SERVICE LIFE EXTENSION POSSIBILITIES BY FATIGUE TESTS ON USED GLIDERS

by

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After attaining their approved service life limits, five R-26/S Gobe two-seaters have been fatigue tested in order to get data for an official service life extension. Using statistical data from ten years of intensive flying, the normal flight program underlying the damage calculations has been revised. The tests have been run on a hydraulic machine using a home-made load distributing lever system. Damage calculations included determination of an effective stress coefficient and of the nominal safe life,respectively. As a result of the tests, a proposal to extend the approved service life of the type could be made.

1. AIM AND ANTECEDENTS OF THE TESTS

Phasing out a type of which some hundred examples are flying is a decision not easily reached by those responsible for it, substantial investments being involved. There is a natural desire to postpone it as far as possible but flying the type beyond its officially approved flight time limits is obviously out of question for safety as well as for legal reasons.

On the other hand, one may always be in some doubt as to the correctness of a safe-life estimation based on past experience and/or, at best, on results of a single-piece full scale fatigue test. Even if everything was correct, the authority had to err to the safe side. In this case, it may be worth sacrificing a few of the time-expired aircraft for acquiring data to determine the possibility of extending the approved service life of the remaining specimens. It would be too expensive to do the same before the initial introduction of the type but with test pieces having practically only scrap value it may pay. The series of fatigue tests done on the two-seater R-26/S Gobe, type tested some ten years ago (Ref. 1), was aimed at such a purpose.

Fatigue tests on worn-out gliders are, as a whole, not new; in fact, sailplane fatigue work was started this way in our country. Even some basic problems of the fatigue endurance of wooden gliders were cleared in this manner by Hadhazi (Ref. 2). But in those early cases rough estimates for the remaining service life sufficed, so uncomplicated first approximation evaluation procedures could be employed evading the difficulties of mixed service/test damage calculations and safe life extrapolation. In service life extension work we cannot take advantage of these concessions and calculation methods as correct as possible have to be employed.

2. FLIGHT PROGRAM AND LOAD SPECTRA

Any reliable flight time extension can only be based on more exact data from exploitation parameters, from flight loads and from the fatigue endurance of the structure. At the beginning of the present test series, the Gobe had seen 10 years of intensive service since its introduction. Damage calculations for the type test had been done on the basis of a flight program forecast giving a mean

Table I

Revised Average Flying Program
(Time is in hours)

Flight Task	Number of Starts	Flying Time	Winch Launch	Aero Tow	Flight in Smooth Air	Thermalling	Glide between Thermals	Number of Spins
Primary Flying by Winch Launch	7000	585	87	--	498	--	--	--
Soaring by Winch Launch	1500	500	19	--	51	228	202	--
Soaring by Aero Tow	350	345	--	35	35	146	128	--
Aero Towing Courses	800	200	--	107	93	--	--	--
Spinning	350	120	--	70	50	--	--	1400
Sum Total	10000*	1750	106	212	727	374	331	1400

* 8500 winch launches and 1500 aero tows

airborne time per flight of 9 minutes (see Table 1 in Ref. 1). Strict official flight-log keeping enabled us to do a check on this. A mean-flying time histogram for the year 1974 and for the years 1965-74 can be seen in Figure 1, giving a total average of 10.3 minutes per flight in both cases. From this, a more-than-estimated activity in thermalling and in advanced flying is evident. Combining this with some other service data available, a revised flying program according to Table 1 was set up.

Fatigue loads on the structure were determined on this basis. Refinements in stochastic load spectra calculations introduced since the type test (Ref. 3) were also taken into account. After revision, nominal load spectra turned out as presented in Figure 2a and 2b.

3. TEST PROGRAM AND EQUIPMENT

The degree of service load simulation possible in a laboratory experiment is determined mainly by the performance of the testing machine available. Ours is of the hydraulic type made by the factory WPM/Leipzig in the German Democratic Republic giving sinusoidal forces with manual setting of the load level. In accordance with this, a short random sequence program block structure as shown on Table II has been devised.

