DYNAMIC TESTS OF
KEYSTONE B-3A BOMBER OLEO SHOCK ABSORBER

(AIRPLANE BRANCH REPORT)
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OBJECT
The object of this report is to give a brief résumé of tests made on the B-3A oleo shock absorbers and landing gear, and their results; and to enumerate the alterations and improvements of the design that were found necessary in order to bring the oleo up to test requirements.

CONCLUSIONS
It was concluded that the alterations made by the Airplane Branch on the shock absorbing strut improved the action of the shock absorber. The impact loads were reduced to such an extent that the tapered welded axles, unsatisfactory with the original shock absorber, could be used with the improved shock absorber. The reduction of the maximum load and the reduction of the rebound were due to a rational design of the metering pin. An improved condition was obtained for filling the oleo with oil and for determining the oil level in the cylinder, which is of importance from the service and maintenance point of view.

HISTORY AND TESTS
The B-3A oleo strut as received from the Keystone Aircraft Corporation was similar to the design used on other bombing airplanes built by this contractor. Breakage of springs in the oleo struts was reported on the airplanes in service, and it was believed that this failure occurred during taxiing. The spring, fully compressed, supported only 120 per cent of the static weight.

Prior to acceptance of the B-3A landing gear a dynamic test of the landing gear attached to the fuselage was conducted according to the requirements for tests of landing gears and fuselage, as contained in the Handbook of Instructions for Airplane Designers (Fifth Edition). The required height of drop for bombers is 18 inches. The landing gear was equipped with a Keystone design of oleo shock absorber having a straight tapered metering pin, as shown on Figure 1; and with tapered wheel axles made of three telescoping pieces of tubing welded at the joints with fish-mouth splices, as shown on Figure 3. Drops were made from 6, 12, and 18 inches, resulting at the 18-inch drop in the failure of the rigid vertical struts as well as the axles. The rigid strut failure was due to the introduction of bending stresses resulting from deflection of the axles and from the unfavorable direction of the strut and bolt axis on the fittings.

For a second test the fittings were redesigned to eliminate the bending of the strut; otherwise the oleo unit and axles were as in the previous test. Failure occurred on the 15-inch drop, in both axles, which constituted an unsatisfactory functioning of the landing gear. Since there were no failures of other parts, the immediate remedy for the condition was to strengthen the axles by using a constant cross-section axle, with a resulting increase in weight.

In order to determine the characteristics of the shock absorbers as submitted, several laboratory tests on the jig for testing shock absorbers were made, and a record taken with the time-deflection recorder. For procedure and equipment see Material Division Report Serial No. 3139 (A. D. M. 1091). Due to the delay in completing a supporting carriage for the 44 by 10 inch wheel used on the B-3A airplane, a wheel 36 by 8 inches was used at 70 pounds per square inch inflation pressure, and the record was made with the full weight of 6,370 pounds. Analysis of the records for the 11-inch drop (see fig. 5) showed a maximum dynamic load of 27,000 pounds accompanied by considerable rebound. Higher drops were not made with 6,370 pounds weight, as the capacity of the 36 by 8 inch tire had been reached. Additional tests were then made with 4,000 pounds. During the 18-inch drop a dynamic load of 22,400 pounds was developed.

From an analysis of the record it was evident that the oleo shock absorber was developing impact loads that were too high; that it was not dissipating enough energy, resulting in breakage of the axles; and that the efficiency could be increased. The problem was to so design a shock absorber, or to make some modifications of the present one, that the original tapered, welded axles would pass a drop test from the required height. Although the standard drop height required for bombers is 18 inches, a deviation was made so that a successful 15-inch drop test would be sufficient for acceptance.

Using the load-deflection data on a 44 by 10 inch tire, the design of a new metering pin for the cylinders and pistons furnished by the contractor was undertaken. A new method, based on a new conception of the action of the oleo shock absorber, was used in the design. This method takes into account the effect of the tire on the behavior of the oleo-tire combination. The desired behavior and action of the shock absorber and tire was first determined, and the design made to conform to the desired predetermined characteristics.
A set of improved metering pins was made according to this design and installed in place of those furnished by the Keystone Company. Some changes were made in the pistons and the cylinders in order to facilitate filling the latter with oil and to provide a means for determining with certainty the true oil level in the cylinders, as some difficulties had been experienced previously in that respect. The pins were also bolted to the bottom of the cylinders to prevent pulling them out while the strut was being extended.

