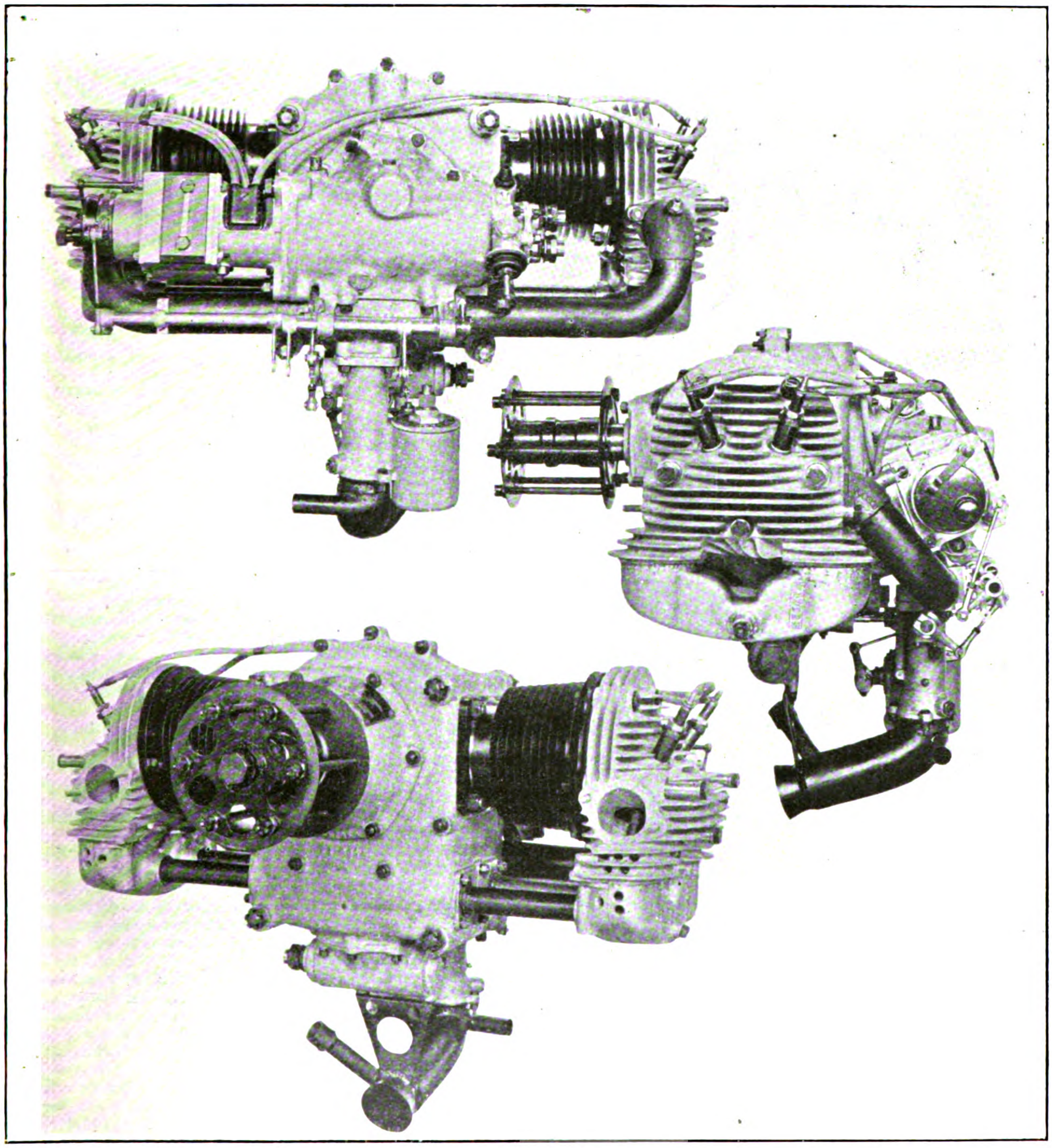
THE NEW BRISTOL "CHERUB"

