measure, by means of well-protected resistance gauges, the stress changes in the steel reinforcing rods of a concrete highway produced by weather changes. Another gives an account of a stress survey round the shell of a 48 ft. dia. Hortonsphere on the neighbourhood of its eight support columns. A third gives an example of design by the process of trial and error for structures in which calculation cannot be relied upon—a tentative design is successively modified in the light of successive sets of strain measurements. One of the remaining two papers deals with the stress distribution in monocoque structures, and shows how the neutral axis position as given by ordinary engineering theory is affected by skin buckling. The subject of the last of this group of five papers is the residual stress in rolled sheet, and how its amount is affected by the percentage change of thickness per pass.

Among the half-dozen papers on dynamic or shock loading, one is devoted to the measurement of transient stresses in an aeroplane wing model and to a comparison of the results obtained with computed values. Agreement is not too good, and the reviewer suggests that this may be caused by the use of unsuitable analytical methods that have been superseded by parallel British work in this field. In this connexion it is a fair criticism, and one that has been voiced in other recent reviews of American books, that there is a strong tendency among American authors to confine all references to American work. The other five papers deal principally with technique; one describes various methods of simulating the different kinds of shock to which naval weapons and their operating mechanisms are subject on board ship, and the remaining papers are concerned with the interpretation of dynamic loads in terms of equivalent plain static loads that produce the same maximum stress. There is little new about these last except the detailed presentation.

Of the miscellaneous papers perhaps the most interesting for aeronautical engineers are the two papers on stress estimation from strains beyond the elastic range. Two other papers on the use of easily deformable models of frame structures are also not without aeronautical applications and remind one of the work done on such lines for many years past under the aegis of Professor Pippard at Imperial College.

D. W.

Computation Curves for Compressible Fluid Problems. By C. L. Dailey and F. C. Wood. [John Wiley (Chapman & Hall). 12s.]

In problems of compressible flow, especially where high accuracy is not necessary, the various functions required can often be obtained more conveniently from graphs than from tables. In this book some of the most useful graphs for solution of these problems are collected together, with a short introduction explaining the physical principles on which the graphs are based.

The first five graphs give the pressure, density, temperature, and area ratios for isentropic flow. These are followed by three graphs giving functions that can be used for calculating the flow in a channel of constant area with the addition of heat. The next ten graphs give the properties of normal and oblique plane shock waves, enabling quantities such as the pressure ratio, density ratio, gain of entropy, wave angle, and final Mach number to be found from the initial Mach number and angle of deflexion. Another graph gives the relation between Mach number and angle of deflexion in a Prandtl-Meyer expansion. The remaining thirteen graphs give the properties of supersonic flow past cones. The first five of these enable the stagnation pressure ratio across the shock wave and the pressure, velocity and Mach number on the surface of the cone to be found from the angle of the cone and the Mach number of the undisturbed flow. The remaining eight graphs give functions from which the pressure and stream direction at any point in the field can be found. In a book of this size it would not be possible to include all the graphs that might be required, but some additional curves giving dynamic pressure and pressure coefficient in terms of Mach number and absolute pressure would have been useful.

The theory given in the introduction is clearly set out and adequate for the purpose of explaining the meaning and limitations of the curves. All the graphs are drawn for Mach numbers up to 4 and the scales are chosen so that the accuracy obtainable in most of the quantities is of the order of 1 per cent. The value assumed for γ is 1.400 except in the section on flow past cones where 1.405 is used. This inconsistency apparently occurs because the M.I.T. Tables, which had already been computed for $\gamma=1.405$, were used in preparing the graphs on flow past cones. The effect of this small change of γ is probably not important, however, within the limits of accuracy given by these graphs. Some curves for lower values of γ are also included in the section on energy relations.

The book is bound in a thin cardboard cover with the metal ring type of binding, allowing the pages to lie flat. Unfortunately, the graphs are printed on rather thin paper and most of them are folded. This means that they are not likely to withstand frequent use without tearing, either at the metal rings or at the fold, and also it is difficult to make the graphs lie flat after they have been unfolded. These defects are compensated to some extent by the fairly low price (12s.).

W. A. M.

Thermocinetique (P.S.T. No. 224, Service de Documentation et d'Information Technique, Ministère de l'Air). By P. Vernotte. [Magasin C.T.O., 2 Rue de la Porte d'Issy, Paris. 1,200 francs.]

Just as in the study of mechanics, kinematics precedes dynamics, so the author of this volume asserts that thermokinetics is an essential prelude to thermodynamics. It considers the movement of heat and is a subject which has had little attention, with the result that many misconceptions and errors in thermodynamics have arisen.

The author has set out to review the fundamentals of heat flow and some of their practical applications in a very detailed manner. He has approached them from the point of view of a pure physicist and consequently his arguments and philosophy may not always appeal to the engineer. They are, however, in some parts strikingly well illustrated and both simple and brief in exposing assumptions, while in others they are both long and tedious. This may be, in part, due to a desire to avoid too much use of mathematics. Nevertheless, it is inevitable that in a treatise of this sort a considerable amount of mathematics should appear. Where it does it is commendably clear.

The book, published in French, has three main

divisions covering the introduction to thermokinetics, the development of its principles, and their applications. The first part gives a résumé of the classical theory of heat transmission as developed by mathematicians and physicists such as Fourier and Laplace and brings in the modern notion of molecular transmission. The second part treats comparatively briefly the simple cases of heat transmission under steady conditions and then passes to considerations of the more difficult cases of variable states in finite and infinite bodies. In these cases the importance of the time element is stressed and many original ideas are introduced. These should be particularly useful in considering, for example, the effect of sudden contact of flame upon the combustion chamber walls of a rocket or internal combustion engine. A great deal of emphasis is placed upon very small differences of temperature within a body or fluid and the difficulties arising from them in practice. This leads on to the third part of the work which considers chiefly the problems of the determination of thermal conductivity. The approximations and corrections involved are mainly of academic interest, but some of the points, such as those indicating the order of errors introduced in temperature measurements by thermocouples with thick or thin wires, and good or bad thermal contact with the object being measured, etc., are of practical value.

While the book has many stimulating thoughts and ideas, these are often so overshadowed by long discussions that they may not be fully appreciated except by the most thorough reader. It is not a work to recommend to the average engineer engaged upon the normal thermodynamic problems of aero-engines in spite of the author's assertions, but it does offer some help to those who may be involved in heat flow calculations involving time as a variable, or for those considering precise measurements on heat.

The decimal system of numbering paragraphs has been adopted and while this assists the author in referring back, it does tend to break down the coherent flow of the discussion and is not of great value to the reader. A preferable division would have been into chapters and a valuable addition would have been chapter summaries.

A. D. BAXTER

An Introduction to the Gas Turbine. By D. G. Shepherd. [Constable. 24s.]

Since the gas turbine first became a subject of general study, numerous papers have been published covering both its broad design features and its many specialist sections, but there have been few attempts to digest and collect them into a convenient single volume. Such a volume is particularly required by the student and may equally be of value to the specialist, who too frequently is amazingly ignorant of the repercussion of his work upon other aspects.

The work under review should be welcomed as a creditable effort to meet this requirement. It is a carefully-written and well set-out book and deals with the various sections of the subject in a logical manner. Its three main divisions cover gas theory and the basic cycles, the major turbine components and their functioning, and complete power plants. These are treated in a comprehensive manner and, although most of the design information is based on aircraft gas turbine experience, the presentation gives a more general picture and includes all the more common cycles and component designs likely to be met in industrial applications. It is to be regretted, however, that this appears to have resulted in some important aero aspects being dismissed with no more than a passing reference. One could have wished, for instance, to see at least a brief discussion on propeller turbines and afterburning for jet thrust boosting.

Such omissions may have been necessary to keep the book within reasonable space limitations, but would have been unnecessary if so much space had not been devoted to elementary prin-

ciples. In the chapters on combustion and heat exchanges nearly 50 per cent of the matter is standard information without any direct reference to gas turbines. Much of this could have been avoided by assuming a certain elementary standard of knowledge on the part of the reader and giving references to the normal sources of such information for inclusion in the excellent bibliographies already included at the end of each chapter. Some inconsistency in this assumption of the readers' technical level is apparent. He is, for example, given a full discussion in the first chapter of basic thermodynamics, which leads up to the consideration of gas turbine cycles in chapter iii. This chapter gives a wide review of the effects of heat exchange, intercooling and re-heat on performance, but leaves the beginner rather at a loss as to how to determine their relative values for himself. In some degree this is remedied by two brief practical examples in an appendix, but a more generous use of numerical examples throughout the book would have been more in keeping with the introductory paragraphs of each chapter.

There are other instances where the author forgets that his readers are being introduced to the subject and are not as well versed in it as himself. These and minor faults such as the sudden change from quoting air/fuel ratios to curves giving fuel/air ratios may prove disturbing to those who are unfamiliar with gas turbine technology. Little fault can be found with the chapters on the compressor and turbine which are well illustrated with diagrams and figures. The same, however, cannot be said for the treatment of secondary components such as starters, fuel systems and other mechanical features which are dismissed with most unsatisfying brevity.

These do not detract unduly from the value of the book which is, in every way, a useful addition to the subject.

A. D. BAXTER

BRITISH STANDARD SPECIFICATIONS

B.S. Handbook No. 10—British Standards for Steel and Steel Products. (British Standards Institution, 28 Victoria Street, S.W.1. 25s.)

The intention of this handbook has been to present a comprehensive picture of the whole field of British steel products, and to give in summarized form all the standards that apply to them. Its compilation has been a co-operative effort of the whole of the British steel industry, acting through an editorial committee under the chairmanship of Mr Sinclair Kerr of the Lancashire Steel Corporation and Mr T. Jolly of Guest, Keen and Baldwin's Ltd.

There are three main parts to the book, and an index. The parts are:

- (1) Articles describing the manufacture of steel and of steel products. pp. 9 to 214
- (2) Classified summaries of the essential technical requirements of British standards for steel and steel products. pp. 216 to 594
- (3) Other information of general interest; e.g. methods of test, heat treatment definitions and conversion factors. pp. 596 to 662

The first part starts with a section of Notes on the Making and Using of Steels, which covers a brief explanation of the essentials of steelmaking, the meaning of such technical terms as 'rimming' and 'killed' steels, some factors to be borne in mind in the selection of a steel, and its heat treatment and ruling section.

There follow 17 sections on various steel products. In each the manufacturing techniques are briefly described, and the applications and the dimensional and other limitations of the available products are discussed and illustrated and as far as possible defined.

These sections deal with: steel castings; blooms, billets, slabs and sheet bars; forgings; drop forgings; plates; sheets; tinplate; terneplate and blackplate; hot and cold rolled steel strip; hot rolled bars and sections; bright steel bars; steel

tubes; wire and wire products; tool steels; rails; steel sleepers; railway wheels, tyres and axles; steel supports for use in mines.

These are followed by a section of Notes on wrought Steels (*En* series). This section provides an exhaustive discussion of the range of wrought steels detailed in BS 970, and their respective uses.

It is in this part of the handbook that most of the illustrations are placed. There are 27 illustrations, for example, of various kinds of steel castings, 17 of forgings, 5 illustrating section and bar rolling processes and so on.

The second part of the book summarizes the great number of British Standards that have been drawn up for British steel and steel products. For convenience these are grouped into 15 sections, as follows: steels for general engineering—bars, billets, drop forgings and forgings, sheet and strip, castings; steels for electrical engineering; structural steel, including sections; steels for ships; pressure vessels materials; gas cylinders; railway materials; tramway materials; aircraft materials; colliery materials; tubes and tubular products; wire and wire products; rivets, bolts, nuts and fastenings.

These are followed by a list of British Standards on welding or which include requirements on welding.

The final part of the book assembles much information about British Standards relevant to the subject, but usually found scattered in various publications. In 12 sections various tensile, bend, cupping, impact, hardness and proof tests are detailed, and there are notes on chemical analysis, British and Continental test pieces, the correlation of Izod and Charpy test results and various other matters. There are also sections of heat treatment terms and definitions, and many tables of conversion factors.

BOOKS RECEIVED

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

La Production d'Energie Electrique a Bord des Avions. H. Lanoy. Paper bound. 154 pages, illustrated. [Edition Desforges, 29 Quai des Grands-Augustins, Paris VI. 750 francs.]

Rocket Propulsion Elements. G. P. Sutton. 294 pages, illustrated. [John Wiley (Chapman & Hall). 27s.]

The Complete Handyman. 576 pages, illustrated. [Odhams Press. 8s. 6d.]

The Hornsby-Akroyd Engine and Later Developments in the Heavy Oil Engine. [Fourteenth Herbert Akroyd Stuart Lecture, 1949.] T. Hornbuckle. Paper bound. 18 pages. [The University, Nottingham, 1s. 6d.]

Deisel Vehicle. Operation, Maintenance and Repair. Fifth Edition. F. J. Camm. 107 pages, illustrated. (George Newnes. 6s.)

The Home Workshop. 384 pages, illustrated. (Odhams. 8s. 6d.)

The Quarterly Journal of Mechanics and Applied Mechanics. Vol. II, Part 2, June 1949. [Oxford University Press. 12s. 6d.]

Dynamic Principles of Mechanics. D. R. Inglis. 174 pages, illustrated. [The Blakiston Company, Philadelphia, U.S.A. No price stated.]

Berlin Air Lift. Dudley Barker. Paper bound, 66 pages, illustrated. [H.M. Stationery Office. 1s. 6d.]

Wind at 100,000 ft. over South-East England. R. J. Murgatroyd. Paper bound, 14 pages, illustrated. [H.M. Stationery Office. 6d.]

Atlas of Isothermal Transformation Diagrams of B.S. EN Steels. 63 pages, illustrated. [The British Iron and Steel Research Association, 4 Grosvenor Gardens, S.W.1. 25s.]

The Fundamentals of Gas Turbine Technology. W. R. Thomson. 148 pages, illustrated. [Power Jets (Research and Development) Ltd., 25 Green Street, W.1. 26s.]

Australian Aviation Annual. Edited by S. Brogden. 173 pages. [S. Brogden, P.O. Box 34, Hawthorn, E.2, Melbourne. No price stated.]

Research Reports and Memoranda

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

SWEDEN

ROYAL INSTITUTE OF TECHNOLOGY
DIVISION OF AERONAUTICS

Stockholm

TECHNICAL NOTES

KTH-AERO TN 1. Composition and Properties of the Atmosphere. By T. Gullstrand. (*In Swedish.*)

No English summary is included and we have unfortunately, been unable to have one specially made.

KTH-AERO TN 2. An Investigation of the Effect of Boundary Layer Suction on the Air Resistance in Channel Elbows. By H. O. Palme. (*In English.*)

The aims of this investigation were:

1. A qualitative study of the effect of various parameters, especially boundary layer suction, on the flow losses in curved channels.

2. A quantitative determination of the loss factors for the elbow, the necessary quantity of suction air and suction power for boundary layer suction, etc., in a number of typical cases.

This has been carried out mainly by means of experiments. These have shown that boundary layer suction is a suitable means of reducing the losses in curved channels and that the losses can then be as low as 2 or 3 per cent of the kinetic energy of the air. These losses are of the same order as the friction losses in a straight channel of the same length. The necessary power for suction of the boundary layer is so great, however, that the total energy consumption (i.e. losses plus suction power) are roughly constant and equal to the losses in an elbow without boundary layer suction. The tests have shown that the most difficult problem to master is the elimination of the losses which arise as a result of the secondary flow occurring at the flat sides of the bend. General principles for the solution of this problem are given.

Literature studies have indicated a method of obtaining small losses without the use of boundary layer suction or guide vanes, by expanding the cross-sectional area at the middle of the bend. A theoretical method of calculating such elbows has also been obtained from previous literature. An elbow designed according to this method gave losses of about 6 per cent in tests without boundary layer suction.

Certain theoretical calculations are made. Satisfactory agreement is obtained between these calculated values and those measured on test. Calculations of this type, together with some of the experimental results, could therefore be a basis for the design of elbows. Principles for the practical construction of duct bends and application of boundary layer suction have thus been worked out and are given at the end of the report.

FRANCE

OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AERONAUTIQUES

3 Rue Léon Bonnat, Paris

PUBLICATIONS

No. 21. Description Technique de l'Equilibreur Pseudyn. (Technical Description of the Pseudyn Balancing Machine.) By G. de Vries and J. Rost.

After recalling the different types of airscrew unbalance, the authors describe the various methods of balancing. The simplest and cheapest method is said to be the pseudodynamic method employing the Pseudyn apparatus which is described in detail, is entirely mechanical in operation, and is designed to check and correct the airscrew in flight. It may be applied to all airscrews.

No. 22. Synthèse sur la Question des Micro-Vibrations d'Avions dues en particulier aux Couples Moteur-Hélice. (Study of the Problem of Micro-Vibrations of Aircraft due particularly to Engine-Airscrew Moments.) By G. de Vries.

This report is devoted to a study of micro-vibrations, their causes and effects and the possibility of eliminating them by reducing the vibrations themselves or their effects. Of the two sources of excitation, the airscrew is regarded as most important, and results are reported of tests made with the Pseudyn apparatus.

August 1949

With regard to the psychological aspects (pilot's judgment, etc.) the author has reviewed the published works and indicated the differences between laboratory test results and the results of tests based on experience gained in flight.

FRANCE

PUBLICATIONS SCIENTIFIQUES ET TECHNIQUES DU MINISTERE DE L'AIR

Magasin C.T.O., 2 Rue de la Porte d'Issy, Paris XV

RAPPORTS

No. 224. Thermocinetique. (The Movement of Heat.) By P. Vernotte. (1,200 francs.)

(See review on p. 259).