The results of the laboratory test showed a good agreement with the predicted performance of the new metering pins. The shock absorber and the wheel withstood satisfactorily the 18-inch and 21-inch drops, whereas a 15-inch drop only was required. The merit factor and the efficiency, based on the maximum load developed and on the amount of dissipated energy, showed the highest values so far obtained in the dynamic test of any shock absorber. The efficiency for energy dissipation exceeded 90 per cent. Figure 6 shows the resulting load-deflection curves. Figure 4 shows the analysis of the record from the time-deflection recorder, made in the 18-inch drop with full load, 6,370 pounds, and with the improved pins. The merit factor\(^1\) is 0.112, approximately double that of an average shock absorber. For the Keystone design, the merit factor is 0.052.

Using the same design of metering pins, two complete struts were made for dynamic acceptance test on the landing gear installed on the fuselage. Previous to the installation on the landing gear, additional laboratory tests were run on the oleo testing jig. One strut was tested to an 18-inch drop, and found satisfactory for installation. The second strut developed a crack in one of the cylinders on the 9-inch drop. The cylinder was replaced, and the test continued to 18 inches. This oleo was also found to be satisfactory. To begin with, the third test on the landing gear, Figure 2, was conducted with straight (heavy) axles, Figure 3, and the required 15-inch drop was made without any failure, after which an 18-inch drop was made equally successfully. It was decided to increase the height of drop still further in order to determine the breaking height, which was found to be 21 inches, when both welded axles failed near the upper welded splice.

**RECOMMENDATIONS**

It is recommended that all improvements as described above be incorporated in the production article.

**APPENDIX**

The merit factor is a criterion for judging the shock absorbing quality of a combination of the shock absorbing element with the tire, and is expressed by the following formula:

\[
M.F. = \left( \frac{W}{L_{\text{max}}} \right)^2 \times \frac{h}{\Delta_{\text{max}}}
\]

where

- \(W\) = static load on the strut with factor 1.
- \(L_{\text{max}}\) = maximum load developed by the impact.
- \(h\) = height of drop.
- \(\Delta_{\text{max}}\) = maximum combined deflection of the shock absorber and the tire (not necessarily the sum of the maximum deflection of the strut and the maximum deflection of the tire).

This criterion takes into consideration not only the effectiveness of the shock absorbing strut, which is expressed by the ratio \(\frac{Wh}{L_{\text{max}}\Delta_{\text{max}}}\), but also the actual decelerations obtained, expressed by the reciprocal of \(\frac{W}{L_{\text{max}}}\).

**Example:**

For the Keystone design,

\[
M.F. = \left( \frac{6,370}{27,000} \right)^2 \times \frac{11}{11.68} = 0.052
\]

For the Matériel Division design,

\[
M.F. = \left( \frac{6,370}{24,300} \right)^2 \times \frac{18}{11.1} = 0.112
\]

\(^1\) See appendix.
Figure 4

Keystone B-3A Oleo Leg

With DePuy pins No. 2. Second leg assembly

For fuselage test

Drop - 18"  Weight - 6000 lb  44 x 16 wheel @ 85 mph

From record No. 169
FIGURE 5

Load deflection curve

Key: lane B-24, Old Leg

First moment = 6720 in-lb

Height of beam = 11 inches

Weight of beam = 12.5 lb/in

Deflection = 0.10 inches

Date of record = 9/14/38

Date of analysis = 10/15/38

Energy input = 6170 x 3/5 = 4170 ft-lb

Strain energy 7000 x .55 = 3900 ft-lb

Energy absorbed = 4800 ft-lb

Energy dissipated = 2900 ft-lb

FIGURE 6

Key: lane B-24, Old Leg

Deflect. plank at 4 ft

Second log assembly

Bar in 1140 test

Defect. weight = 6720 lb

Wheel A X 10 6d 42 lb

Efficiency = 292500 

Deflection at deflection = 0.10 inches