Series III Light 'Plane Engine Passes 100 Hours Type Tests

As a result of the outstanding successes of the original Bristol "Cherub" engines in the 1924 and 1925 Lympne Light 'Plane meetings, and other competitions in Germany and the United States of America, the Bristol Aeroplane Company decided to develop this engine further, with the idea of putting it on a basis fully equal to the best modern large aero engines as regards reliability and performance. Although there were those who doubted the possibility of obtaining real reliability in a small very high speed light 'plane engine, the Bristol Company has managed, by taking advantage of their valuable experience gained in competition work, by careful re-designing, and as a result of nine months of development work, to produce a small light engine, which compares well with aero engines of more than ten times the power. Thus the "Cherub" series III develops a normal power of 33 b.h.p. at 2,900 r.p.m., and a maximum of 36 b.h.p. at 3,200 r.p.m. The weight of the engine is only 95 lb., or 2·88 lb. per h.p. on normal power. At the same time the fuel and oil consumptions are low, the former averaging 2 galls. per hour and the latter 1 pint per hour, both at normal speed and power. That the reliability claimed for it has been attained in the "Cherub" III is proved by the fact that one of these engines has passed



THE LATEST "CHERUB": These three views illustrate the Series III engine, which has recently passed the Air Ministry's 100 hours' type test.

the 100 hours type tests imposed by the Air Ministry. Any engine capable of passing successfully this severe test may be assumed to have left the experimental stage behind it.

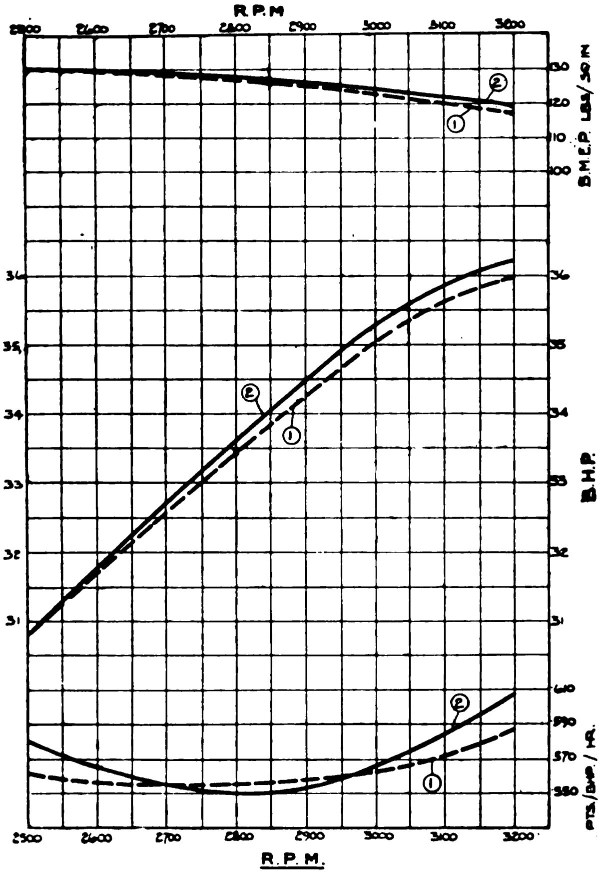
Changes in Design.

A brief outline of the changes in design which have been incorporated in the series III "Cherub" may be of interest, the older "Cherub" being already familiar to readers of FLIGHT. To begin with, the bore has been increased to 90 mm. and the capacity to 1,228 c.c. The cylinder heads have been re-designed, and have new type valves with triple-valve springs. An extra gas ring has been added to the pistons, and a scraper ring of new design is used. The crankcase has been re-designed with dry sump, and is now more robust, smaller and more symmetrical. There is now a full floating bush big end bearing, and the lubrication system is of the full pressure type by engine-driven duplex gear pump, one suction and one pressure unit. The rear of the engine has been modified to allow easier attachment of engine mounting, and a special "Cherub" type of Zenith carburettor is tucked up more snugly to the engine, with new float mechanism. The ignition control is automatic, inter-connected with the throttle. The altitude control is inter-connected with the throttle so as to ensure automatic return to ground position when throttle is closed.