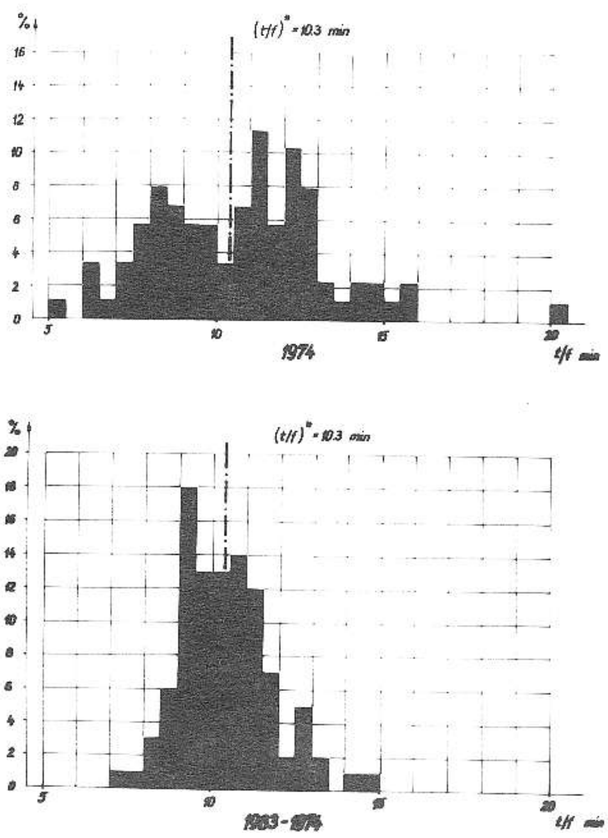


Figure 1. Average Flying Time Histogram.

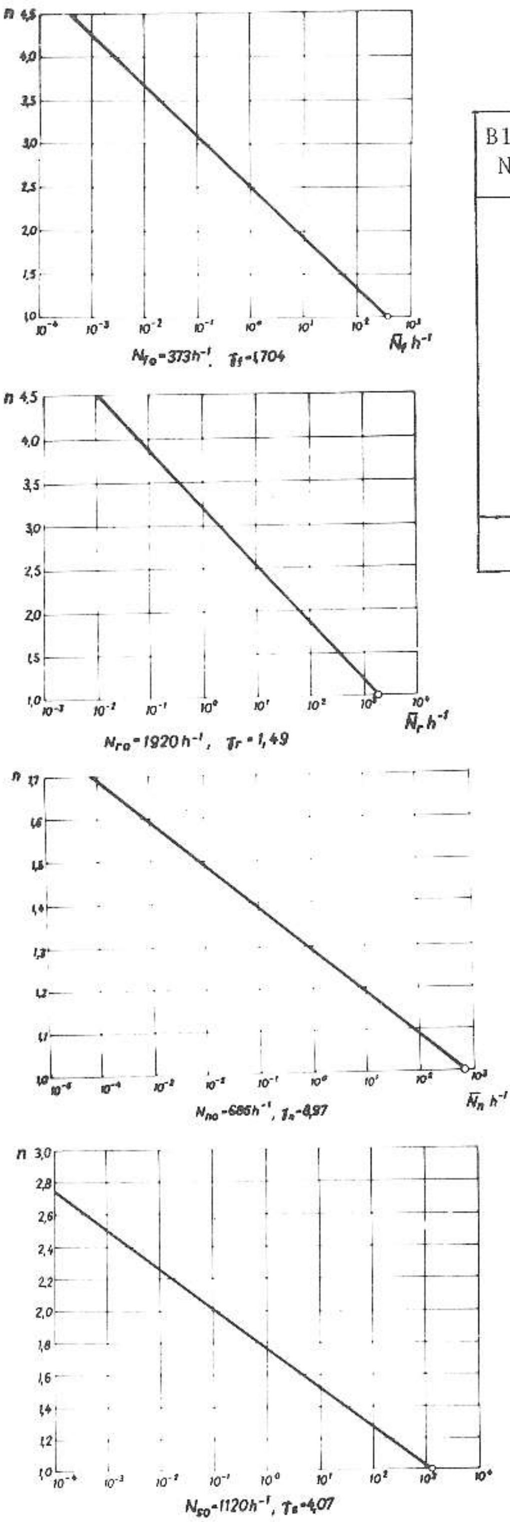


Figure 2a. Service Load Spectra: Start-landing, Aero Tow, Calm Air Flying, Gliding between Thermals.