CANADA

NATIONAL RESEARCH COUNCIL

Ottawa

AERONAUTICAL NOTES

AN-3. A Method of Measuring Vertical Velocity Immediately Before Landing. By A. D. Wood.

A method is described for measuring the vertical velocity of an aircraft immediately before landing. Some results are included of a series of landings made on dry and snow-covered runways. Accuracy of vertical velocity determination on a 95 per cent probability basis is estimated to be ± 9 per cent on rolled snow and ± 6 per cent on a tarmac or concrete surface.

AN-4 1949. The Available Theoretical Analyses of Two-Dimensional Cascade Flow. By R. A. Tyler.

Many mathematical analyses exist of the two-dimensional potential flow past infinite cascades of aerofoils. Both the direct problem of ascertaining the potential flow past a given cascade of aerofoils and the inverse problem of deriving the aerofoil shape required to provide a given pressure distribution in cascade have been attacked. The methods available for the first problem may be categorized as those that provide exact solutions for special classes of shapes; e.g. straight blades of zero thickness, those that provide, with relatively little labour, a very approximate answer to the general problem of a cascade of arbitrary aerofoils, and lastly those methods which attempt an exact solution of the general problem. The labour involved in the application of the methods of the latter class is naturally great, increasing with the degree of accuracy required, and depending also on the nature of the aerofoil section and the cascade geometry.

The results of this category, however, because of their generality, are the most valuable theoretically and the description of these methods in particular is the main purpose of this note, which forms the first section of a general review (now in preparation) of the currently available data in the general field of axial flow compressor design. This section is included for completeness to form the initial stage in a logical progression through experimental two- and three-dimensional stationary cascade data to the theoretical and experimental analysis of the behaviour of rows of compressor blades rotating in association with rows of stator blades in one or more stages.

AN-5 1949. A Theoretical Survey of Induced Vertical Velocity in Front of an Aircraft Wing. By M. M. Callan.

A calculation of induced vertical velocity in front of wings with rectangular and elliptic loading was made, for the purpose of finding a suitable position for mounting an angle of incidence indicator on a glider. Charts were compiled for certain spanwise stations which will give downwash contours where the downwash is small, and also, for different positions of the instrument on the glider, the downwash at the indicator as angle of incidence changes.

U.S.A.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL MEMORANDA (TRANSLATIONS)
Secretary, N.A.C.A., Washington, D.C.

No. 1205. Exact Calculation of Laminar Boundary Layer in Longitudinal Flow over a Flat Plate with Homogeneous Suction. ('Exakte Berechnung der laminaren Grenzschicht an der längsängestromten ebenen Platte mit homogener Absaugung.' Schriften der Deutschen Akademie der Luftfahrtforschung, Band 8 B, Heft 1, 1944. Report of the Mathematical Institute of the Technical Academy Braunschweig. Presented to the German Academy of Aviation Research by the corresponding member Hermann Schlichting on January 26, 1944.) By Rudolf Iglisch.

A general calculation method is given with which to determine the boundary layer developing along an infinitely extended flat plate under the influence of an arbitrary suction or blowing law. For the special case of homogeneous suction the numerical calculation of the velocity within the boundary layer is performed completely.

No. 1212. On the Theory of the Laval Nozzle. ('K Teorii Sopla Lavala.' Prikladnaya Matematika i Mekhanika. Vol. 10, no. 4, 1946, pp. 503-512.) By S. V. Falkovich.

Presents an investigation of a plane streamline flow of a gas in a Laval nozzle in the vicinity of the transition line (sound line) between the subsonic and supersonic velocities. The investigation rests on the basic equations of motion.

An analysis of the mathematical solution leads to the conclusion that the point of intersection of the axis of symmetry of the nozzle and the sound line is a singular point. The Frankl results presented are thus obtained by a simpler method.

No. 1217. Lecture Series 'Boundary Layer Theory'. Part I—Laminar Flows. ('Vortragsreihe "Grenzschichttheorie". Teil A: Laminare Strömungen.' Zentrale für wissenschaftliches Berichtswesen der Luftfahrtforschung des Generalluftzeugmeisters (ZWB) Berlin-Adlershof, pp. 1-153. Given in the Winter Semester 1941[42] at the Luftfahrtforschungsanstalt Hermann Göring, Braunschweig. The original language version of this report is divided into two main parts, Teil A and Teil B, which have been translated as separate N.A.C.A. Technical Memoranda, Nos. 1217 and 1218, designated Part I and Part II respectively.) By H. Schlichting.

The flow of laminar viscous fluids is treated in detail. Most of the known exact solutions of the Navier-Stokes equations are presented together with various approximate solutions of the equations. The Prandtl boundary-layer theory is developed in detail and examples of applications to flows of importance in aeronautics are given.

No. 1218. Lecture Series 'Boundary Layer Theory'. Part II—Turbulent Flows. ('Vortragsreihe "Grenzschichttheorie". Teil B: Turbulente Strömungen.' Zentrale für wissenschaftliches Berichtswesen der Luftfahrtforschung des Generalluftzeugmeisters (ZWB) Berlin-Adlershof, pp. 154-279. The original language version of this report is divided into two main parts, Teil A and Teil B, which have been translated as separate N.A.C.A. Technical Memoranda, Nos. 1217 and 1218, designated Part I and Part II, respectively. This report is a continuation of the lecture series presented in Part I, the equations, figures, and tables being numbered in sequence from the first part of the report. For general information on the series, reference should be made to the preface and the introduction of Part I.) By H. Schlichting.

The subject of turbulent flow is treated in detail. The available data on flow through pipes and over flat plates are presented. Turbulent wakes and jets are treated by means of the Prandtl mixing length theory. A section is devoted to the Gruschwitz method for calculating turbulent boundary layers in accelerated and retarded flows.

The methods of Betz and Jones for determining profile drag from wake surveys are given.

A chapter on the theory of the stability of the laminar boundary layer, developed from the point of view of small oscillations, is also included.

U.S.A.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL REPORTS

1945

Report No. 824. Summary of Airfoil Data. By Ira H. Abbott, Albert E. von Doenhoff and Louis S. Stivers, Jr. (1 Dollar 50 Cents)

Recent aerofoil data for both flight and wind-tunnel tests have been collected and correlated in so far as

possible. The flight data consist largely of drag measurements made by the wake-survey method. Most of the data on aerofoil section characteristics were obtained in the Langley two-dimensional low-turbulence pressure tunnel. Detail data necessary for the application of N.A.C.A. 6-series aerofoils to wing design are presented in supplementary figures, together with recent data for the N.A.C.A. 00-, 14-, 24-, 44- and 230-series. The general methods used to derive the basic thickness forms for N.A.C.A. 6- and 7-series and their corresponding pressure distributions are presented. Data and methods are given for rapidly obtaining the approximate pressure distributions for N.A.C.A. four-digit, five-digit, 6- and 7-series aerofoils.

The report includes an analysis of the lift, drag, pitching-moment, and critical-speed characteristics of the aerofoils, together with a discussion of the effects of surface conditions. Data on high-lift devices are presented. Problems associated with lateral-control devices, leading-edge air intakes, and interference are briefly discussed. The data indicate that the effects of surface condition on the lift and drag characteristics are at least as large as the effects of the aerofoil shape and must be considered in aerofoil selection and the prediction of wing characteristics. Aerofoils permitting extensive laminar flow, such as the N.A.C.A. 6-series, have much lower drag coefficients at high speed and cruising lift coefficients than earlier types if, and only if, the wing surfaces are sufficiently smooth and fair. The N.A.C.A. 6-series also have favourable critical-speed characteristics and do not appear to present unusual problems associated with the application of high-lift and lateral-control devices.

1946

Report No. 851. Thin Oblique Airfoils at Supersonic Speed. By Robert T. Jones. (15 cents.)

The well-known methods of thin-aerofoil theory have been extended to oblique or sweptback aerofoils of finite aspect ratio moving at supersonic speeds. The cases considered thus far are symmetrical aerofoils at zero lift having plan forms bounded by straight lines. Because of the conical form of the elementary flow fields, the results are comparable in simplicity to the results of the two-dimensional thin-aerofoil theory for subsonic speeds.

In the case of untapered aerofoils swept back behind the Mach cone the pressure distribution at the centre section is similar to that given by the Ackeret theory for a straight aerofoil. With increasing distance from the centre section the distribution approaches the form given by the subsonic-flow theory. The pressure drag is concentrated chiefly at the centre section and on long wings a slight negative drag may appear on outboard sections.

Report No. 852. Flight Investigation at High Speeds of the Drag of Three Aerofoils and a Circular Cylinder Representing Full-scale Propeller Shanks. By William H. Barlow. (15 cents.)

Tests have been made at high speeds to determine the drag of models, simulating propeller shanks, in the form of a circular cylinder and three aerofoils, the N.A.C.A. 16-025, the N.A.C.A. 16-040, and the N.A.C.A. 16-040 with a rear 25 per cent chord cut off. All the models had a maximum thickness of $4\frac{1}{2}$ inches to conform with average propeller-shank dimensions and a span of $20\frac{1}{2}$ inches. For the tests the models were supported perpendicular to the lower surface of the wing of an XP-51 aeroplane. A wake-survey rake mounted below the wing directly behind the models was used to determine profile drag at Mach numbers of 0.3 to 0.8 over a small range of angle of attack. The drag of the cylinder was also determined from pressure-distribution and force measurements.

The results of the tests indicated that the drag of the aerofoils was lower than that of the cylinder over the Mach number range investigated. The drag reduction obtainable through the use of these aerofoil sections in place of a round shank increased with a decrease in aerofoil thickness ratio and reached maximum values at a Mach number of 0.63 for the N.A.C.A. 16-040 aerofoils and 0.71 for the N.A.C.A. 16-025 aerofoil.

Report No. 853. Cylinder-Temperature Correlation of a Single-Cylinder Liquid-Cooled Engine. By Benjamin Pinkel, Eugene J. Manganiello, and Everett Bernardo. (15 cents.)

An analysis based on non-boiling forced-convection heat-transfer theory is made of the cooling processes in liquid-cooled engine cylinders. Semi-empirical equations that relate the average head and barrel temperatures with the primary engine and coolant parameters are derived.

A correlation method based on these equations is applied to data obtained from previously reported investigations, which were conducted over large ranges of engine and coolant conditions with two liquid-cooled cylinders using water and various aqueous ethylene glycol solutions as coolants. Upon evaluation of empirical factors, an equation for the cylinder-head temperature as a function of the engine operating conditions and the flow rate, temperature, and physical properties of the coolants is obtained, which represents the data with good accuracy. A similar equation is obtained for the barrel-temperature data. The physical properties of the coolant appearing in these equations in order of their importance in determining the heat-transfer quality of the coolant are thermal conductivity, specific heat, and viscosity. The cooling performance of the various coolants investigated is adequately correlated by these physical properties in the correlation equation. The application of the correlation equation is, however, limited to conditions for which boiling of the coolant on the engine walls is an unimportant part of the cooling process.

Report No. 854. Compressibility Effects on the Longitudinal Stability and Control of a Pursuit-type Aeroplane as Measured in Flight. By William N. Turner, Paul J. Steffen, and Lawrence A. Clousing. (15 cents.)

Measurements of the longitudinal stability and control of a pursuit-type aeroplane were made in flight up to a Mach number of 0.78. The data are presented in the form of curves showing the variation, with centre-of-gravity position, dynamic pressure, and Mach number, of the stick-fixed and stick-free stability, control, and balance of the aeroplane.

It was found that large increases in stability occurred at high Mach numbers, reducing the controllability of the aeroplane. Large increases in diving moment were also encountered at high Mach numbers and moderate lift coefficients. These changes were caused almost entirely by increases in the tail angle of attack and the rate of change of tail angle of incidence with aeroplane lift coefficient resulting from the shock-stalling of the wing. An increment of stalling moment, however, was encountered at high Mach numbers and very low lift coefficients, apparently caused by a negative shift in the aeroplane angle of zero lift.

Distortion of the elevator fabric at high speeds, but not necessarily high Mach numbers, caused the stick-free neutral point as measured in steady straight flight to move far rearward and increased the stick-force gradient in accelerated flight.

Report No. 856. The N.A.C.A. High-Speed Motion-Picture Camera Optical Compensation at 40,000 Photographs per second. By Cearcy D. Miller. (15 cents.)

The principle of operation of the N.A.C.A. high-speed camera is completely explained. This camera, operating at the rate of 40,000 photographs per second, took the photographs presented in numerous N.A.C.A. reports concerning combustion, pre-ignition, and knock in the spark-ignition engine.

Many design details are presented and discussed, but details of an entirely conventional nature are omitted. The inherent aberrations of the camera are discussed and partly evaluated. The focal-plane-shutter effect of the camera is explained. Photographs of the camera are presented. Some high-speed motion pictures of familiar objects—photoflash bulb, firecrackers, camera shutter—are reproduced as an illustration of the quality of the photographs taken by the camera.

Report No. 857. Analysis of Spark-Ignition Engine Knock as seen in Photographs taken at 200,000 Frames per second. By Cearcy D. Miller, H. Lowell Olsen, Walter O. Logan, Jr., and Gordon E. Osterstrom. (15 cents.)

A motion picture of the development of knock in a spark-ignition engine is presented, which consists of 20 photographs taken at intervals of 5 microseconds, or at a rate of 200,000 photographs per second, with an equivalent wide-open exposure time of 6.4 microseconds for each photograph. A motion picture of a complete combustion process, including the development of knock, taken at the rate of 40,000 photographs per second is also presented to assist the reader in orienting the photographs of the knock development taken at 200,000 frames per second.

The photographs taken at 200,000 frames per second are analysed and the conclusion is made that the type of knock in the spark-ignition engine in-

volving violent gas vibration originates as a self-propagating disturbance starting at a point in the burning or auto-igniting gases and spreading out from that point through the incompletely burned gases at a rate as high as 6,800 feet per second, or about twice the speed of sound in the burned gases. Apparent formation of free carbon particles in both the burning and the burned gas is observed within 10 microseconds after passage of the knock disturbance through the gases.

Report No. 858. Comparison of several methods of Predicting the Pressure Loss at Altitude Across a Baffled Aero-Engine Cylinder. By Joseph Neustein and Louis J. Schafer, Jr. (15 cents.)

Several methods of predicting the compressible-flow pressure loss across a baffled aero-engine cylinder were analytically related and were experimentally investigated on a typical air-cooled aero-engine cylinder. Tests with and without heat transfer covered a wide range of cooling-air flows and simulated altitudes from sea level to 40,000 feet.

Both the analysis and the test results showed that the method based on the density determined by the static pressure and the stagnation temperature at the baffle exit gave results comparable with those obtained from methods derived by one-dimensional-flow theory. The method based on a characteristic Mach number, although related analytically to one-dimensional-flow theory, was found impractical in the present tests because of the difficulty encountered in defining the proper characteristic state of the cooling air.

Although the cylinder-baffle resistance coefficient determined by the density method was consistent for wide range of heat-transfer values, a distinct difference was observed between the values with and without heat transfer that could not be explained by one-dimensional flow theory. Accurate predictions of altitude pressure loss can apparently be made by these methods provided that they are based on the results of sea-level tests with heat transfer.

Report No. 860. Analysis of Cooling Limitations and Effect of Engine-Cooling Improvements on Level-Flight Cruising Performance of Four-Engine Heavy Bomber. By Frank E. Marble, Mahlon A. Miller and E. Barton Bell. (15 cents.)

The N.A.C.A. has developed means, including an injection impeller and ducted head baffles, to improve the cooling characteristics of the 3,350-cubic-inch-displacement radial engines installed in a four-engine heavy bomber. The improvements afforded proper cooling of the rear-row exhaust-valve seats for a wide range of cowl-flap angles, mixture strengths, and aeroplane speeds. The results of flight tests with this aeroplane are used as a basis for a study to determine the manner and the extent to which the aeroplane performance was limited by engine cooling. By means of this analysis for both the standard aeroplane and the aeroplane with engine-cooling modifications, comparison of the specific range at particular conditions and comparison of the cruising-performance limitations were made.

The analysis of level-flight cruising performance of the aeroplane with both the standard- and the modified-engine installations indicated that the maximum cruising economy is attained at the minimum brake specific fuel consumption when engine cooling under these conditions is possible. Operation at lean mixtures, high altitudes, and large gross weights was limited for the standard aeroplane by engine cooling at the point where larger cowl-flap openings increase the power required for level flight at such a rate that the additional cooling air available is insufficient to cool the engine when developing the additional power. When cooling becomes impossible at the minimum brake specific fuel consumption, the maximum cruising economy is obtained with a cowl-flap angle of approximately 5° and with the leanest mixture (above the stoichiometric value) giving satisfactory engine cooling.

Comparison of the calculated performance of the standard and the modified aeroplane indicated that cooling improvements increased the maximum specific range as much as 38 per cent for operation where wide cowl-flap angles and enriched mixtures are required to cool the standard aeroplane. Corresponding increases in cruising range were calculated for flights in which conditions allowing large increases in cruising economy were encountered. The cooling improvements allow either an increase of more than 10,000 feet in operating altitude at a given aeroplane weight or a gross-weight increase of from 10,000 pounds at sea level to 35,000 pounds at all operating altitudes above 10,000 feet.

**GREAT BRITAIN
AERONAUTICAL RESEARCH COUNCIL**

H.M. Stationery Office, London

R. & M. No. 2341. Body Interference on a Tractor Propeller. The Results of 24 ft. Tunnel Model Tests. By R. J. Monaghan. May 1946. (2s. 6d.)

The aim of these model tests, made in the R.A.E. 24 ft. tunnel, was to compare the interference effects of the 1,500 h.p. electric motor nacelle and of a radial engine nacelle (Mercury) on the performance of a typical propeller.