The Type Tests.

Concerning the Air Ministry Type Tests, which took place in December last, the essential information may, perhaps, best be given in the form of tables. One of our illustrations this week shows the power, etc. curves taken before and after the type tests, from which it will be seen that the power given at the end of the 100 hours was greater than before the test. Attention may also be drawn to the fact that the official report on the condition of the engine after being stripped stated that "The general condition of the engine was excellent."

A synopsis of the type tests is as follows: First run of 1½ hours on Froude dynamometer, during which the first power curve was taken; 40 hours on Froude at 90 per cent. power at 2,900 r.p.m.; 50 hours on hangar at 90 per cent. power, at 2,900 r.p.m.; 9 hours on Froude at 90 per cent. power and 2,900 r.p.m.; 1 hour on Froude at full power and 2,900 r.p.m.; 1 hour on Froude at high speed of 3,350 r.p.m.; 10 mins. on Froude, slow-running at 890 r.p.m.; 1 hour on Froude, high power of 36·9 b.h.p., at 3,190 r.p.m.; and finally 1½ hours on Froude, during which second power curve was taken.



Power curves of the Bristol "Cherub," Series III: Curves No. 1 show readings taken before the 100 hours type tests, and curves No. 2 readings taken after the type tests. The fuel used was 60 per cent. petrol and 40 per cent. benzol.

Details of 100 hours Test at 2,900 r.p.m.

The following table shows particulars of the 100 hours test:

Run	Hours. non-stop.	Power at End.	Average Consumptions. Fuel. Gals./h.	Fuel. Pts./hp./h.	Oil. Pts./h.	Oil. Pts./h.p./h.
1	10	34·2	1·94	0·59	1·22	0·046
2	10	34·5	1·9	0·58	0·98	0·037
3	10	34·5	1·9	0·58	0·612	0·023
4	10	34·2	1·93	0·59	0·570	0·022
5	10	Hangar	1·94	—	0·625	—
6	10	Hangar	1·94	—	0·75	—
7	10	Hangar	1·92	—	0·56	—
8	10	Hangar	1·91	—	0·48	—
9	10	Hangar	1·94	—	0·42	—
10*	10	34·2	1·91	0·58	0·58	0·022

* The last hour of this run was at full power. The fuel used was 60 per cent. petrol and 40 per cent. benzol. The average consumptions for the 100 hours were: Fuel, 1·92 gals. per hour = 0·586 pts./hp./h. Oil: 0·68 pints per hour = 0·026 pts./h.p./h.

The following table shows the average wear on major components during the 100 hours' type tests:—

Component.	Average Wear.
Cylinder Bore	0·001
Piston Skirt	0·0015
Piston Pin Bore	Nil
Gudgeon Pin Diameter	Nil
Con. Rod Small End Bush Bore	0·0027
Con. Rod Big End Bush Bore	Nil
Crankpin Floating Bush O/Dia.	Nil
Crankpin Floating Bush I/Dia.	0·0007
Crankpin Diameter	0·0003
Crankshaft Rear End	Nil
Cam Timing Internal Wheel	0·0001
Camshaft	0·0002
Rocker Box Bush	0·0002 oval
Rocker Shaft Diameter	0·0005 oval
Cam Fingers	0·0008
Valve Guides	Nil

It will be agreed that the above figures are very good indeed, and that the "Cherub III" withstood the very searching test with flying colours.

GENERAL DESCRIPTION

The "Bristol" Cherub engine is of the two-cylinder opposed type, and has a total swept volume of 1,228 c.c.

The bore and stroke are 90 mm. and 96·5 mm. respectively.