Table II
Program Block Structure

Block No.	Mean Load n_1	Alt. Load $\pm n_2$	Number of Cycles	Loading Frequency/m	Remarks
1	1.0	1.3	60,000 .	180	Landing
2	1.0	0.85	45,000	80	Straight Flt.
3	1.0	0.6	70,000	80	"
4	1.6	1.4	6,000	80	Circling
5	1.4	1.2	18,000	80	"
6	1.2	0.8	41,000	80	"
7				80	Tangential
Block sequence: 5, 6, 2, 1, 7, 4, 3.					

Due to lack of available space the fore and aft part of the fuselage had to be omitted leaving only the center part attached to the wings. The loading lever system arrangements and the general view of the test can be seen in Figure 3.

The lever system giving the same spanwise load distribution as employed in the type test was used for blocks 2 - 6. Block 1 for the start-landing case was run as resonance test-

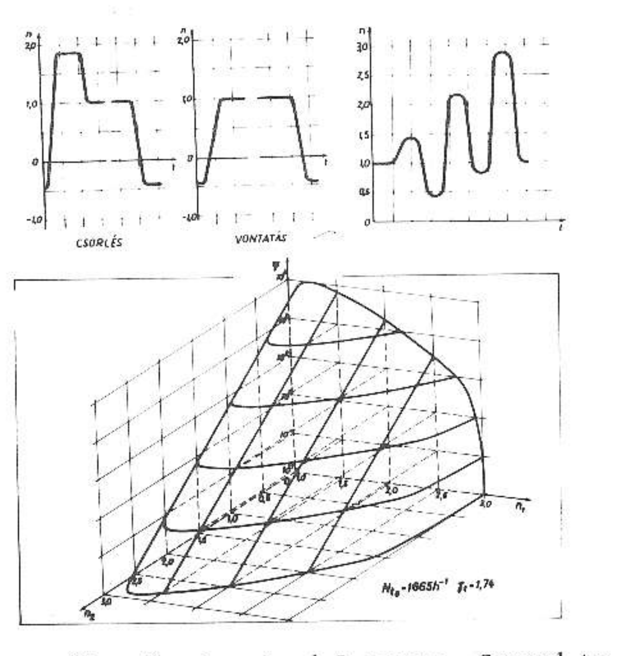


Figure 2b. Service Load Spectra: Ground to Air Cycles, Spinning, Thermalling.

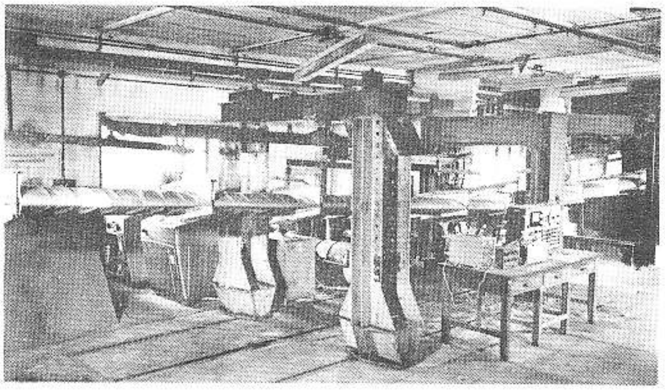


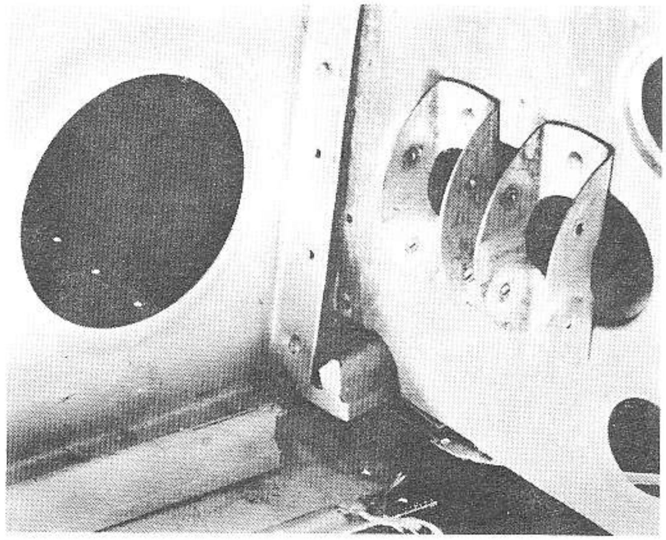
Figure 3. General View of the Test.

ing at the first bending mode of the wing without levers. The 2 x 30 kp tangential force of block 7 was applied by means of a mechanical exciter. The stroke-augmenting lever transmitting the force from the hydraulic cylinder to the main fuselage frame and the vertical guide rail system taking the tangential forces and the torsional moments are perhaps not too easy to pick out, but the main structure and lever system are clearly visible. Additional views are shown in Figures 11 and 12.