Unfortunately the experimental accuracy which could be achieved was not so high as had been hoped, but the results give the following indications:

1. At blade angles up to 35 deg. a correction to J of 3 per cent is about sufficient to account for changes in power absorption. This would confirm previous theoretical results reproduced in Fig. 9.

2. Although the thrust results are not considered reliable, the values at the lowest blade setting (15 deg.) would indicate that the same J correction might account for thrust differences below the stall, i.e. the combined effects of other factors (such as increased drag in slipstream, spoiling drag, etc.) would appear to be about the same for either nacelle.

R. & M. No. 2313. A Statistical Note on the Variation of Porosity of Nylon Fabric to Specification D.T.D. 556A. By A. Glaskin. June, 1945. (2s. 6d.)

This note describes the tests which have been made in order to carry out a statistical investigation of the variation of porosity of Nylon Fabric to Specification D.T.D. 556A as used in man-carrying parachutes.

A large number of high-pressure porosity measurements have been made on Twill and Plain Weave Nylon samples and it has been found that, in general, the porosity across the width of a piece of fabric, along a line parallel to the weft threads, increases

from a minimum value at the selvedge to a maximum at the centre of the width. The difference between these minimum and maximum values are large compared with the overall range of porosity for the fabric. The variation is such that the mean porosity at a distance of 9 inches from the selvedge is very close to the overall mean porosity.

The variation of porosity along the length of a piece of fabric, at a constant distance from the selvedge, is very nearly the same at all positions from the selvedge.

It has been found that the porosity readings for each type of fabric obey the Normal Distribution Law and in accordance with this law, the standard error of the mean obtained from a number of random readings is inversely proportional to the square root of the number of readings.

It is shown that little advantage is gained in taking the mean of more than ten random readings on a sample or parachute in order to assess the mean porosity of the sample or parachute.

R. & M. No. 2266. Measurements of Bending Moment on a Model Tailless Glider Wing. By P. R. Owen, H. V. Becker and C. H. Bethwaite. March 1946. (2s.)

Bending moment at the wing root and total lift have been measured on a model wing for the General Aircraft tailless glider (V plan form and 28.4 deg. sweepback). The tests included measurements of the effects of flap and elevon deflection and of end fins. The span loading due to incidence has been deduced from the results.

The bending moments and span loading have been compared with estimates based on Schrenk's approximate method and in some cases with Falkner's more rigorous method. Schrenk's method appears, on the whole, to be reliable enough for a first estimate of load distribution in the early stages of design and to

show the effects of major modifications on wings of not too large sweepback. For a final estimate Falkner's method is more accurate.

**THE COLLEGE OF AERONAUTICS
Cranfield, Bletchley, Bucks**

Report No. 26. March, 1949. On the Natural Frequencies of a Reinforced Circular Cylinder. By W. S. Hemp.

This report is concerned with the calculation of the natural frequencies of an ideal structure somewhat representative of an aircraft fuselage. The results are based upon a simplified 'shell' theory which permits proper allowance to be made for the shear stresses and the corresponding displacements. No use is made of the so-called 'shear deflexion', but it is shown in the Appendix that, for the special case considered, this approach would yield the same answer. Numerical results are given and comparison is made with both the usual beam theory results and the frequencies calculated on the assumption that flexibility in shear is of primary importance.

Report No. 27. April, 1949. Some Related Oscillation Problems. By W. J. Duncan.

Two simple means for establishing a relation between a pair of oscillation problems are briefly discussed. In the first, the displacements are connected by use of a differential operator. The set of natural frequencies is identical for the two problems and results of interest are obtained when the transformed boundary conditions can be physically interpreted. In this manner it is shown, for example, that a flywheel on a uniform shaft can be transformed into a flexible coupling and a mass carried on a uniform beam into a flexible hinge. In the second, the connexion is established by use of the concept of mechanical admittance. Here the frequency equations are simply related but the frequencies are not.

Professional Publications

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

The Royal Aeronautical Society

JOURNAL (Monthly)

Vol. 53, No. 462, June 1949

French Practical Aerodynamic Methods (Second Louis Bleriot Lecture). J. Brocard and F. Hussenot.

Flutter and Stability. W. J. Duncan.

The General Theory of Cylindrical and Conical Tubes under Torsion and Bending Loads—Part IV Concluded. J. Hadji-Argyris and P. C. Dunne.

Vol. 53, No. 463, July 1949

The Aeronautical Research Scene—Goals, Methods and Accomplishments (37th Wilbur Wright Memorial Lecture). H. L. Dryden.

Planned Servicing in the Royal Air Force. Sq.-Ldr. F. A. Harrop.

L'Office National d'Etudes et de Recherches Aéronautiques (France)

LA RECHERCHE AERONAUTIQUE (Alternate months)

1949, No. 9, May-June

Les Alliages Légers à Haute Résistance. A. Guinier.

Oscillateurs Electroniques pour Systèmes de Télécommande et Télémétrie. G. Lehmann.

Oscillateurs à Résistances et Capacités. J. Zakheim.

Critère de Stabilité pour des Equations Caractéristiques à Coefficients Réels ou Complexes. A. Hermann and J. M. Soureau.

Dosage du Plomb Tétrahyde dans les Combustibles. R. Lautie and M. Sarrat.

Propriétés Mécaniques du Nylon aux Faibles Humidités. J. Beaudoux.

Etudes des Régimes Transitoires en Aérodynamique Supersonique à Deux Dimensions. C. Roumieu.

Un Extensomètre Euregirteur. M. Bassier.

La Haute Atmosphère. J. Delarbre.

Captation par un Corps de Révolution: Application à la Sphère. M. Vasseur.

No. 10, July-August 1949

Soufflerie Sonique de l'Institut de Mécanique des Fluides de Lille. G. Gontier

Sur la Stabilité des Mouvements qui Commencent sans Glissement. R. Mazet

Etude Métallurgique de Quelques Points de Soudure sur Tôles Védal de 1 mm. d'Épaisseur. L. Pelletier

Flutter en Régime Supersonique. R. Weber and W. Ruppel

Altérations Systematiques Écartant la Verticale Apparente de la Verticale Vraie à Bord d'un Mobile. J. Bouzitat

Chambre Sonore par une Source Ponctuelle en Mouvement Rectiligne Uniforme dans un Fluide Parfait, Spécialement dans le Cas d'une Vitesse Supersonique. P. Lienard

Résistance des Tubes. A. Tonski

Sur les Méthodes de Calcul Employées pour la Recherche des Valeurs et Vecteurs Propres d'une Matrice. R. Weber

Conditions Géodésiques d'un Radiophase Directionner. G. Eckart

L'Association Française des Ingénieurs et Techniciens de l'Aéronautique (France)

TECHNIQUE ET SCIENCE AERONAUTIQUES (Alternate Months)

No. 2, 1949

Méthodes Françaises d'Essai Aérodynamiques Industriels. J. Brocard and F. Hussenot.

La Filtration Appliquée aux Moteurs à Combustion. M. Chirac.

Domaine d'Utilisation des Moteurs à Pistons et des Turbo-Machines en Aéronautique. M. Laming.

Institute of the Aeronautical Sciences (U.S.A.)

JOURNAL OF THE AERONAUTICAL SCIENCES (Monthly)

Vol. 16, No. 6, June 1949

Propeller Flutter. M. J. Turner and J. B. Duke.

The Drag Problem at High Supersonic Speeds. A. Busemann. Station Functions and Air Density Variations in Flutter Analysis. M. Rausches.

Compression Tests of Curved Panels with Circular Hole Reinforced with Circular Double Plates. W. D. Knoll and A. E. McPherson.

The Lift Distribution on Conical and Nonconical Flow Regions of Thin Finite Wings in a Supersonic Stream. T. R. Goodman.

A Method of Least Square Adjustment for Measured Wing Deflections. D. R. Blanchflower.

Vol. 16, No. 7, July 1949

A Study of the Bending-Torsion Aeroelastic Modes for Aircraft Wings. M. Goland and V. L. Luke.

The Flutter of Servo-Controlled Aircraft. J. Wilson.

Theories of Plastic Buckling. S. B. Batdorf.

Note on the Relations Between Viscous and Structural Damping Coefficients. W. W. Soroka.

Interference Between Wing and Body at Supersonic Speeds—Analysis of Characteristics. C. Ferrari.

Performance Analysis of Centrifugal Compressors. S. P. Liang.

AERONAUTICAL ENGINEERING REVIEW

(Monthly)

Vol. 8, No. 6, June 1949

Personal Aircraft.

The Beech Twin-Quad Power Plant. J. W. Massey.

An Analysis of the Economy and Utility of the Personal Airplane. E. W. Norris.

Vol. 8, No. 7, July 1949

Research for Aircraft Safety. Dr C. C. Furnas.

Design Trends.

Personal Aircraft for Military Purposes. Lt.-Col. C. L. Shepard.

Major R. L. Long and Major D. G. Cogswell.

The Boeing 200 h.p. Gas Turbine and the Light Airplane. S. D. Hage.

Society of Automotive Engineers (U.S.A.)

S.A.E. JOURNAL (Monthly)

Summaries:

Nitromethane as a Monopropellant. F. Zwicky and C. C. Ross. Physiological Aspects of High Speed and High Altitude Flying. W. R. Lovelace.

S.A.E. National Aeronautic Meeting.

AN AMERICAN GAS TURBINE OF LOW POWER

(Concluded from p. 243)

not developed as a commercial undertaking, it is believed by Boeing engineers to indicate a promising line of development of power-plants for many vehicle applications, not necessarily to make vehicles of present design better, but to evolve different vehicles of superior performance in the future. Advantage can be taken of the reduction of weight per horse-power and of the power output characteristics of the engine. It seems probable that production costs of the gas turbine would be less per horse-power than for reciprocating engines because of its simplicity and few parts. Many lines of improvement of the engine are open and prospects are good that the power/weight ratio can be raised and the rate of fuel consumption reduced. Fuel consumption could be lowered 25 per cent by use of regenerative heat exchangers, although they would double the power-plant weight. A regenerator designed to take care of heat strains would be relatively inexpensive to produce and maintain.

The possibilities of reaching high practical limits of efficiency with the type of small gas turbine are indicated in FIG. 6. The curves are plotted in h.p./lb./sec. and thermal efficiency (η_o), against cyclic pressure ratio (P/P) for various air intake temperatures (T_i), nozzle-box temperature (T_g), compressor efficiencies (η_c), turbine efficiencies (η_t), and regenerator effectiveness (E).

FIGS. 7, 8 and 9 suggest promising lines of investigation for raising the pressure ratio of Model 502 equipped with regenerators and having a free-power turbine.

Trade Announcements

A monthly feature giving news of recent Government and professional appointments, industrial developments and business changes, etc.

B.S.A. Tools in Glasgow

The Glasgow Branch of B.S.A. Tools Ltd., and of the distributing organization, Burton, Griffiths & Co. Ltd., Machine Tools and Small Tools, has been moved to new premises at 46 Carlton Place, Glasgow, C.5. Telephone No.: South 1121/2.

Civil Aviation Appointments

The Ministry of Civil Aviation announce that Mr G. S. Lindgren, M.P., Parliamentary Secretary to the Ministry of Civil Aviation, has appointed Mr Walter Monslow, M.P., to be his Parliamentary Private Secretary.

Mr W. Ronnie has been appointed Chief Constable of the Ministry of Civil Aviation Constabulary.

He has been Deputy Chief Constable since July 1948 and succeeds Sir John Bennett, the first Chief Constable, who died last month.

Mr Ronnie is 43 and before joining the Ministry of Civil Aviation was Chief Constable of Breconshire. A member of the Bucks Constabulary from 1927 to 1947, during the war he was seconded to the Army for police security duties in Italy. He returned to the U.K. on demobilization as Superintendent of Police in charge of Buckingham Division.

The College of Aeronautics Awards

The following awards have been made at the conclusion of the two-year post-graduate course 1947 to 1949 of the College of Aeronautics, Cranfield, Bletchley, Bucks. Specialization is denoted in brackets:

Diploma with Distinction

E. M. Dowlen, R. S. Jones, B. W. B. Shaw, D. A. Treadgold (Aerodynamics); A. N. Byron, W. R. Heald, K. L. C. Legg, C. B. Lewis (Aircraft Design); J. J. Bukovsky, G. E. Thirlwall (Aircraft Propulsion).

Diploma

T. B. Booth, T. B. A. Boughton, E. G. Cane, L. W. J. Hall, P. A. Hearne, J. E. Rossiter, H. D. Ruben, J. M. L. Thomas, K. J. Turner (Aerodynamics); A. Clegg, L. Ellerd-Styles, R. B. L. Foster, I. D. H. Gibbins, J. W. Hitchcock, S. Pallis, J. Speechley, W. Taylor, R. W. Trail, V. D. Trimm (Aircraft Design); S. Buck, W. R. Cushing, L. S. Davey, E. N. Grantham, P. C. Gupta, T. G. F. Hardy, D. E. Parish, P. Ramsden, D. J. N. Wakeling (Aircraft Propulsion). *Second Year only*: K. Alming, G. E. Gadd, W. F. Wiles (Aerodynamics).

Gauge and Tool Makers

The Officers and Council of the Gauge and Tool

Makers' Association, 2 Old Bond Street, W.1, for the new Session, 1949-1950, are as follows:

President: F. W. Halliwell.

Immediate Past President: H. H. Harley.

Chairman: H. S. Holden.

Vice-Chairman: A. L. Dennison.

Honorary Treasurer: R. Kirchner.

Council: G. P. Barrott, L. H. Barton, K. Brierley, A. Dormer, J. P. Fox, E. N. Hall, A. N. Harley, F. O. Horstmann, F. C. Jearum, J. Loxham, J. E. MacLaren, A. E. Morrison, T. Ratcliffe, A. M. Redman, H. J. Rowe, A. H. R. Shaw, S. Carlton Smith, R. H. Try, L. E. Van Moppes, L. H. Wadsworth, H. G. Carmichael Wilson, A. Wood.

Hiller Helicopter Canadian Agency

G. R. Wooll, general manager of Weston Aircraft Limited, Oshawa, an associate company of the Hunting Aviation Group, of Luton Airport, Beds, has announced that his firm has been appointed sole Canadian distributors for the new Hiller helicopter, manufactured at Palo Alto, California, by United Helicopters Inc.

Netherlands Airport Construction Office

The address of the Netherlands Airport Construction Office (NACO) has been changed from: 93, Gevers Deijnotweg, Scheveningen, to: 9, Hofweg, The Hague, Holland.

New Director of the N.P.L.

The Lord President of the Council has appointed Professor E. C. Bullard, M.A., Ph.D., F.R.S., Professor of Physics in the University of Toronto, to be Director of the National Physical Laboratory, Teddington, Middlesex. It is expected that Professor Bullard will take up the appointment in January 1950.

Professor Bullard will succeed Sir Charles Darwin, K.B.E., M.C., Sc.D., F.R.S.

Rotax Canada Limited

Rotax Ltd., of Willesden Junction, N.W.10, announce the formation of Rotax Canada Ltd. at Montreal Airport.

The company will embrace all the interests of Rotax Ltd., and Joseph Lucas (Gas Turbine Equipment) Ltd. in Canada, and the activities in the first instance will be limited to Engineering and Commercial liaison, servicing of Electrical and Gas Turbine Equipment and the stocking of spare parts for the two companies' equipment used in Canada.

The Directors of the Company are: E. J. Earnshaw

(President), J. Hulbert, F. P. Turville, E. B. Fairbanks.

The Vice-President in charge of the company's operations is Mr J. Hulbert who was formerly a senior Rotax liaison engineer with the industry in England.

Rotax in Australia

In the previous paragraph details are given of the establishment by Rotax Ltd. of Willesden Junction, N.W.10, of their Canadian Company, and brief reference was made to the formation of an Australian Company.

It is now announced that the Australian Company will be known as Rotax Australia Pty. Ltd. with headquarters at 81 Bouverie Street, Melbourne, N.3, Australia. The Directors are A. R. Harrison (Chairman), L. W. Marks, E. J. Earnshaw (London), C. H. Dutton (London), J. G. Webb (Managing). Consultant: R. J. Ifield.

Suffolk Iron Foundry

Mr A. Gilliard, who is very well known in the South-West of England, has left the British Oxygen Co. and taken up an appointment with the Suffolk Iron Foundry (1920) Ltd. of Stowmarket, and will represent that company in Cornwall, Devon, Somerset and Wiltshire.

Tecalemit Aviation Sales Manager

Mr R. R. Parker has been appointed Sales Manager of the Aviation and Motor Manufacturers Divisions of Tecalemit Ltd., and Mr B. E. Richmond, previously General Manager of the Tecalemit Scottish Works, Sales Manager, Industrial and Marine Divisions, in succession to Mr Parker.

Mr Parker joined Tecalemit in 1938 and was appointed Divisional Sales Manager in 1943.

These appointments take place following the resignation of Mr C. B. Brudenell from this Company where he was for many years Sales Manager of the Aviation and Motor Manufacturers Divisions. Mr Brudenell is joining Hills Patents Ltd. as Sales Director.

Tenaplas Limited

Tenaplas Ltd. are vacating their temporary offices at 78 Buckingham Gate, S.W.1, and all orders and enquiries affecting home sales of Teneplas products should in future be sent to the Sales Department, Upper Basildon, near Pangbourne, Berks. Telephone Nos.: Upper Basildon 208, 228, 269, 283. Cables: Tenaplas, London.

All export sales enquiries should be sent direct to the Export Department, 24/25 Manchester Square, London, W.1. Telephone Nos.: Welbeck 7941/7950. Cables: Tenaplas, London.

New Vokes Directors

Mr J. Phillips, for many years Secretary to the company, and Mr A. G. Osborne, General Manager, have been made Directors of Vokes Ltd., of Guildford.