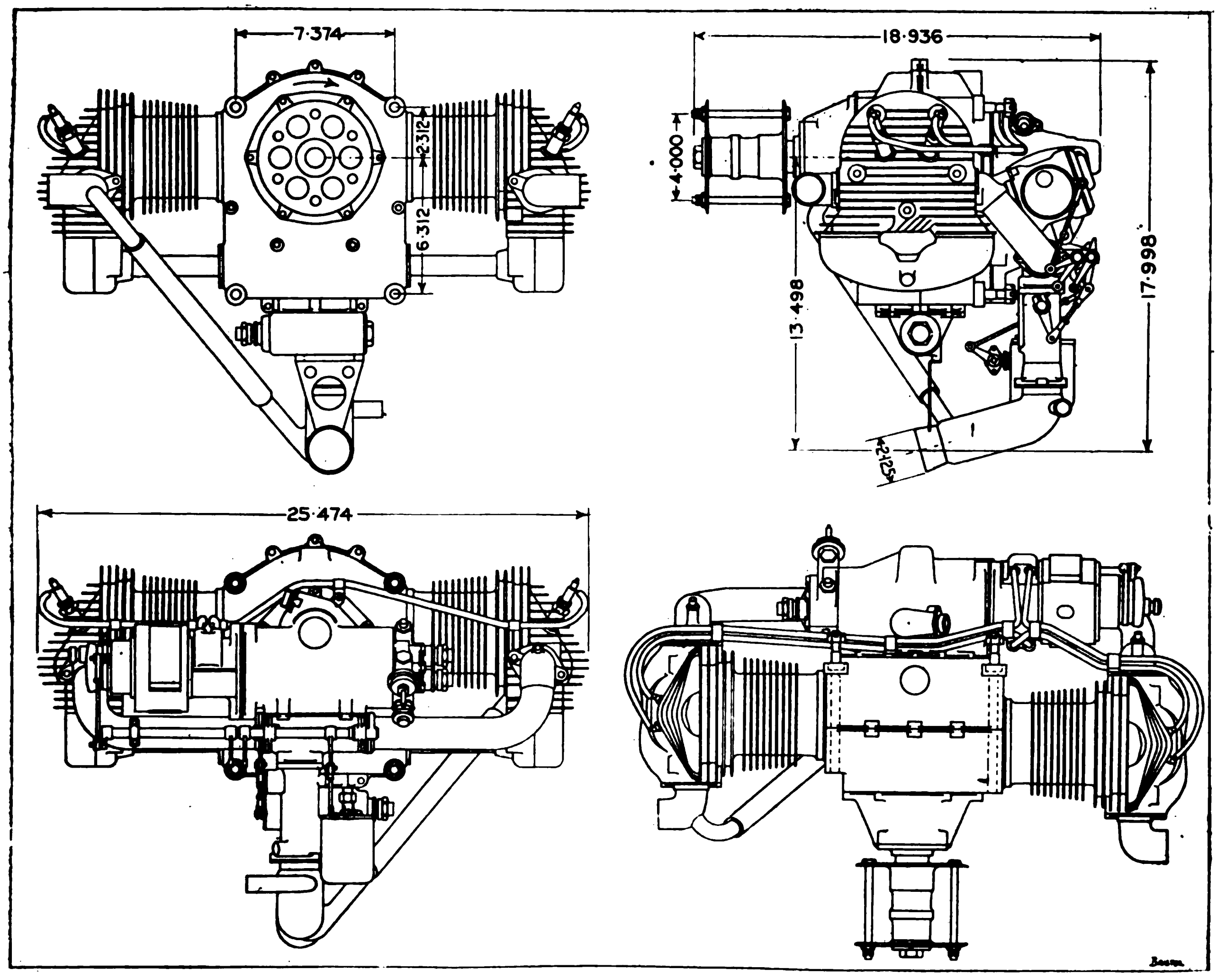
Crankshaft.—The crankshaft is a case hardening alloy steel stamping of ample dimensions, carried in four bearings; the crankcase is an aluminium casting, split vertically on the engine centre line, and provided with separate front and rear covers.