4. TEST RESULTS

The fact that the five sailplanes tested all failed at the same part, the diagonal spar, though not all at the same end, and on right and left wings alternatively, may speak for the design. A main spar lower boom fatigue fracture at the diagonal junction is to be seen in Figure 4. The crack started at the rivet hole (see lower part of the picture). Figure 5 shows the appearance of the other typical failure point, a plate corner of the built-up box holding the wing attachment bolt at the rear end of the diagonal spar. Fatigue endurance of these built-up structure details could be improved by substituting forgings, but only at prohibitive cost. Electron micrographs of the spar boom fracture are shown in Figure 6. The pictures were taken from a point near the rivet hole with enlargements of 30, 150, 450 and 1500 respectively.

Damage calculations were done by the Palmgren - Miner linear method using the Smith graphs published by Johnstone and Payne from their Mustang tests (Ref. 4). Nominal stress values were taken from the static strength test of the wing as for the fatigue type test in 1965.



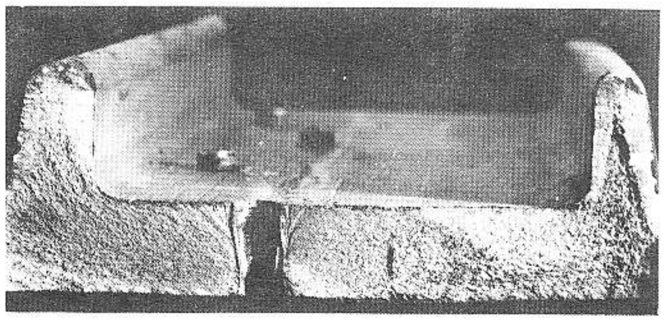


Figure 4. Main Spar Boom Failure at the Diagonal Junction.

For damage calculations to be realistic, not only nominal stress values are required but also the stress peaks occurring in dynamic loading and influences of surface parameters etc. have to be taken into account. For that purpose we proceeded as follows:

At first, service and test damage calculations for the five test specimens were done at the nominal stress level. The combined service+test damage values of the five machines gave five points on the Weibull paper and the best-fit three-parameter Weibull distribution could be obtained giving a 50% failure probability damage below unity. From this value a first estimation of the effective stress coefficient could be made. Using this, the calculation was repeated, giving a second approximation to the effective stress value, and so on. The procedure was continued until a 50% failure probability damage value approximating unity to within 1% was obtained. A sample of the service damage distribution D curves, that for the start-and

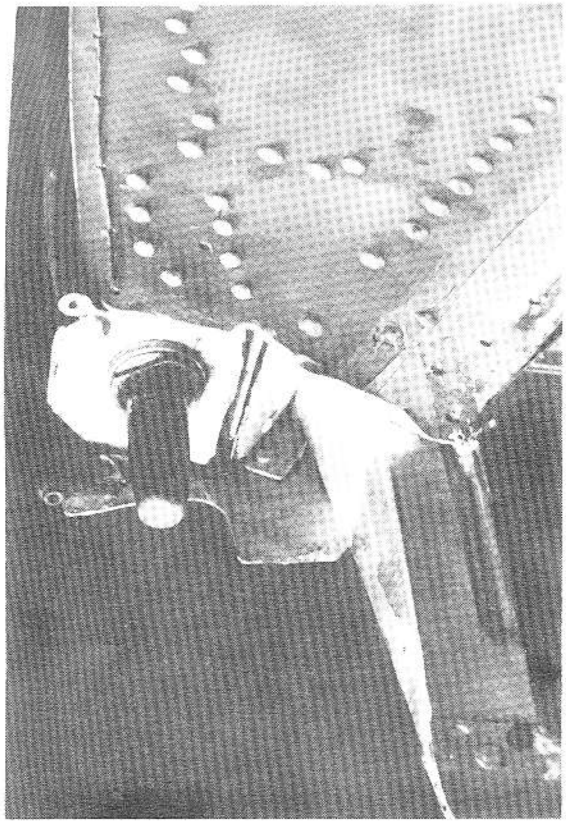


Figure 5. Fatigue Failure at the Rear Wing Attachment Bold.