Trade Publications Received

Murex Booklet P.M. 13

[Murex Limited, Rainham, Essex]

'Anglgear' Standardized Gear Units

[Airborne Accessories Corp., 25 Montgomery Street, Hillside 5, N.J., U.S.A.]

Churchill Centreless Grinding Machines

[The Churchill Machine Tool Co. Ltd., Broadheath, Manchester]

Mercury in Steel Thermometers

[Negretti & Zambra, Regent Street, W.1]

'Mitia' Carbide Tips and Tools Instruction Book

[Firth Brown Tools Ltd., Bessemer Building, Carlisle Street, Sheffield, 1]

Adhesives for Industry

Aero Research Technical Notes

Bulletin No. 73. Photo-elastic Stress Determination in Glued Joints—Part II
[Aero Research Ltd., Duxford, Cambs]

Dunlop Transmission Belting

[Dunlop Rubber Co. Ltd., Cambridge Street, Manchester]

'Sorbsil' Brand Silica Gels

[Joseph Crosfield & Sons Ltd., Unilever House, E.C.4]

Sherardizing. By J. C. Mills

[Zinc Alloy Rust-Proofing Co. Ltd., Shakespeare Street, Wolverhampton.]

Aluminium Casting Alloys

[Renfrew Foundries Ltd., Hillington, Glasgow, S.W.2]

'Astra'. Vol. 1, No. 3, Feb. 1949

[Air Service Training Ltd., Hamble, Southampton]

Matrix Micro-Maag Internal Micrometer

[Coventry Gauge & Tool Co. Ltd., Coventry]

Flight Refuelling: Its effect on Airline Operation and Aircraft Design

[Flight Refuelling Ltd., St Nicholas, Littlehampton]

First in Flight

[Curtiss-Wright Corp., 30 Rockefeller Plaza, New York, U.S.A.]

Focus on Finishing (Industrial Finishes Exhibition, Earl's Court. Aug. 31-Sept. 13, 1949)

[Industrial Finishes Exhibition Ltd., 26 Old Brompton Road, S.W.7]

The Magnetic Properties of the Nickel-Iron Alloys

[The Mond Nickel Co. Ltd., Sunderland House, Curzon Street, W.1]

Coil Springs of All Descriptions

[Hewell Spring Co. Ltd., Astwood Bank, Redditch]

Watts Microptic Measuring Machines

Watts Optical Flats

Hilger Measuring Instruments

[Hilger & Watts Ltd., 48 Addington Square, S.E. 5]

'Rigidal' Corrugated Aluminium Sheet

[The British Aluminium Co. Ltd., Salisbury House, London Wall, E.C.2]

Machining Bakelite Laminated

Bakelite Progress

[Bakelite Ltd., 12 Hobart Place, S.W.1]

'Multibelt' Variable Speed Gears

'Multibelt' Variable Speed Unit

[R. W. Knowles Ltd., 39 Victoria Street, S.W.1]

G.E.C. Torches and Batteries

[The General Electric Co. Ltd., Magnet House, Kingsway, W.C.2]

Protection by Precaution—Pioneer Oil Seals

[Pioneer Oilsealing and Moulding Co. Ltd., Bull Buildings, Southam, Nr. Rugby]

Hot-rolled Strip

[United Strip and Bar Mills, 17 Westbourne Road, Sheffield, 10]

Sentinel-Ganz Industrial Diesel Engine

[Sentinel (Shrewsbury) Ltd., Shrewsbury]

Aero Research Technical Notes

Bulletin No. 74. Pattern Making for Foundries
Bulletin No. 75. 'Araldite' Surface Coating Resin for the Protection of Metal Surfaces
[Aero Research Ltd., Duxford, Cambridge]

Timken Tapered Roller Bearings

Reasons for the Adoption of Inch Sizes for the Standardization of Tapered Roller Bearings
[British Timken Ltd., Cheston Road, Aston, Birmingham 7]

Lubrication in Assembly and Running-in

[Acheson Colloids Ltd., 9 Gayfere Street, S.W.1]

Tools for the Workshop

A Selection of Notes on Recent Equipment and New and Well-Tried Methods and Materials

The Matling Pallet Truck

At the Mechanical Handling Exhibition this year there was on show for the first time, a pallet truck which had been evolved for the Admiralty. Since then, the War Office, R.A.F., British Railways, Post Office and other Government departments have made tests of the truck.

Although it will be seen from the illustrations that the truck looks almost a miniature, nevertheless it has a load capacity of two tons and its hydraulic mechanism quickly lifts pallet or stillage loads up to a weight of 4,500 lbs.

At a demonstration some months ago at Kidbrooke, Admiralty and British Railways officials witnessed the prototype truck loading a closed railway wagon with 12 one-ton pallet loads in 12 minutes. This was done entirely without the aid of the forktruck, although, of course, the pallet loads had been lifted out of their stacked storage in the depot and brought to the loading bank by a forktruck.

The secret which enables this truck to perform this remarkable feat, is primarily its extreme manoeuvrability, coupled with its slender body which is only 9 in. overall, thus enabling a pallet load to be pivoted on its own axis, the truck to be withdrawn from a pallet in as little as the length of the pallet, and owing to the cleverly shaped fingers of the truck, for entry and exit to the pallet to be made at acute angles.

The lowered height of the truck without a stillage attachment is only 3½ in. and it will, therefore, work with any standard gap pallet throughout the world. Special leading and trailing wheels are fitted to the

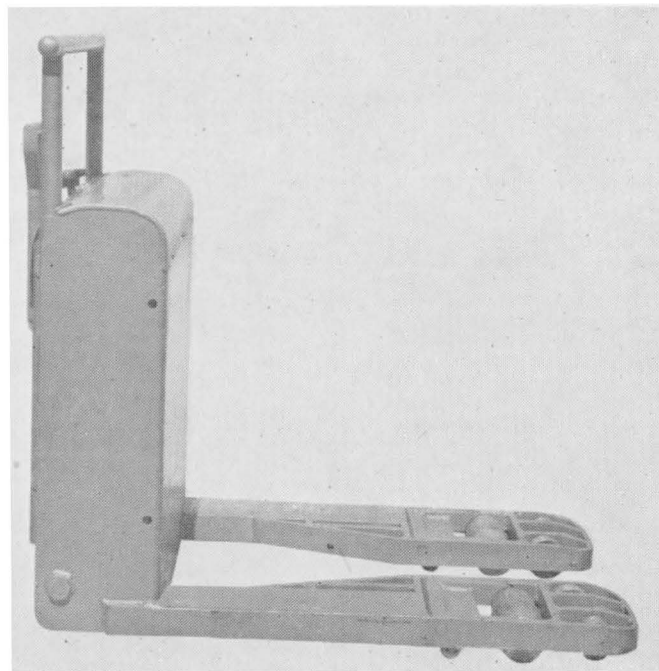


Fig. 1—The Matling Pallet

fingers, thus facilitating the mounting of pallet-bottom deck slats.

Alternative locking positions of the handle enable the truck to be pushed or pulled conveniently by people of different height, the hydraulic pump handle

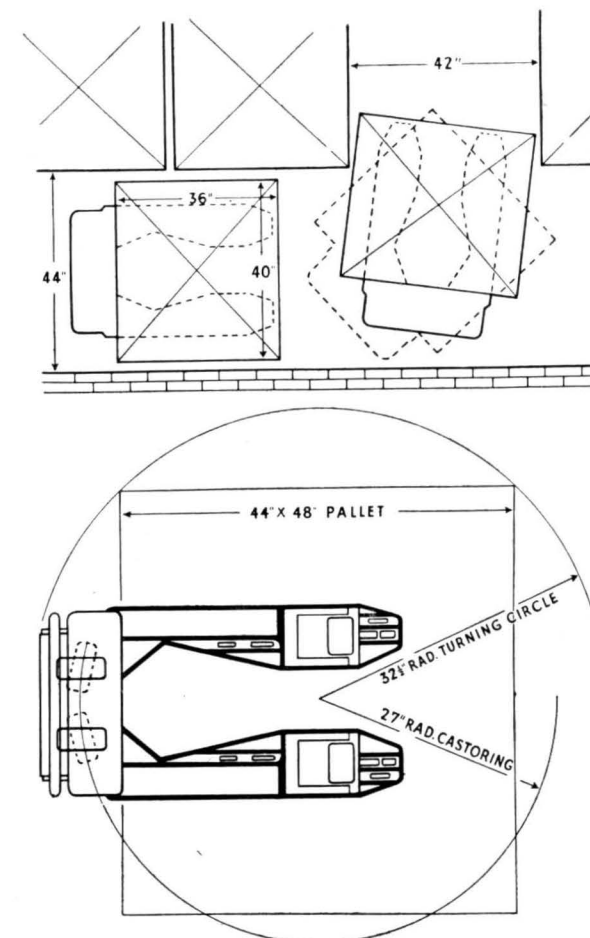


Fig. 2—Matling Pallet

being conveniently placed for raising the load. Lowering is effected by a knob which controls the lowering speed.

Full particulars can be had on application to the designers and manufacturers, who are now in full production, Matling Ltd., 14 Ossington Street, London, W.2.

British Standard Specifications

Copies of the following Specifications can be obtained, at the prices indicated, from THE BRITISH STANDARDS INSTITUTION, 28 Victoria Street, London, SW1

B.S. No. 771: 1948. Synthetic Resin (Phenolic) Moulding Materials.

This revision of B.S. 771, is of unusual interest, not only because of the wide use of phenolic moulding materials, but also because it is based on statistical principles. The reason for the adoption of this basis for the Standard is the knowledge that little confidence can be placed in the results of tests on a small number of specimens made from a batch of materials, when these results are considered on their own.

It therefore relies on continual control of the product during manufacture. It defines basic values for the properties of phenolic moulding materials, and specifies the evidence which will be accepted as indicating conformity with those basic values.

It may nevertheless be used for accepting or rejecting a single batch of moulding material, in any case when it is desired to do this.

It specifies mandatory requirements for the following properties of eight types of moulding materials: tensile strength, impact strength, surface resistivity, volume resistivity, heat resistance, power factor and permittivity.

It also specifies optional requirements, any of which may be invoked by a purchaser, for water absorption, plastic yield, electric strength, and acetone-soluble matter.

Methods of test for each of these properties are given and the Standard also includes methods of test for eight further physical properties of these materials. Price 5s. 0d. post free.

B.S. No. 1493: 1948. Polystyrene Moulding Materials.

This Standard covers both general purpose moulding material and material suitable for electrical use. The requirements for both types of material cover screen analysis, percentage of methanol soluble matter, percentage of volatile matter, viscosity in benzene solution, impact strength and softening point. In the case of the material for electrical use, an additional requirement is that the power factor and permittivity of the material shall not exceed specified values when determined at a frequency of one megacycle per second by the Hartshorn and Ward method.

It differs in several respects from its A.S.T.M. equivalent and particularly in the addition of a test for volatile matter. This test has been included as there is some evidence to show that crazing in polystyrene mouldings may be controlled by a check on the amount of volatile matter present. Another point of difference is that the British method of determining softening point uses a very small test specimen which would be easier to mould and likely to be more free from internal strain than the relatively large A.S.T.M. specimen. The small size of the British specimen will also reduce to a minimum the temperature lag between the specimen and the liquid in which it is immersed. Price 2s. 0d. post free.

B.S. 1524: 1949. Cellulose Acetate Moulding Materials.

This is a further Standard in the series of British Standards for plastics moulding materials. The other Standards available in this series are B.S. 771-1948, Synthetic resin (phenolic) moulding materials;

B.S. 1322-1946, Synthetic resin (aminoplastic) moulding materials and mouldings; B.S. 1493-1948, Polystyrene moulding materials.

B.S. 1524 has the statistical basis already adopted for B.S. 771-1948, and for the same reason—the knowledge that, although it is impracticable to test more than a few specimens from each batch of moulding material, little confidence can be placed in the results of testing a few specimens when these results are considered on their own.

Therefore, instead of a familiar requirement such as that 'three specimens shall be tested of which not more than one shall fail', the new Standard defines basic values for the properties of cellulose acetate moulding materials and specifies the evidence which will be accepted as indicating conformity with those basic values. It does, in fact, require demonstration by manufacturers of the materials that the processes of manufacture have been controlled to secure a satisfactory product. Nevertheless, the Standard may be used for accepting or rejecting a single batch of mould-

ing material in any case when it is desired to do this.

It specifies methods of test and qualifying requirements for the physical properties of three grades of material which are distinguished by different softening points.

It also lays down further optional requirements for electric strength fines and impurities, and colour bleeding, any of which may be invoked by a purchaser. Price 3s. 0d., post free.

B.S. No. 1523: 1949. Glossary of Process Control Terms.

This Standard forms Section Two of a comprehensive glossary which is planned to cover terms used in automatic controlling and regulating systems of the closed-loop type, namely, systems in which the actual value of the controlled condition is continuously compared with the desired value.

Section Three, covering the nomenclature of position control servo-mechanism is now in course of preparation and this will be followed by Section Four, covering automatic regulators. Section One of the glossary will contain those terms common to all automatic controlling and regulating systems of the closed-loop type and will be prepared when the other Sections have been completed.

The terms and definitions given in Section Two have been accepted by both manufacturers and users of automatic control apparatus. There has hitherto been a degree of conflict and ambiguity in the nomenclature and it is hoped that these standard terms and definitions will find general acceptance and thus provide a basis for a unified nomenclature for use in the theory and practice of automatic control.

It is intended to review this standard after a period of twelve months in order to incorporate any alterations or improvements which its use may have rendered desirable, and the Institution will be glad to receive any suggestions for consideration. Price 2s. 6d. post free.

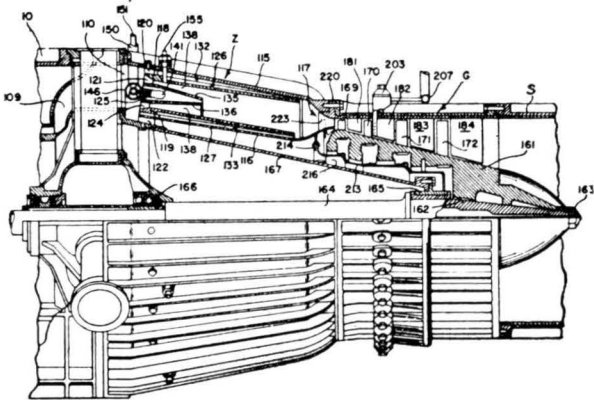
B.S. No. E.20: 1949.—High Tension Ignition Cables for Aircraft Engines.

This standard covers the requirements of two types of high tension ignition cable for aircraft engines, namely cotton braided and lacquered ozone-resisting cable, and metal braided cable. Details are given of the construction of the cables and the methods of testing for flexibility, adhesion, effect of oil, petrol and ozone, capacitance test, and high voltage tests. Price 1s. post free.

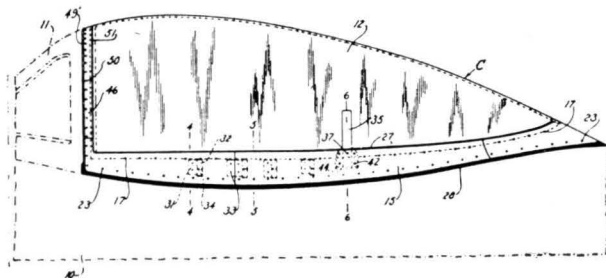
U.S. Patent Specifications

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.

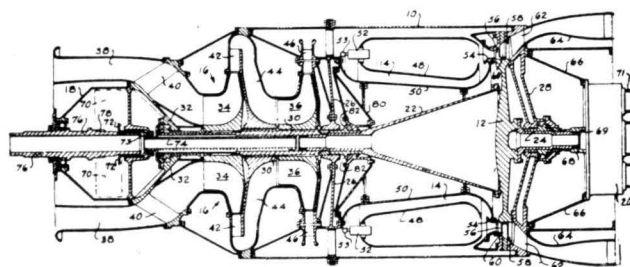
2,468,461. Nozzle Ring Construction for Turbo-power Plants. Nathan C. Price, Hollywood, Calif., assignor to Lockheed Aircraft Corporation, Burbank, Calif. Application May 22, 1943. Serial No. 488,029. 6 Claims. (Cl. 60—41.)



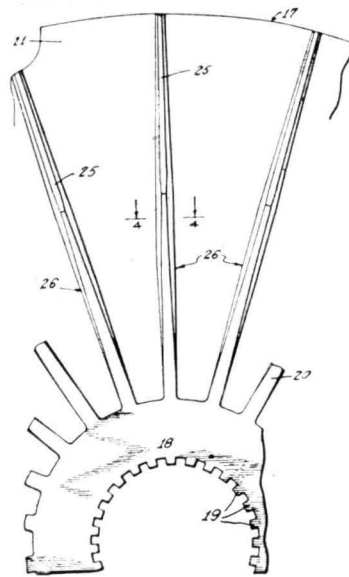
Delaware. Application November 21, 1944. Serial No. 564,438. 13 Claims. (Cl. 244—121.)



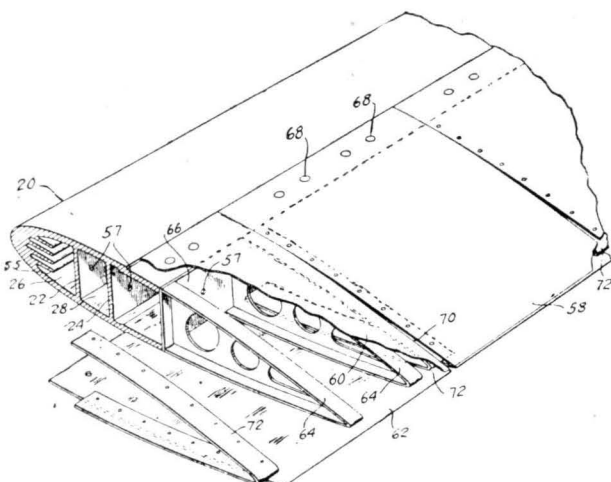
2,469,439. Gas Turbine. Wilton G. Lundquist, Hohokus, N.J., assignor to Wright Aeronautical Corporation, a corporation of New York. Application November 24, 1944. Serial No. 565,019. 1 Claim. (Cl. 60—41.)