Bearings.—There are three main journal bearings. The front one is of the deep groove type, located in the nose of the conical front cover, and transmits the propeller thrust from the crankshaft to the case. The other two are of the double-row self-aligning type, and situated adjacent to the crank throws, one in front and the other behind, and are housed in the front and rear half crankcases respectively. The tail end of the shaft is supported in the rear cover by a plain white metal bearing, which provides an oil seal, allowing oil to be supplied through the hollow tail end and drilled oilways to the big end bearings. On the shaft between the two rear bearings a spur wheel and two spiral gear wheels provide drives for the camshaft, tachometer and magneto and oil pump, respectively.

Connecting Rods.—Connecting rods are alloy steel forgings with hardened liners, pressed into the big ends, the proportions of which are such that the rods may be threaded over the shaft. When in position, the split bronze floating bushes are inserted and the two halves secured to each other by high tensile steel screws which are locked by split pins.

Pistons.—The pistons are of aluminium alloy fitted with three rings, the lower one of which serves as a scraper and returns surplus oil from the cylinder walls through drain holes in the piston skirt. The hollow gudgeon pins float both in the piston bosses and in the connecting rod small ends and are located endways by bronze buttons pressed into their open ends.

Cylinders.—The cylinders have steel barrels, but the inlet and exhaust passages are formed in the aluminium alloy heads which also carry the screwed-in alloy steel valve seats, valve guides, valves and springs. A deep spigot for the head is provided on the barrel with a flange to which the head is bolted. The spigot protects the vital joint which is formed by a copper ring spigotted and very carefully fitted in annular grooves cut in the head and barrel flanges. As the rates of expansion of aluminium and steel are different great difficulty is usually encountered in the maintenance of a really gastight joint with this type of head. In the Cherub heads, this difficulty has been entirely overcome by inserting packing pieces of a special alloy, having an unusually low rate of expansion between the cylinder heads and the heads of the securing bolts. This arrangement combined with the copper ring joint has proved so satisfactory that the ends of the bolts are riveted over on their nuts, the head and barrel being regarded as one unit which need never be disturbed. The cylinders are secured to the crankcases by a spigotted and flanged joint, a Dermatine ring serving to make the joint oil-tight.



THE BRISTOL "CHERUB," SERIES III: These four views, with main overall dimensions given, should provide sufficient data for designing mountings and cowling for the engine.

Valves.—Inlet and exhaust valves are of cobalt-chrome steel and are interchangeable, and three concentric springs are used on each valve. The valve-operating gear is somewhat unusual, and has distinctive features of considerable importance.

The camshaft which, with its four cams, is machined from the solid, runs across the crankcase below the crankshaft, and is driven by plain spur gears of ample dimensions. The cams are of the constant acceleration type. The valves are operated by rocker shafts which run parallel to the cylinder axes from crankcase to cylinder head. These may be regarded as the precise equivalent of the normal type of rocker arm which is interposed between camshaft and valve in the overhead camshaft type of engine, with the single difference that a rocker which is operated through a finger, by the cams, is separated from that which operates the valves by a length of shafting. As the valve stems project from the cylinder heads radially relative to the cylinder bore, any difference between the expansion of the cylinder and that of the rocker shaft merely moves the valve stem slightly across the face of the operating rocker, but does not alter the valve clearance. A torsion spring fitted to the rocker shaft keeps the cams, finger, and operated rocker in contact, and the whole valve gear is entirely enclosed.

Magneto.—As already mentioned, the magneto is driven by spiral gears from the rear end of the crankshaft. It is mounted on the rear cover by a flange and spigot, and lies behind and parallel to the port side cylinder with the contact-breaker readily accessible. The magneto is a double-pole double-slip-ring type which fires two plugs in each cylinder. It is fitted with an impulse starter to render starting easy.