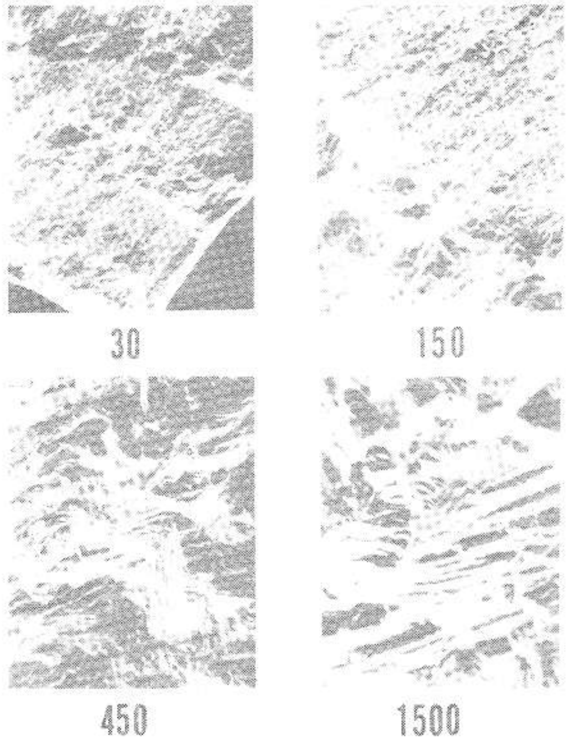


Figure 6. Scanning Electron Micrograph of the Spar Boom Fracture.

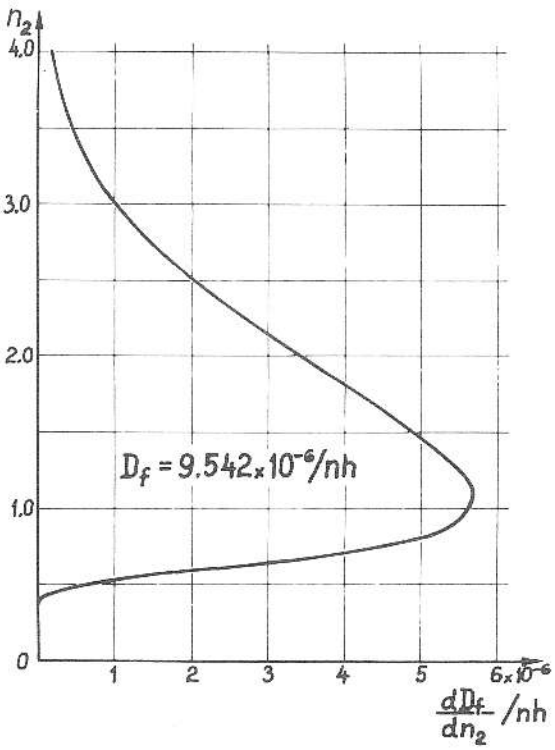


Figure 7. Damage Curve for Start and Landing.

landing case, is shown in Figure 7. Fatigue life distribution on Weibull paper according to Palmgren-Miner, giving a nominal safe life of $D_o = 0.2835$, is in Figure 8. The square points are for the service damage of the aircraft tested, circles giving the combined service+test damage at failure. By comparing these with the service damage computed for a normal flying hour of the revised flight program (Table I) the results could be converted to normal flying hours (Fig. 9). The nominal safe fatigue life obtained thus amounts to $t_{o.1}$ = 2195 normal hours.

All these calculations were done in a single run on the ODRA 1204 type computer of the Faculty Computing Center using our program VIKAR G developed for this purpose.

Different kinds of flying are not all equally severe on the fatigue life of the sailplane. First of all, elementary flying instruction is done mostly in relatively calm air as against, for example, soaring in ther-