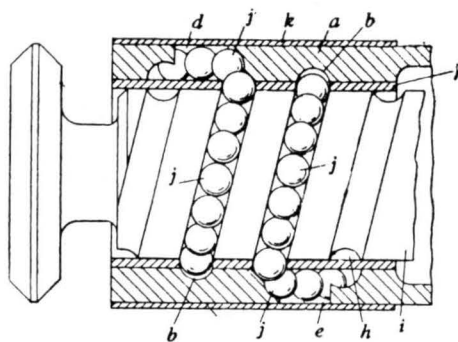
2,469,458. Blade Form for Supercharger Impellers. Norman A. Dunnells, Manchester, and Robert E. Gorton, East Hartford, Conn., assignors to United Aircraft Corporation, East Hartford, Conn., a corporation of Delaware. Application September 24, 1945. Serial No. 618,300. 5 Claims. (Cl. 230—134.)



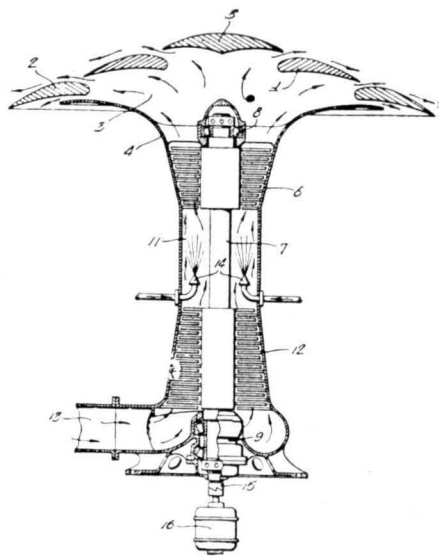
2,469,480. Rotor Blade. Igor I. Sikorsky, Bridgeport, Conn., assignor to United Aircraft Corporation, East Hartford, Conn., a corporation of Delaware. Application October 13, 1943. Serial No. 506,058. 12 Claims. (Cl. 244—134.)



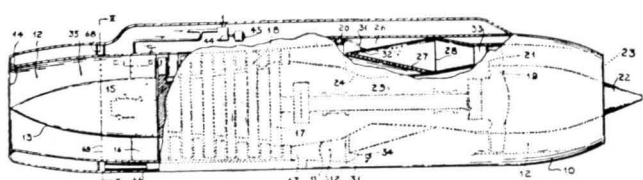
2,468,506. Screw and Nut Mechanism. Terence William Millns, London, England, assignor to Rotax Limited, London, England. Application March 12, 1947. Serial No. 734,147. In Great Britain March 16, 1946. 2 Claims. (Cl. 74—459.)



2,468,787. Aerodynamic Impelling Device. John S. Sharpe, Haverford, Pa.; Catherine D. Sharpe, executrix of said John S. Sharpe, deceased. Application September 9, 1943. Serial No. 501,708. 3 Claims. (Cl. 253—36.)

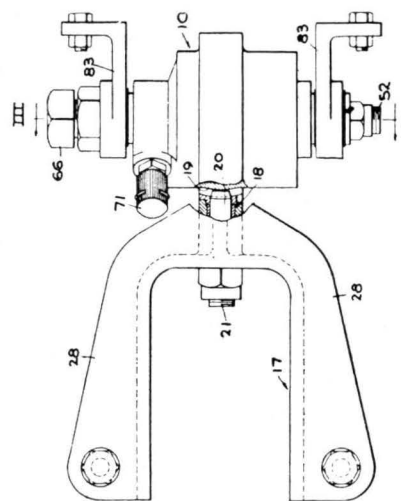


2,469,375. De-icing Apparatus for Compressors. Charles D. Flagle, Swarthmore, Pa., assignor to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania. Application September 24, 1945. Serial No. 618,140. 5 Claims. (Cl. 230—1.)

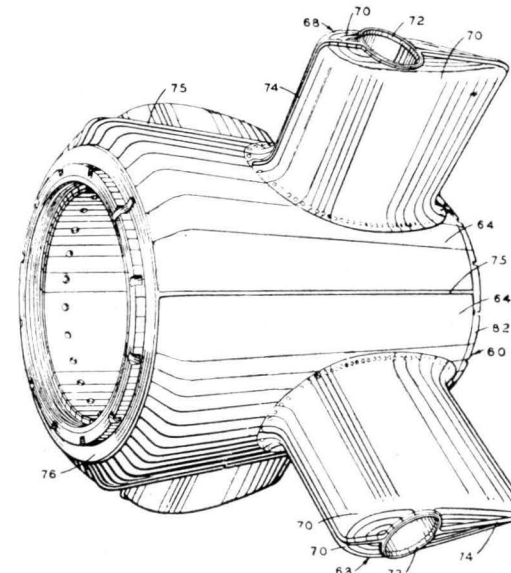


2,469,436. Canopy Construction. Carl C. King, Massapequa, N.Y., assignor to Republic Aviation Corporation, Farmingdale, N.Y., a corporation of

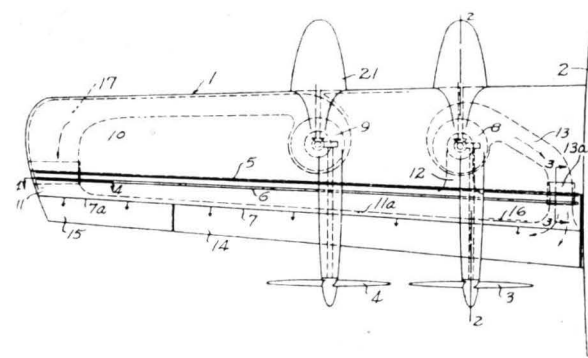
2,469,488. Flutter Dampener. Robert J. Woods, Grand Island, N.Y., assignor to Bell Aircraft Corporation, Wheatfield, N.Y. Application October 23, 1945. Serial No. 624,038. 2 Claims. (Cl. 188—93.)



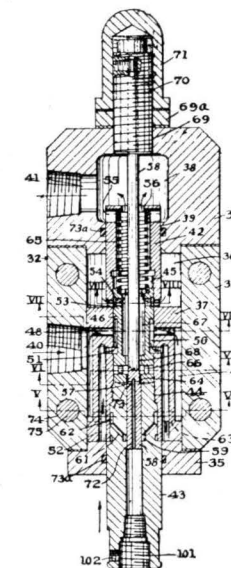
2,469,711. Fairing Assembly for Turbine Bearings. Charles A. Baresch, Hartford, Conn., assignor to United Aircraft Corporation, East Hartford, Conn., a corporation of Delaware. Application August 23, 1944. Serial No. 550,870. 11 Claims. (Cl. 308—15.)



2,469,902. Aircraft Wings having Boundary Layer Control. Edward A. Stalker, Bay City, Mich. Application June 14, 1943. Serial No. 490,712. 15 Claims. (Cl. 244—42.)



2,470,087. Expansible Chamber Hydraulic Motor with Distributing Valve in Piston. Cecil E. Adams, Columbus, Ohio, assignor to The Denison Engineering Company, Columbus, Ohio, a corporation of Ohio. Application December 14, 1944. Serial No. 568,139. 23 Claims. (Cl. 121—123.)





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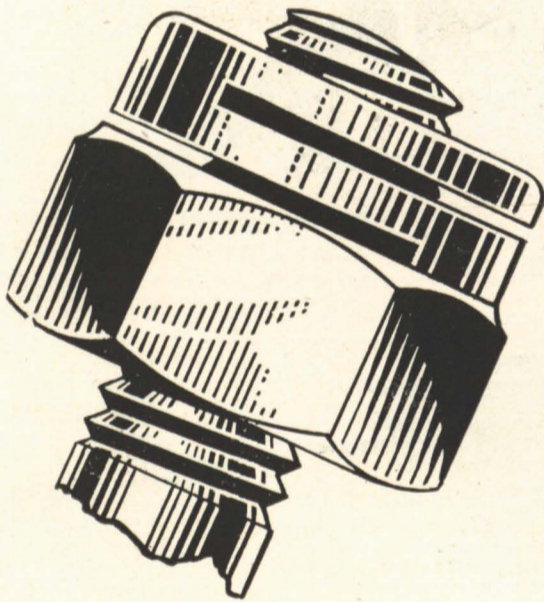
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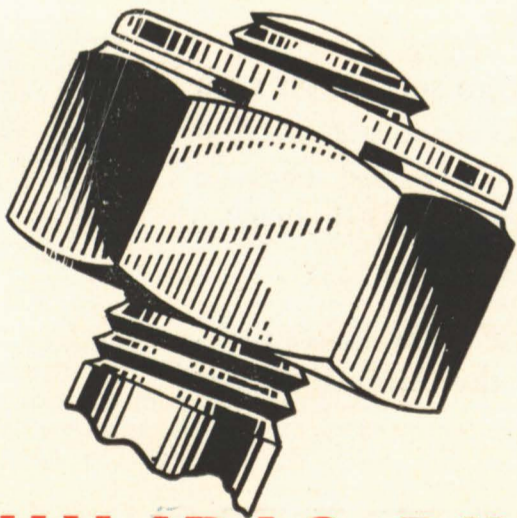


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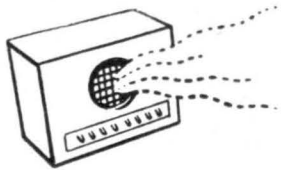
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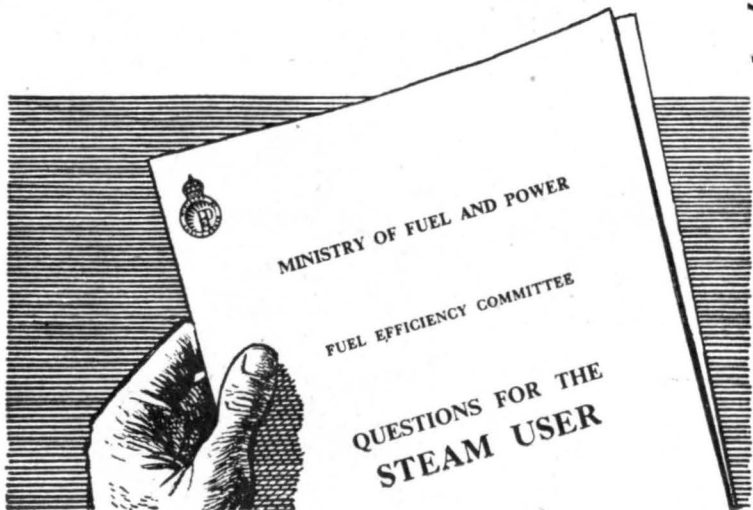
To Ministry of Fuel and Power, Information Branch (1),
7, Millbank, London, S.W.1.

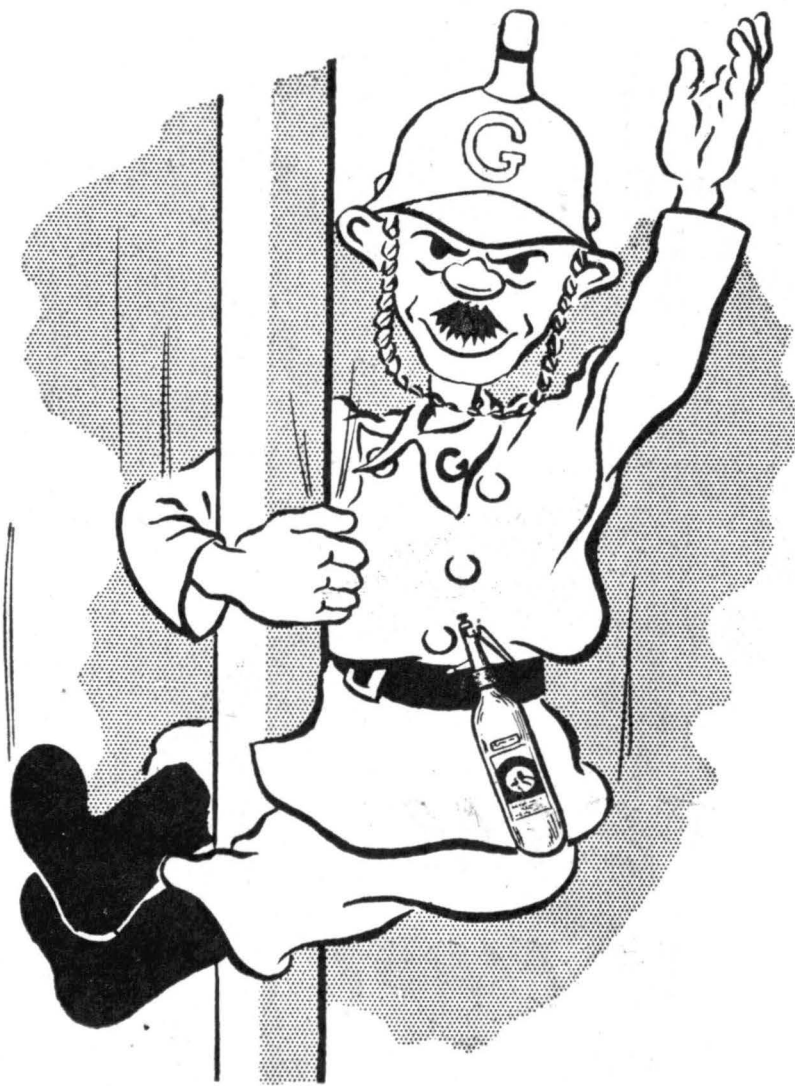
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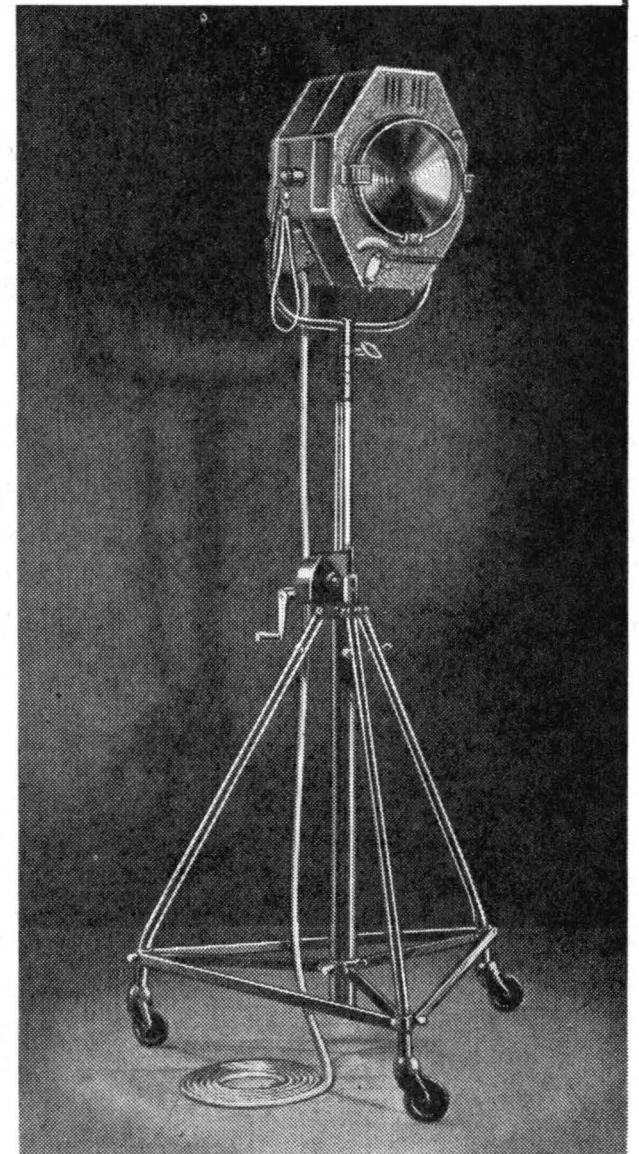
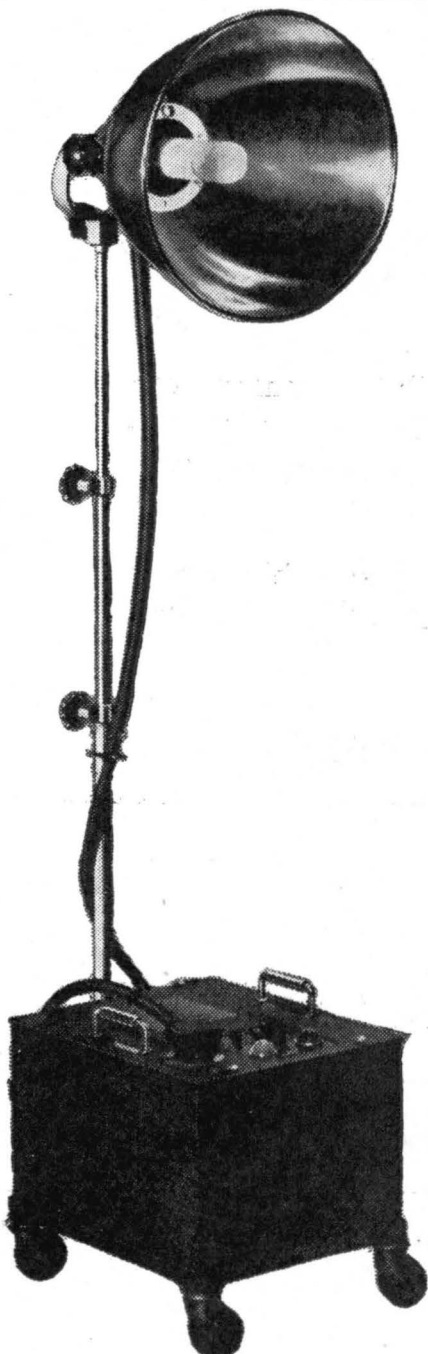
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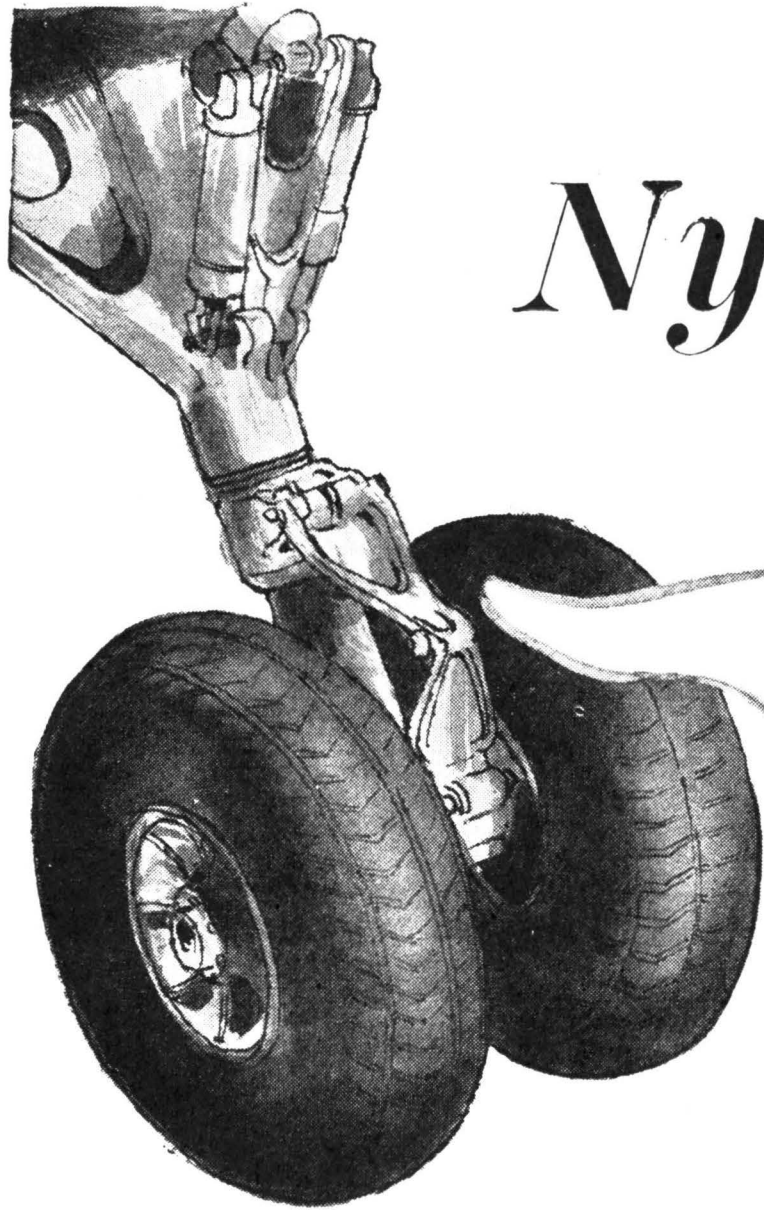
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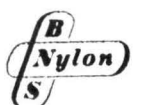
BENDS ITS KNEES