Lubrication System.—The oil pump is located behind the starboard cylinder in an extension of the magneto housing on the rear cover, where it also is readily accessible, and is driven by the same spiral gears that drive the magneto. It is detachable as a complete unit, and consists of two independent gear pumps. At the bottom of the crankcase is provided a detachable oil sump containing an easily removable oil filter. The larger of the two pumps draws oil drained from the crankcase through this filter, and returns it to the tank *via* a filter in the bulkhead, and supplies it under pressure through drilled oilways to the big-end bearings and the bushed bearings of the camshaft and intermediate wheel. This pump is provided with a spring-loaded pressure adjuster, the by-passed oil being returned to the suction side of the pump. The spiral gears are adequately lubricated by oil collected in a well into which the lower gear dips. The bearings of this gear are automatically lubricated by the oil which flows from a similar but smaller well, special provision being made to prevent leakage through this bearing into the magneto housing. The oil pressure is 40 lb. per sq. in.

Carburettor.—The carburettor is a special type of Zenith, with hand-operated altitude control of the extra diffuser air type and is bolted to a cast aluminium induction T-piece, which is attached by studs and nuts to a broad facing on the underside of the magneto and pump housing on the rear cover. The throttle and magneto advance and retard are inter-connected by a suitable arrangement of levers and links. The altitude control is independent except that it is closed automatically if the throttle is closed. The air intake to the carburettor is an exhaust jacketed steel elbow. The induction pipes run from the T-piece parallel to the cylinders, and are fitted into it with airtight expansion joints, and are provided with bosses to take primer jets.

Mounting.—The engine is mounted from screwed extensions on the ends of the four crankcase bolts at each corner of the crankcase. A standard connection for a tachometer is arranged on the port side above the magneto.

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EXPERIMENTAL STRESS ANALYSIS.

THE paper on the above subject, read before the Royal Aeronautical Society on January 7 by Prof. A. J. Sutton Pippard, M.B.E., D.Sc., F.R.Ae.S., was in many ways a most remarkable one, but unfortunately it was of such a technical character as to preclude any possibility of making a useful résumé of it for the benefit of readers of FLIGHT, and we can only advise those interested in the subject to obtain the forthcoming issue of the Royal Aeronautical Society's *Journal*, in which the paper will be published in full.

Prof. Pippard is, of course, an authority on matters pertaining to stress calculations, and it may be recollected that he is the joint author with Mr. J. L. Pritchard of the book " Aeroplane Structures," which has become the recognised text-book on the subject of aeroplane stress calculations in this country.

In his paper Prof. Pippard referred to the report of the Accidents Investigation Sub-Committee of the Aeronautical Research Committee, and quoted from this report the following passage : " The existing methods of calculation at present in use for determining the scantlings of structural members of an airship are insufficiently accurate for the purpose, and more exact methods should be developed."

The lecturer then briefly recalled the formation of the Airship Stressing Panel, under the Chairmanship of Mr. R. V. Southwell, and the published report of the Aeronautical Research Committee (R. & M. 800) containing certain results of the work of the Airship Stressing Panel. He pointed out that these results were only obtained by the introduction into the analysis of various simplifying assumptions, the validity of which required checking. The Panel recommended that experiments should be initiated on models representative of the structure of a rigid airship, as a check on the theoretical results of their report.

At the end of 1923, Prof. Pippard, who was then in a position to undertake experimental work, suggested to the Aeronautical Research Committee that he should carry out a research into the properties of redundantly braced frameworks. This course was agreed to, and the experimental work was begun almost immediately, and has proceeded continuously up to the present date at Cardiff University College. It was with the results of these experiments that Prof. Pippard's paper dealt.

Prof. Pippard then referred briefly to a series of investigations commenced by Mr. Southwell, inspired by the problems of the torsional stresses in an aeroplane fuselage, and gave an outline of this work.