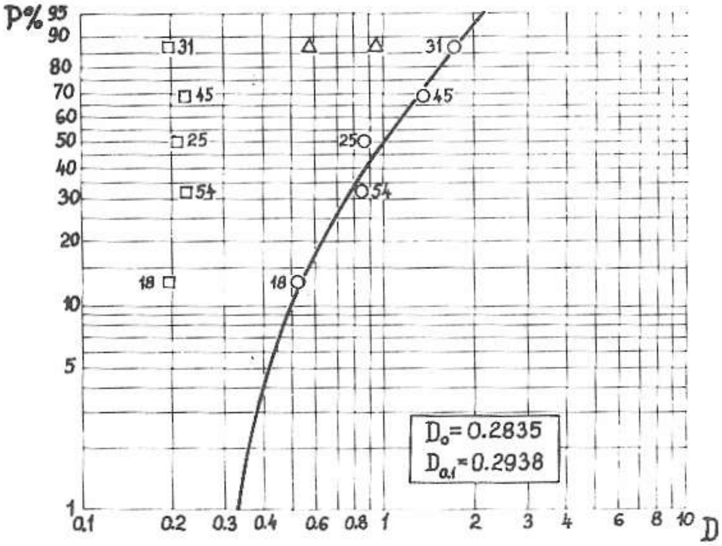


Figure 8. Fatigue Life Distribution in D

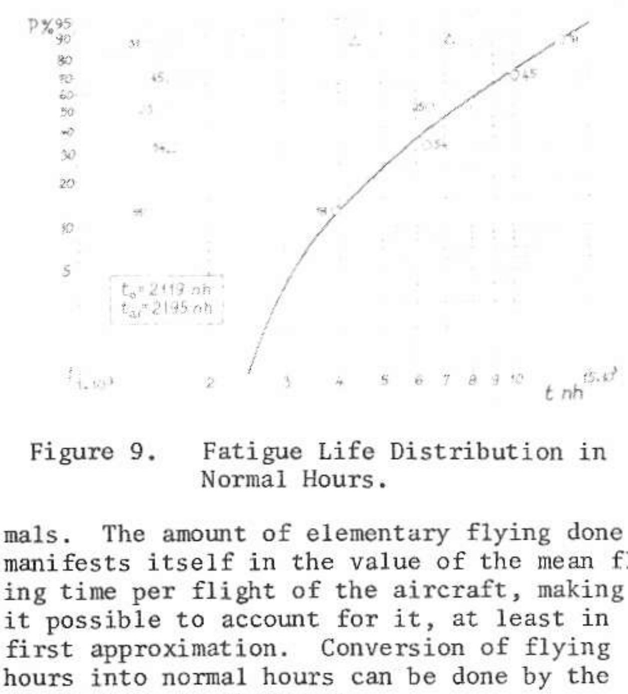


Figure 9. Fatigue Life Distribution in Normal Hours.

mals. The amount of elementary flying done manifests itself in the value of the mean flying time per flight of the aircraft, making it possible to account for it, at least in first approximation. Conversion of flying hours into normal hours can be done by the graph shown in Figure 10.

As a result of the tests, a proposal to extend the licensed service life of the R-26/S Gobe could be made giving the type a substantial additional lease of life.

ACKNOWLEDGEMENT

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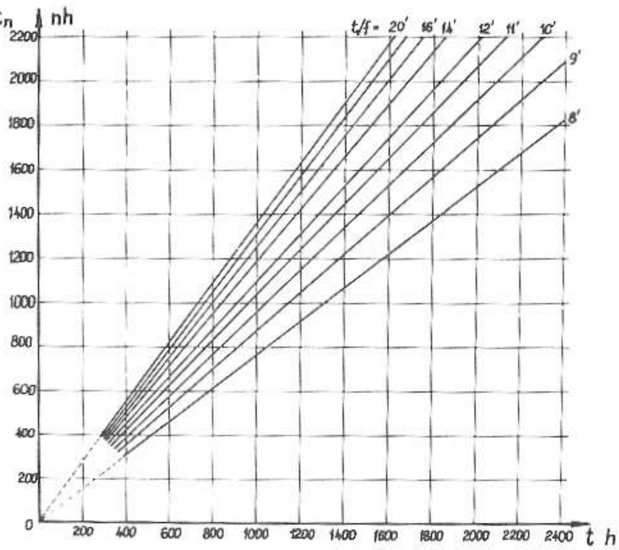

Figure 10. Conversion of Flying Hours into Normal Hours.

Planning and execution of the tests was done by two combined teams, from the Technical University and from the Research Institute for Ferrous Metallurgy respectively. The authors are grateful to Prof. dr. Paul Michelberger and to Prof. dr. Elmer Racz. George Devescovi, dr. Edmund Posfalvi, and dr. Zoltan Susanszki were responsible for running the tests and for the test fixture design, respectively. Much patient work on program development was done by the team of the Faculty Computing Center lead by dr. Attila Agoston. Photographs of the test rig and specimens are by Charles Kastaly.