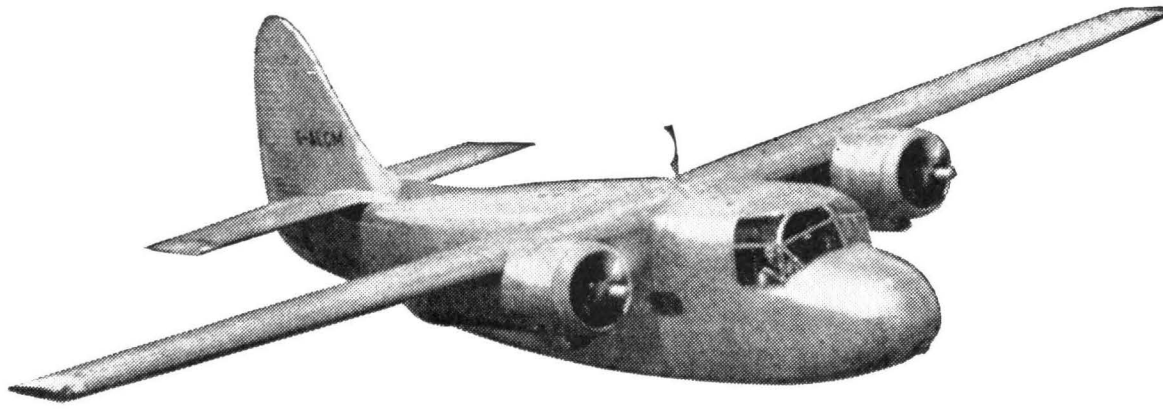
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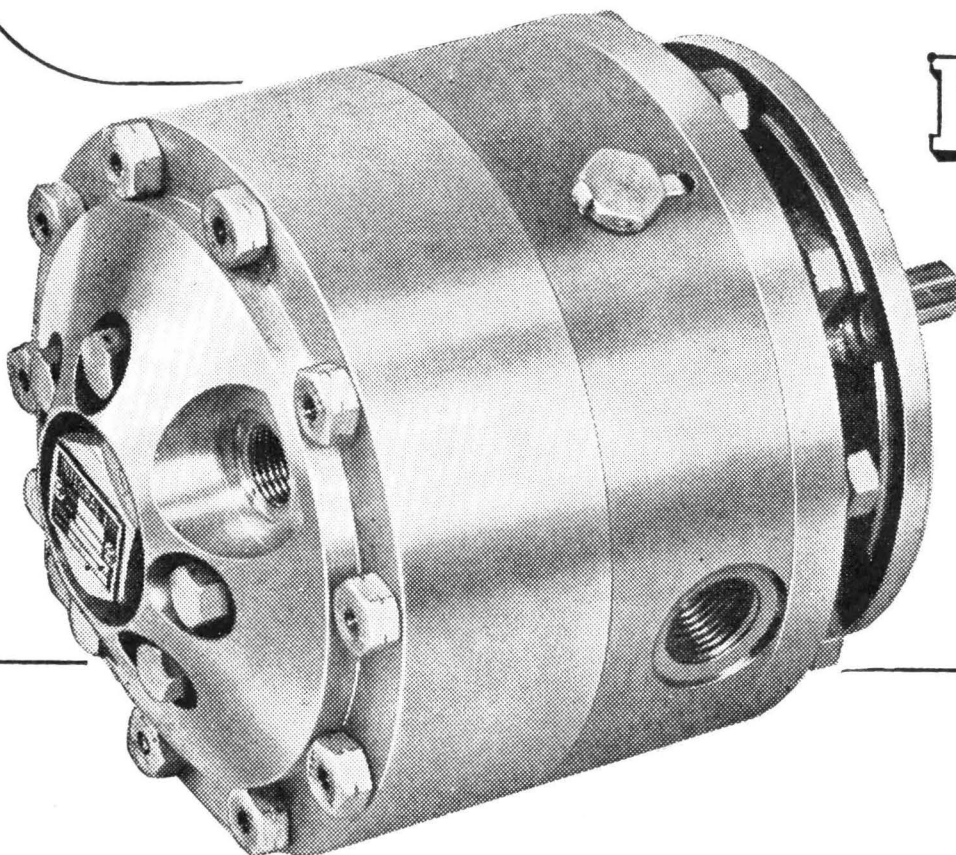
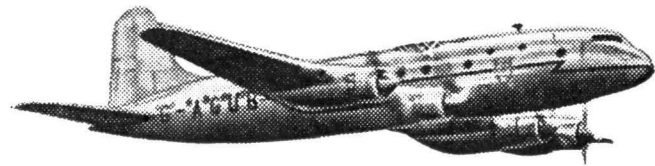
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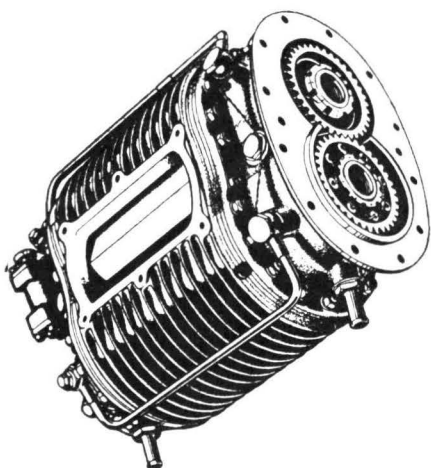
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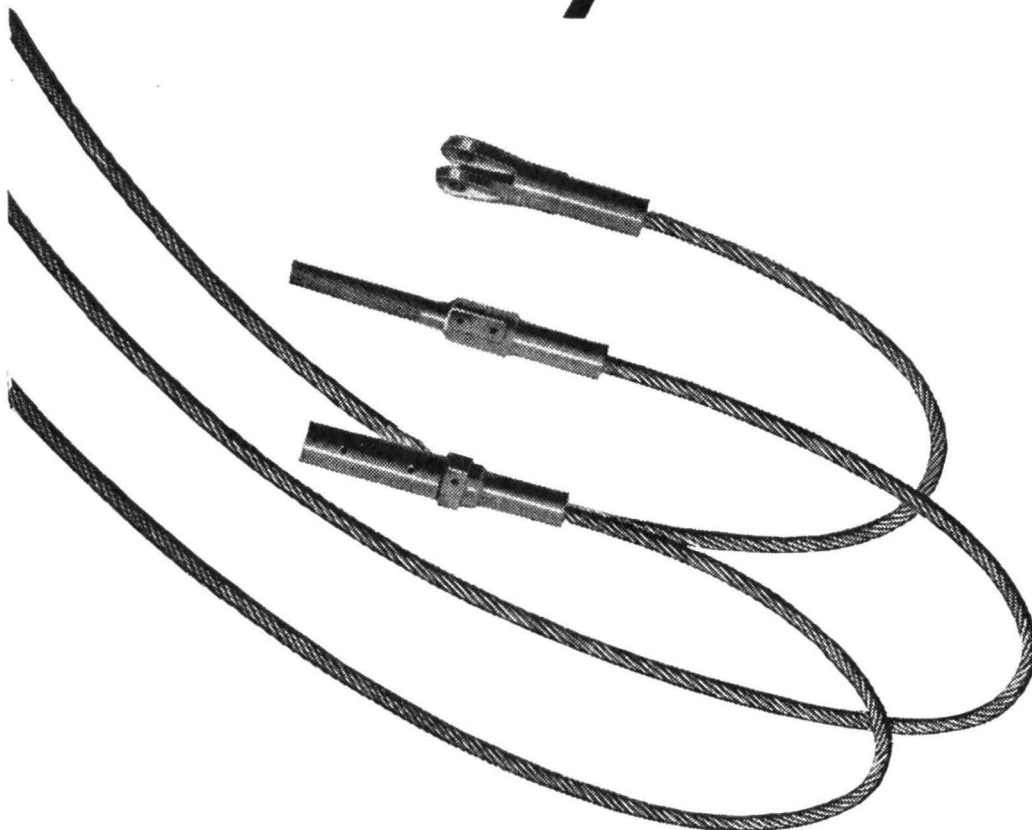
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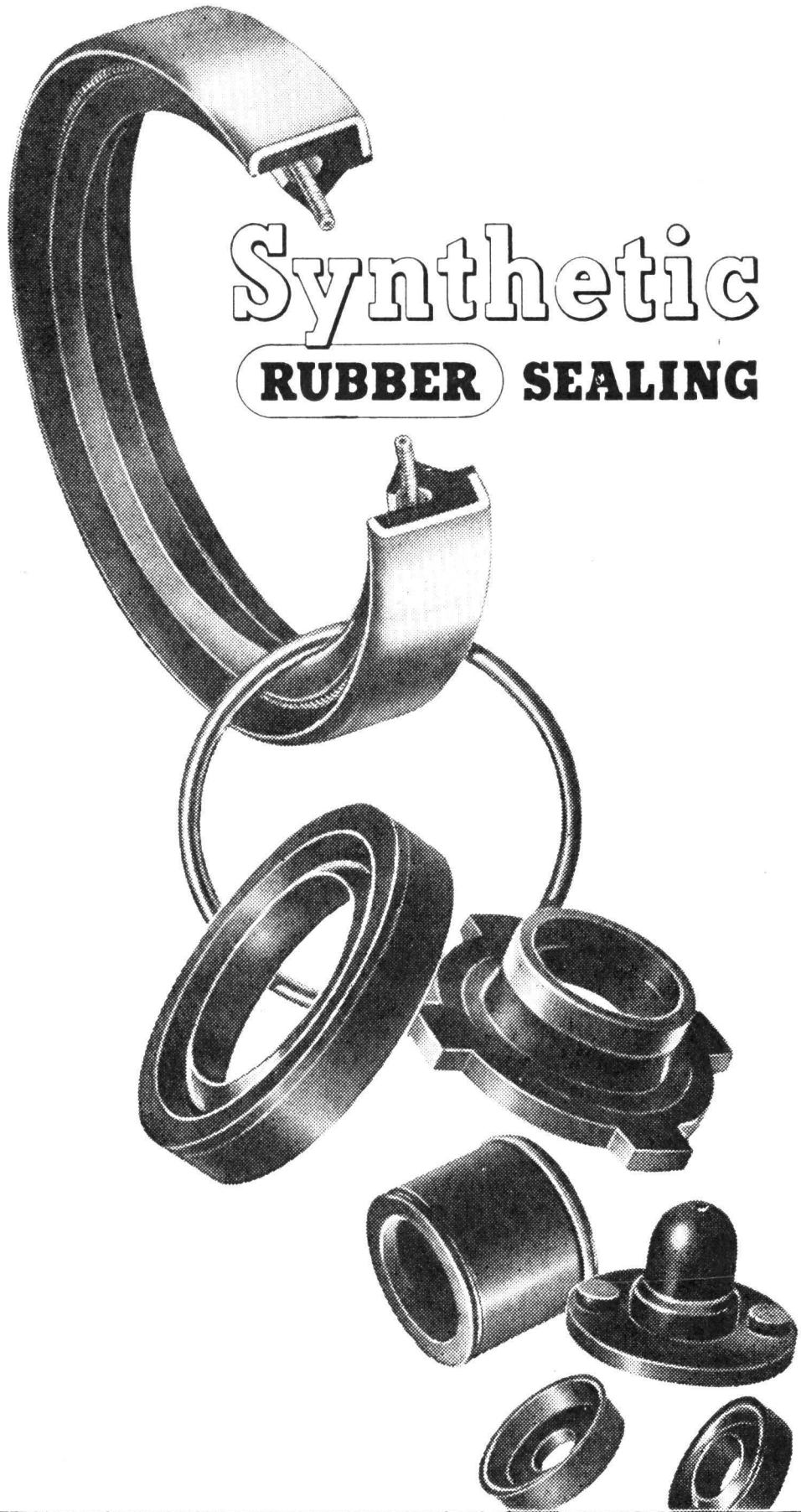
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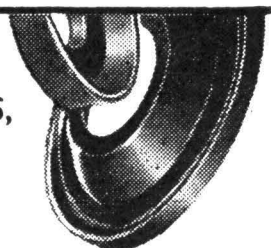


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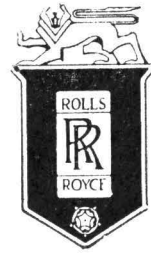
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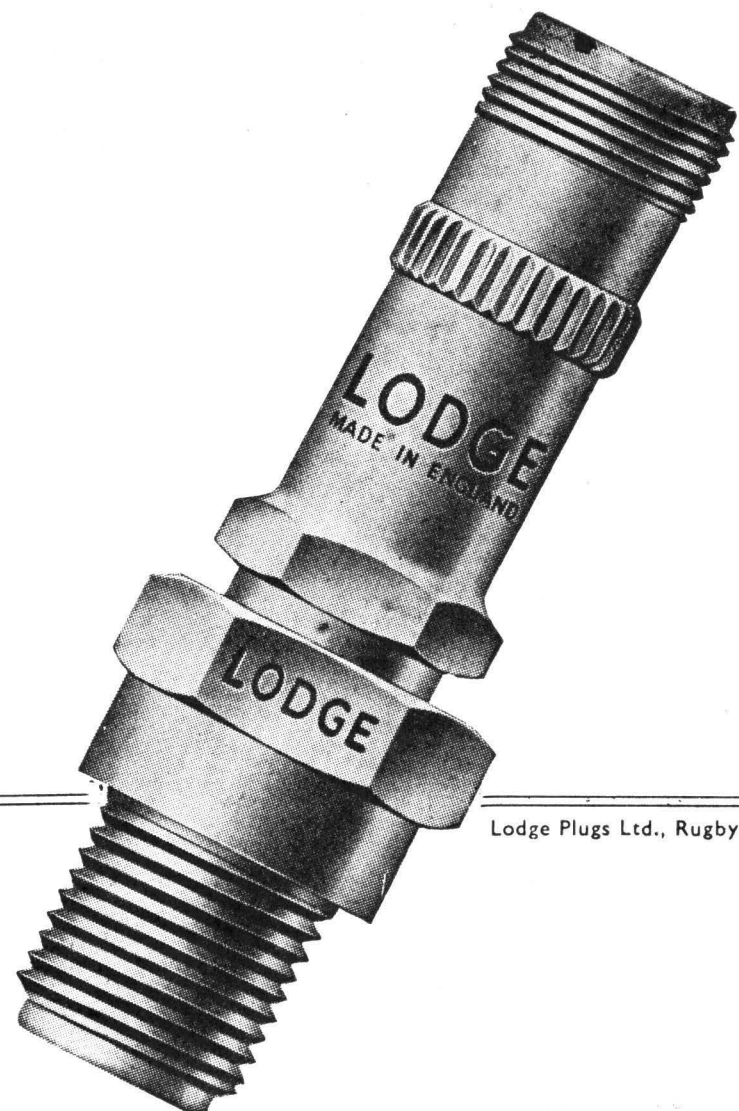