The lecturer then showed slides illustrating the model used by him in his experiments, which was a framework three bays in length, each bay being 30 in. long. In section the framework was hexagonal, the side of the hexagon being 25 in. As the theoretical analysis had been based on the assumption that the structure was pin-jointed throughout, an attempt was made to design a suitable joint of this type. It may be imagined that to design a frictionless joint in which there should be no fixing factors would have been well-nigh impossible, and ultimately a suggestion made by Mr. Southwell that the members of the structure should be attached to the joints by short dowels or pins was adopted. Preliminary tests on these joints indicated that the dowels might be relied upon to serve as a satisfactory means of attachment without introducing any serious fixing effect.

Accurate means for measuring the stress in all the members of the structure were essential, and for this purpose none of the standard types of extensometers were suitable, and consequently a special instrument had to be designed, and this was done in collaboration with the Cambridge Instrument Co., Ltd. The result was a micrometer microscope which gave the high degree of accuracy required.

A series of experiments on the stresses in various members in this structure under various loads was then described, but space does not permit of referring to these in detail, and all that is possible here is to give the general conclusions arrived at by Prof. Pippard, which were as follows :—

" 1. When a tubular framework with redundant bracing is provided with efficient bracing in the plane of the applied load system, the stresses in the members tend quickly to become independent of the arrangement of the load system.

" 2. The provision of additional bracing in other planes parallel to that of loading produces a much quicker equalisation of stresses.

" 3. Unless efficient bracing is provided in the plane of loading to act as an initial distributor of the external load, even if the tube exhibits a high degree of redundancy in other planes, the process of equalisation is a very slow one, and the stresses even at a distance from the plane of loading would be dependent to a considerable extent upon the arrangement of the load system.

" 4. If in the design of such structure (*e.g.*, the hull of a rigid airship) formulæ are used which determine the stresses in the members in terms only of the resultant actions at the section considered, it is important that effective bracing should be provided in the plane of the load system. Unless this is done there is a very serious liability of error."

Effect of Non-operating Members

In conclusion the lecturer dealt with the case when certain members of a framework are capable of resisting compression only up to a definite value, such as slender struts in which the load will increase as the external load is increased until its magnitude reaches the Euler critical value, after which it will bow, and the load remain constant at the critical value. In the case of an initially tensioned wire, the member behaves as a strut until the induced compression just balances the initial tension. It then ceases to function and is no longer an integral part of the framework.

" A framework containing such members," the lecturer said, " presents difficult problems, since all members are operative under small external loads and the structure may exhibit a high degree of redundancy : under large external loads it may reduce to a simply stiff frame, while intermediate loads may produce any degree of redundancy between these extremes."

For practical stress analysis, it was generally sufficient to take account of the two extreme cases, but in the design of rigid airship hulls the work involved was prohibitive. Approximate methods had been given by the Airship Stressing Panel in R. & M. 800, but while this analysis was legitimate for normal flight conditions of loading, some or all of the counter-bracing panel wires resisting compression might become inoperative under exceptional loads. It was essential that the stresses in the frame under the extreme loading conditions should be known. A method had been suggested by Mr. Southwell by which such stresses could be simply deduced from a knowledge of the stresses in the various members of the framework in its normal fully redundant state. To apply this method it was necessary to calculate the loads in all members of the framework under the extreme conditions, assuming it to be fully redundant and all members capable of resisting compression of any required amount. In order to obtain such conditions, external forces were imagined to be applied to the joints connected by the members, of such magnitude as to reduce the hypothetical stresses in them to the actual values. An example was given in which reversed loads were superposed on the panel, and it was pointed out that if this superposition were made for each panel in a framework and the complete structure analysed under such superimposed loads, an exact solution of the problem would be obtained, but the work would be heavy. It was therefore suggested that each panel should be treated as if it were an independent frame. If this were done the work was very easy, but it necessitated an assumption that required check to determine the degree of approximation involved. During his experiments Professor Pippard made a check of this point, and the check showed that the general agreement was good. It was therefore concluded that the method described was sufficiently reliable to give a good indication of the stresses in the extreme condition when redundant members had ceased to operate. Finally Professor Pippard referred to some experimental work now in progress, in which the longitudinal members of the model structure were continuous instead of being pin-jointed at the transverse frames.