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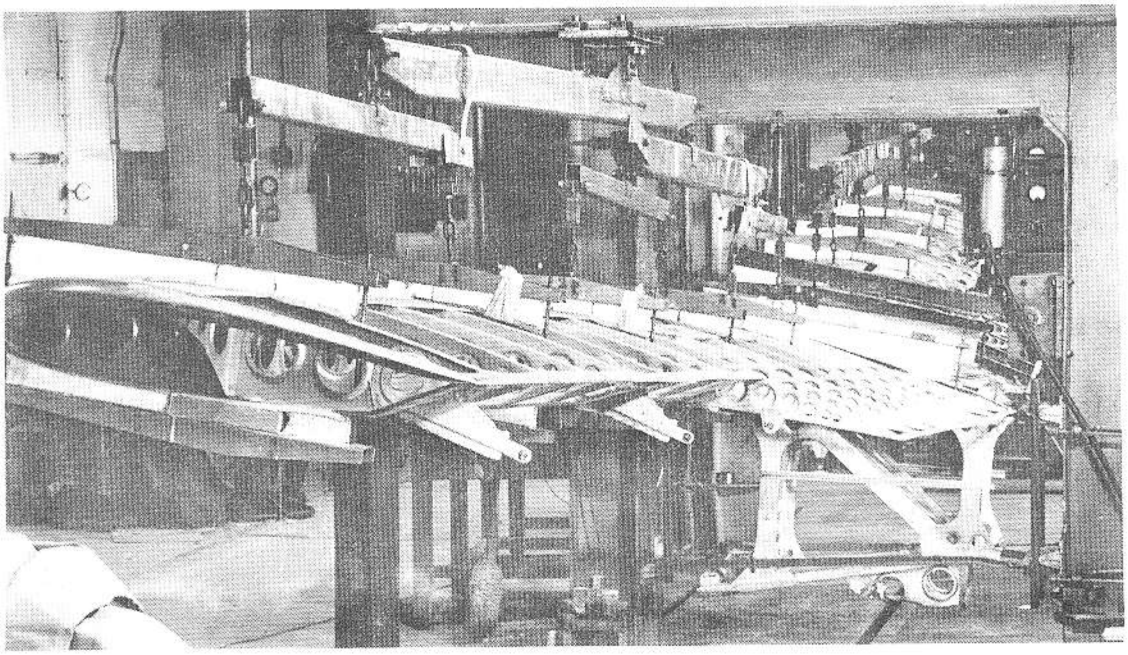

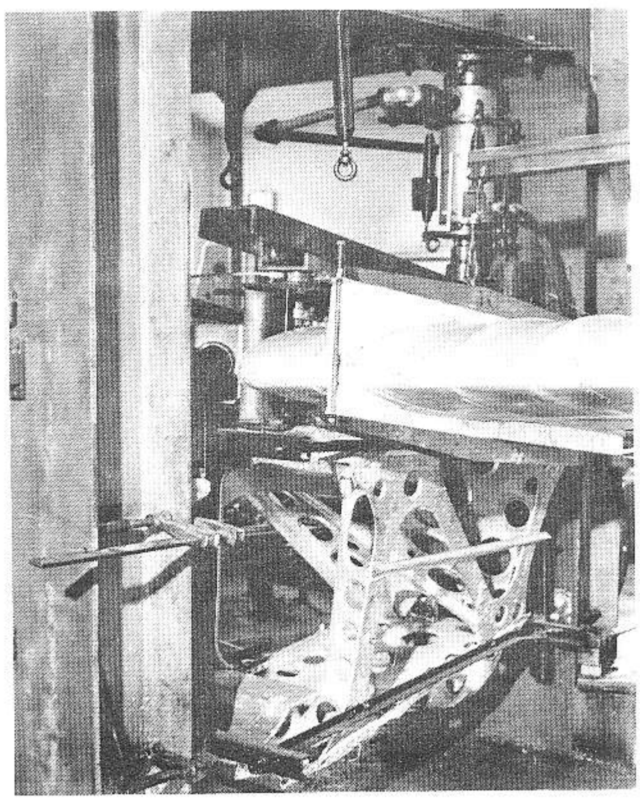

Figures 11 and 12. Gobe fatigue test.