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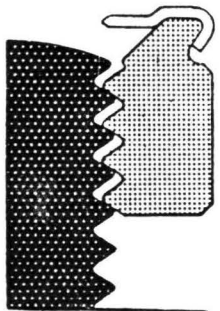
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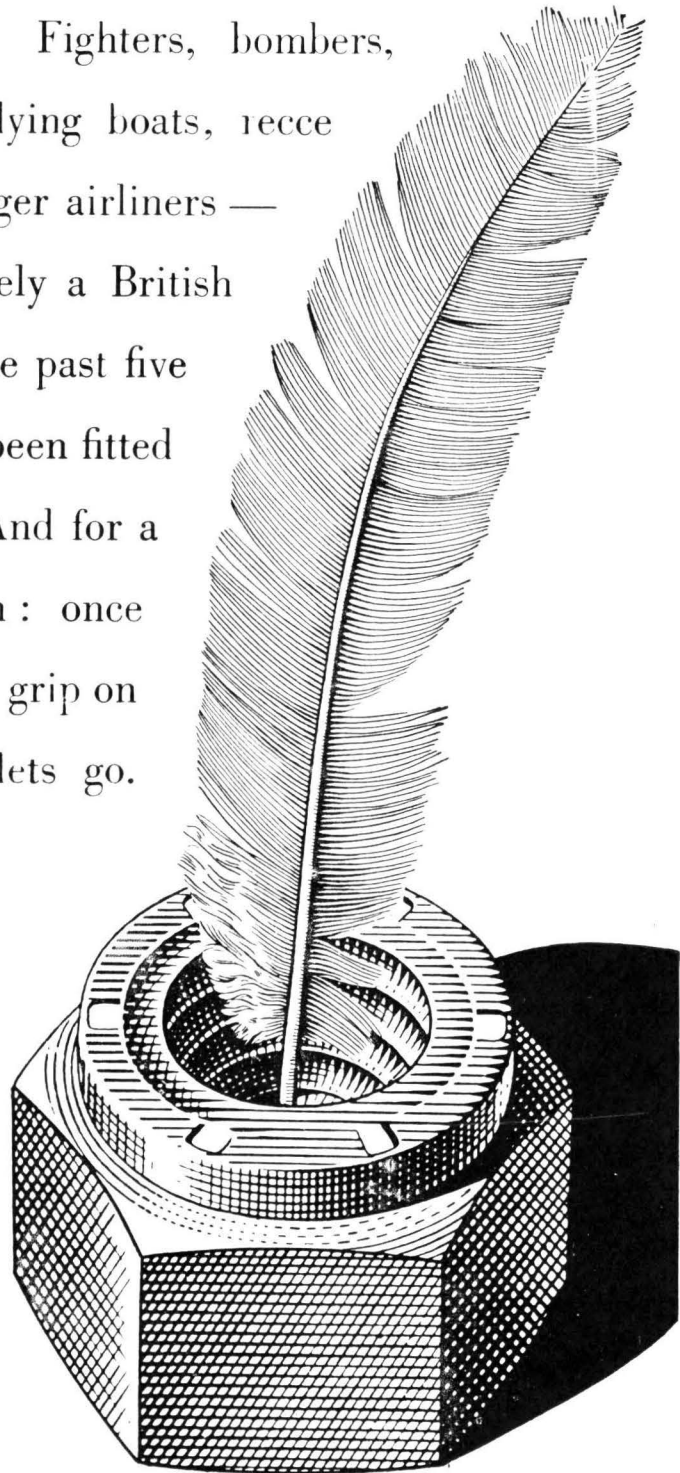
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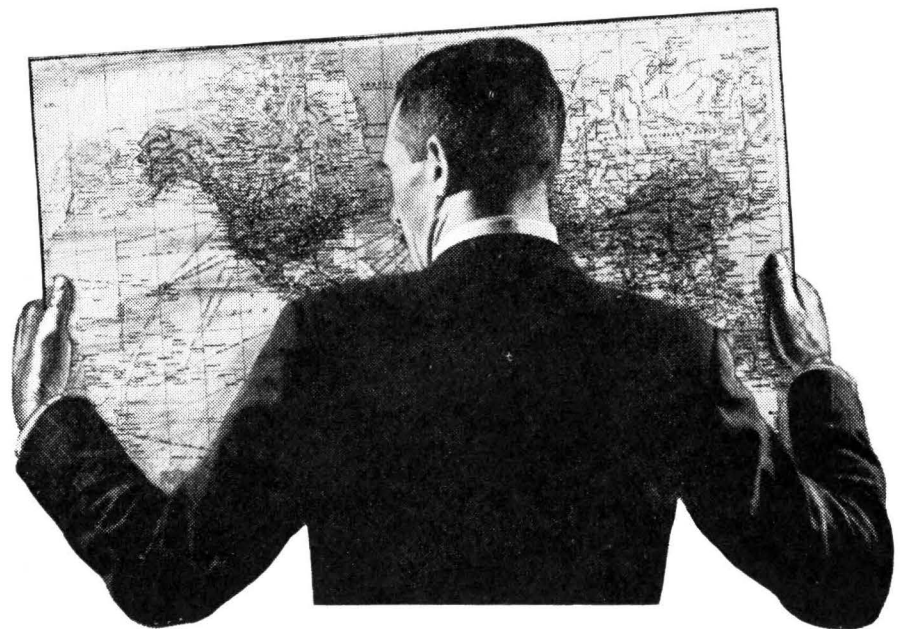


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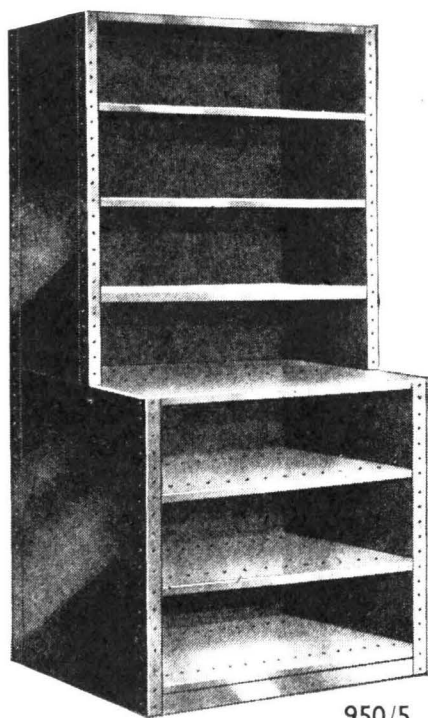
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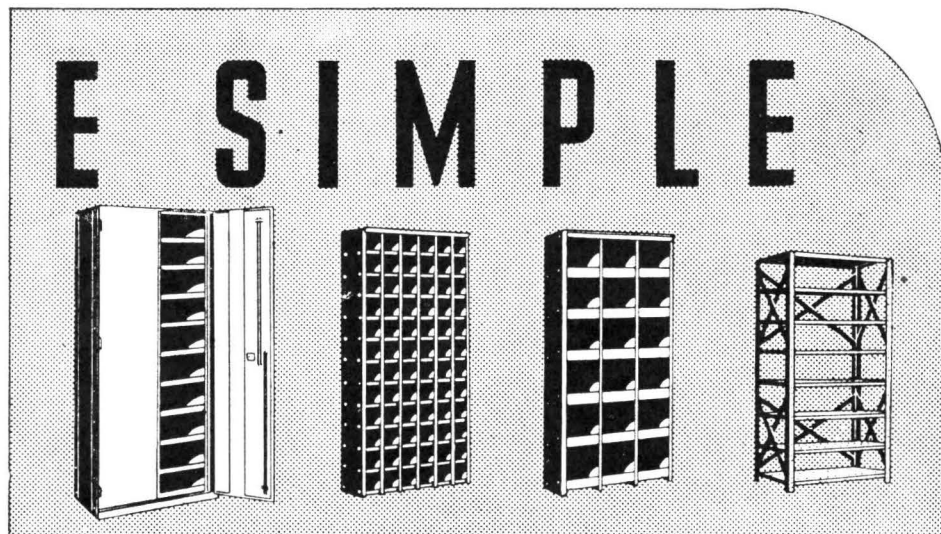
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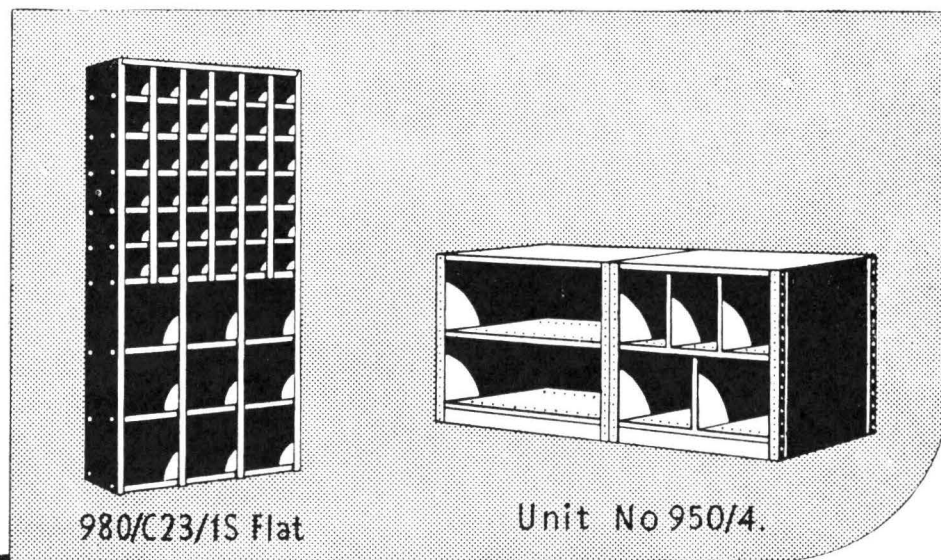
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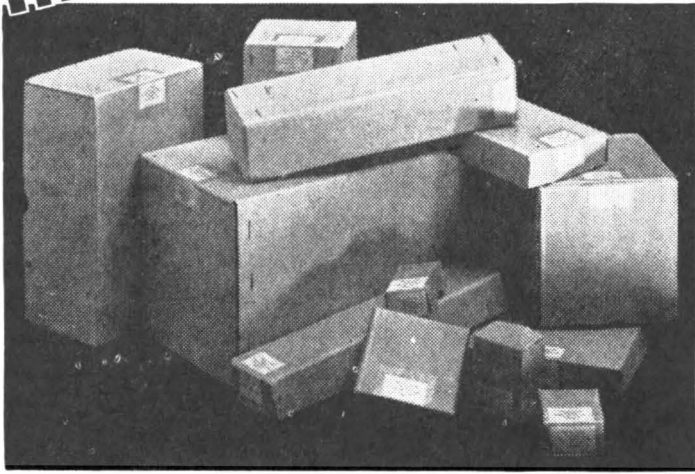
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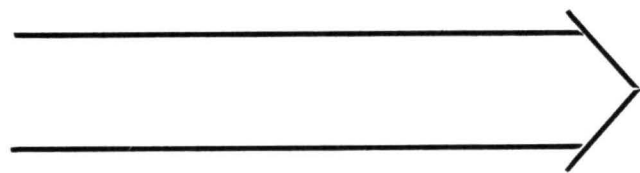
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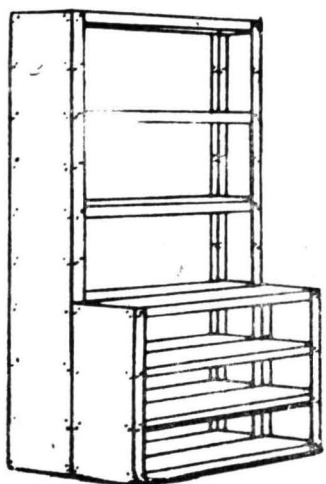
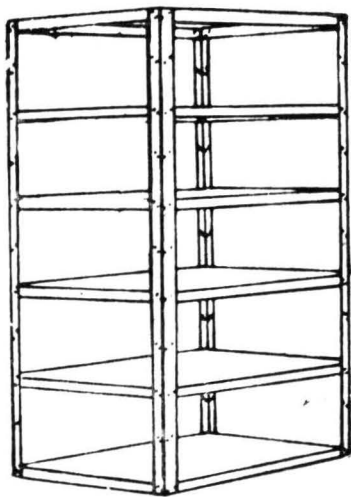
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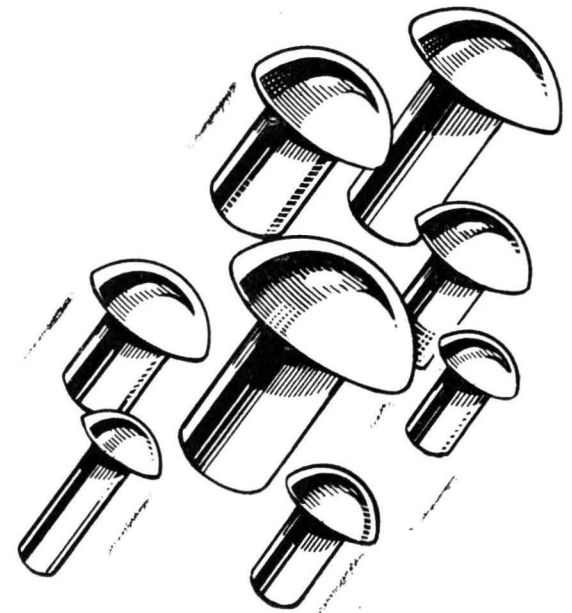
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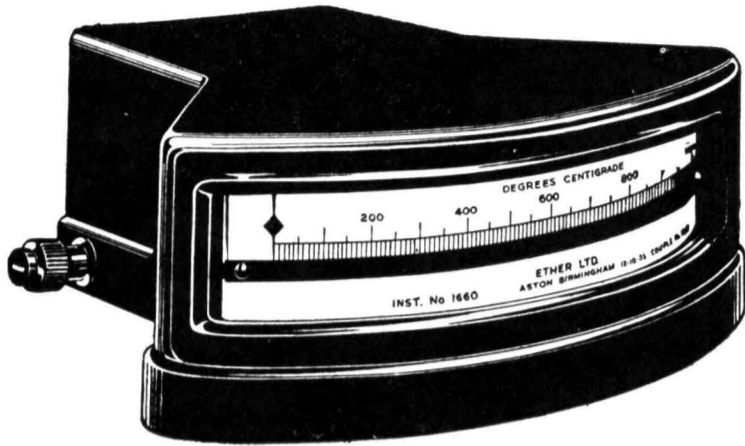
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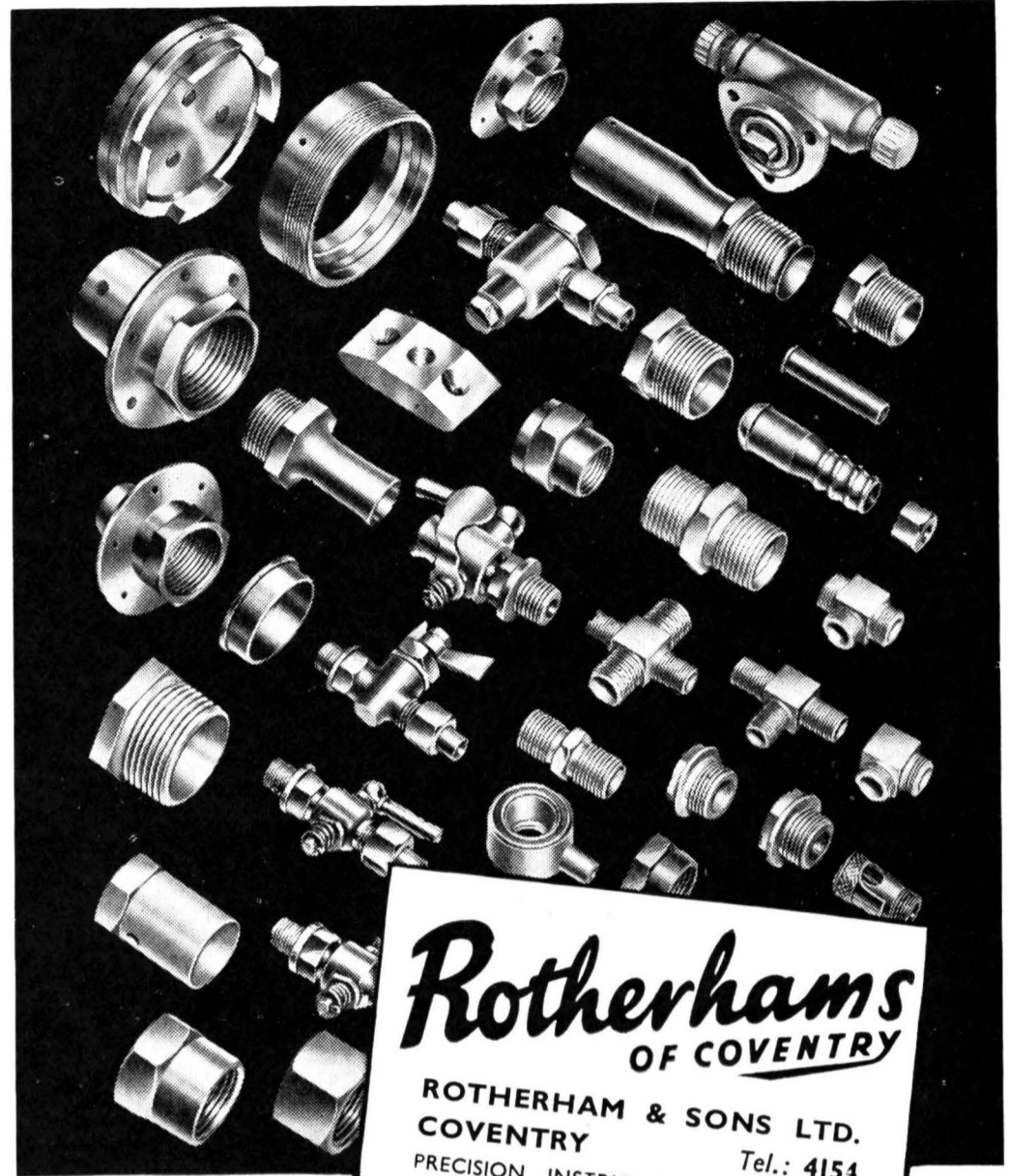
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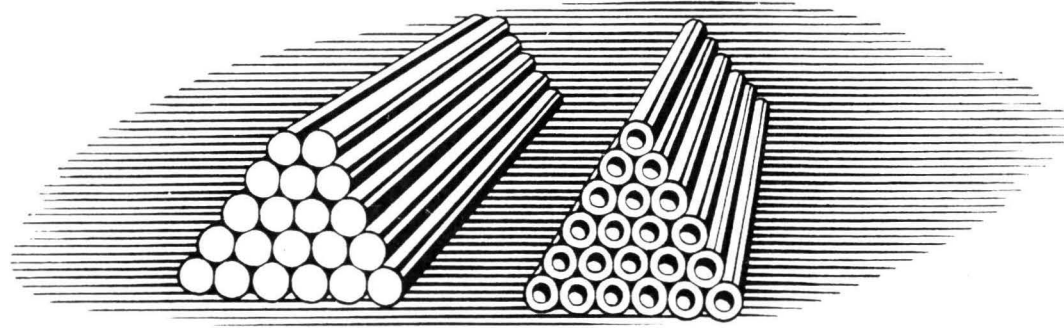
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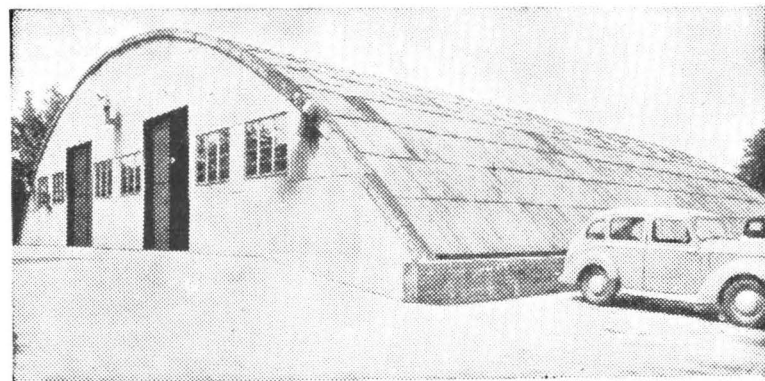
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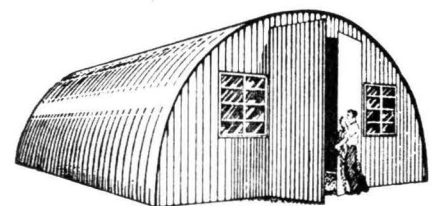


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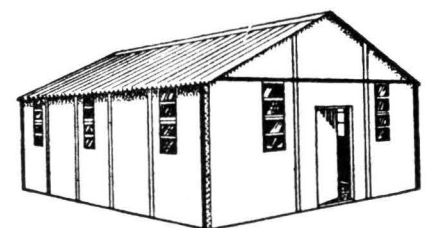
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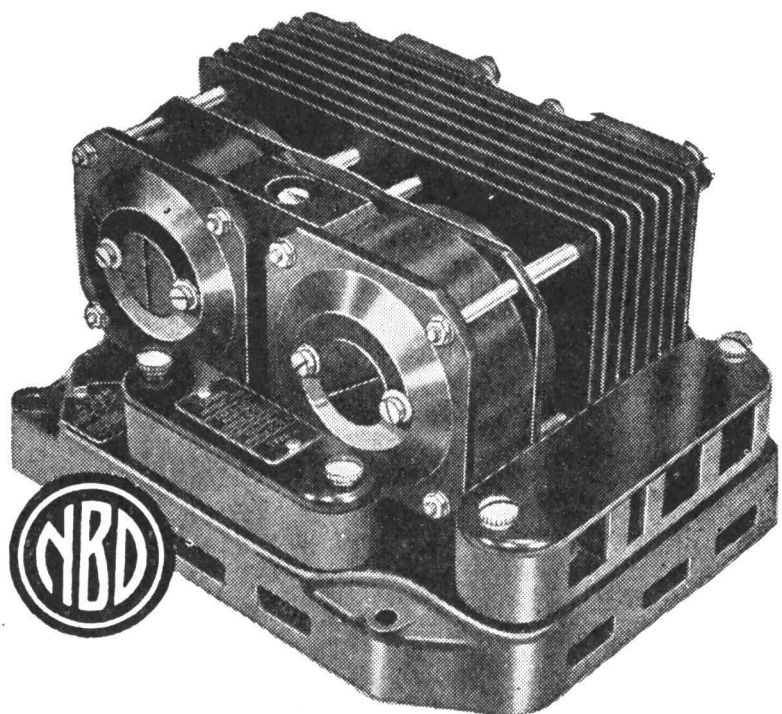
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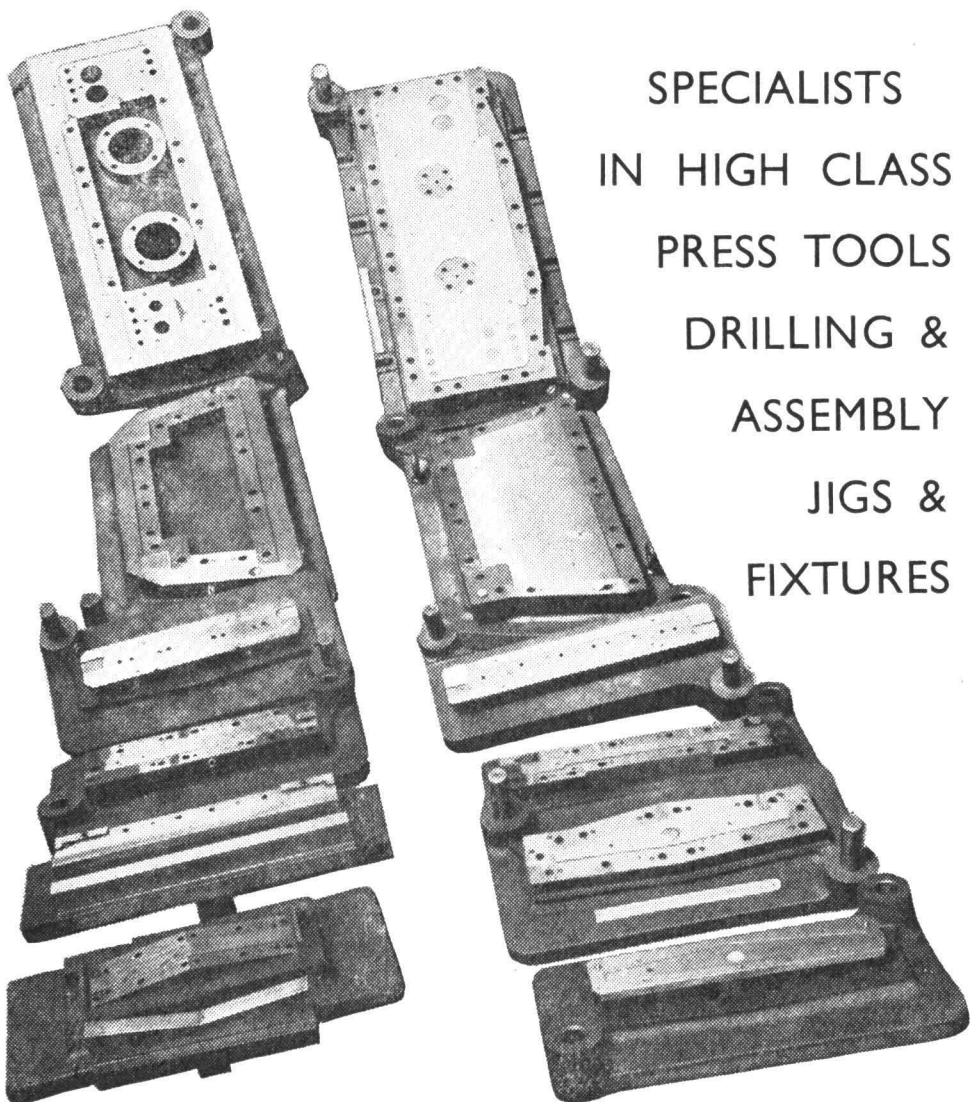
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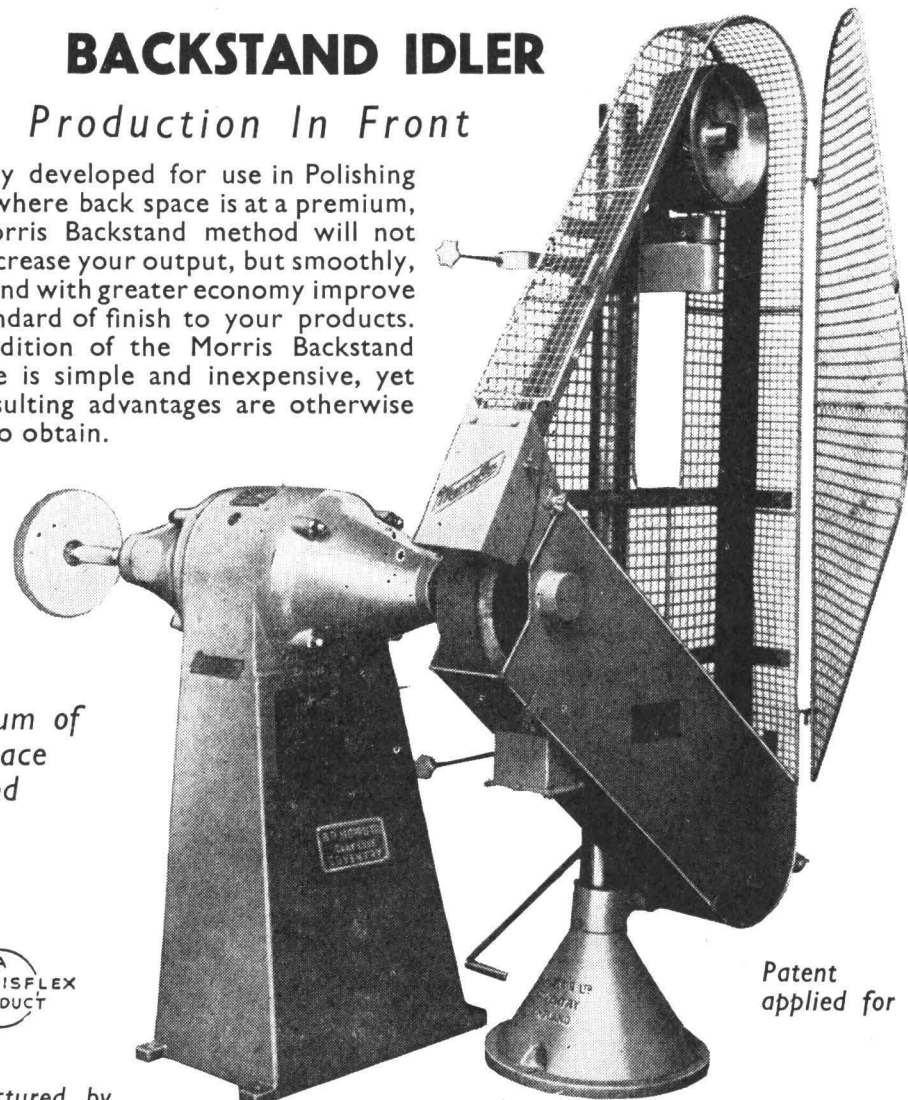
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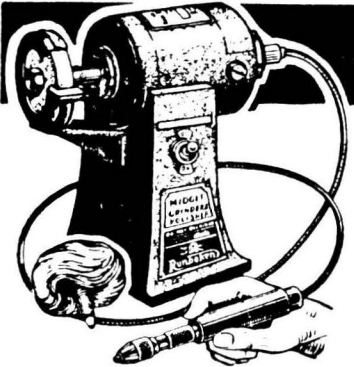

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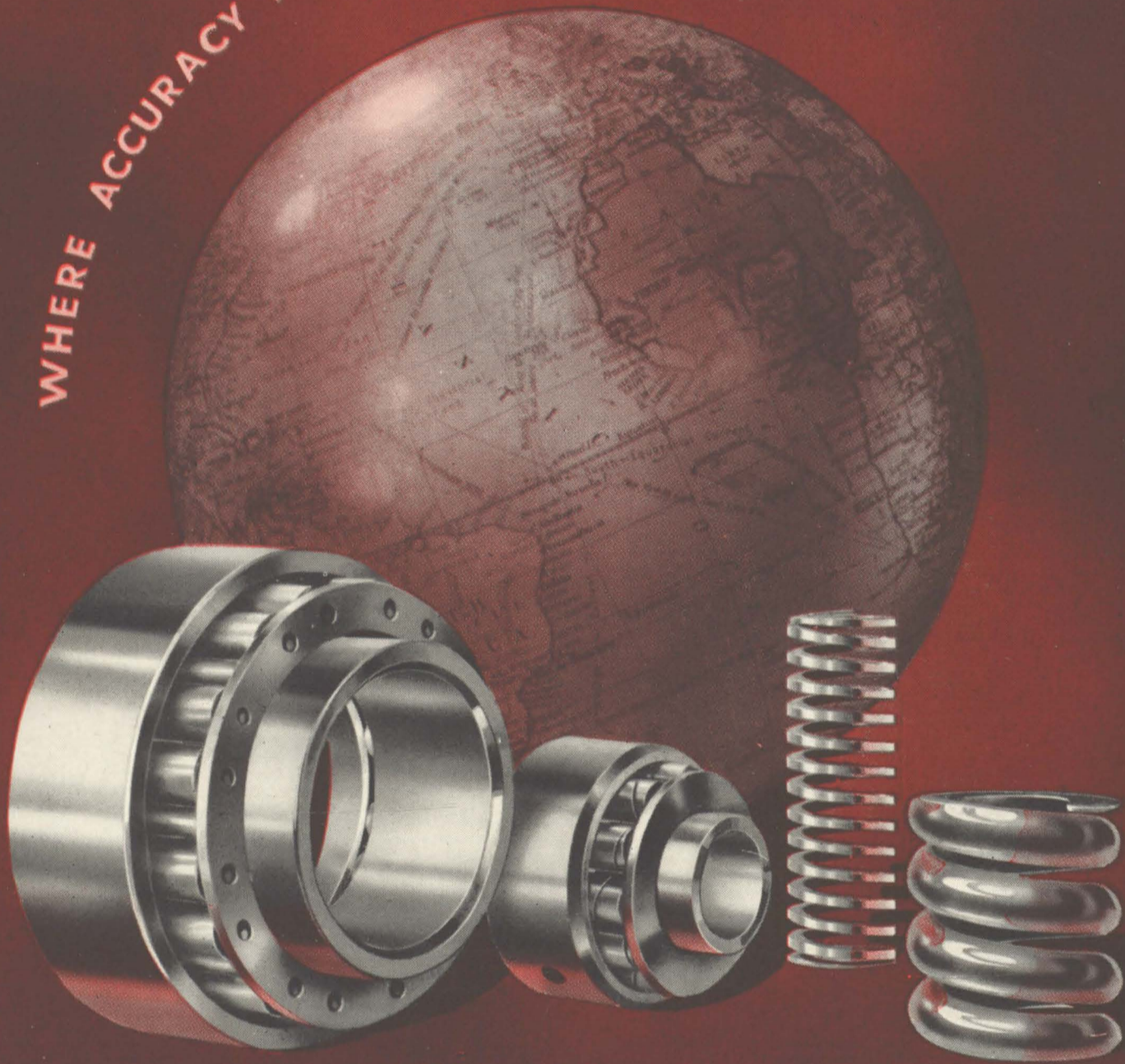
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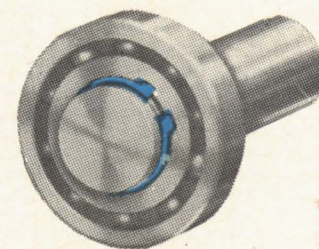
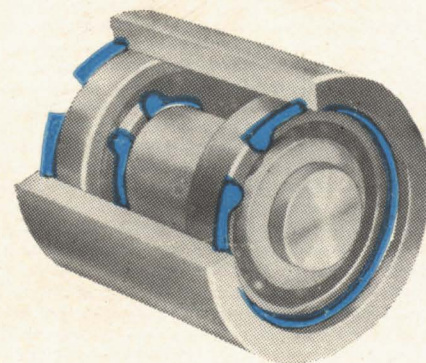
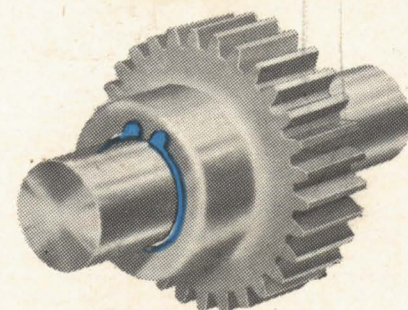
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