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LANDING GEAR LOADS RESULTING FROM
TAXYING AN AIRPLANE OVER A PROJECTING RUNWAY LIGHT

Progress Report 2

To

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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

LANDING GEAR LOADS RESULTING FROM TAXYING AN AIRPLANE OVER A PROJECTING RUNWAY LIGHT

by

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SUMMARY

An analysis neglecting damping was made to determine the deflection of an airplane wheel when an airplane is taxied over a protruding runway light. Although the method would be useful for predicting the maximum load, the computation of the action of the masses following the run-over should include damping.

1. INTRODUCTION

In reference 1, the damping action of the oleo strut was taken into account by using data obtained from drop tests of the shock strut. Since it is not known if such data are applicable, it was decided to repeat the analyses for cases in which the oleo would remain partially compressed. The movement of the oleo is not smooth and this would approximate that part of its action which occurs for very short periods of time when, due to friction, the oleo neither extends nor closes. The two degree-of-freedom system representing the airplane then becomes, in effect, a one degree-of-freedom system. The loads on the tires as a result of the airplane taxying over two different shapes of runway lights under these conditions are presented.

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Long Beach Division, Douglas Aircraft Co., Inc.
Convair Division, General Dynamics Corporation
The B. F. Goodrich Company
California Division, Lockheed Aircraft Corporation
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North American Aviation, Inc.
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Republic Aviation Corporation

2. METHOD OF COMPUTATION

The airplane, figure 1, is represented as a single mass m_1 connected rigidly to a small additional mass m_2 representing the wheel. The tire is a simple spring whose constant k_2 is given by the load-deflection curve of the tire. W is the vertical force, other than the impact force, acting on the airplane (airplane weight minus lift). W_1, then, is the part of W attributed to one landing gear.

For the airplane of figure 1(a) taxying down the runway and hitting an obstruction, such as a light projecting above the runway surface, the differential equation of motion of the masses is

$$(m_1+m_2)\ddot{x}_2 + k_2\left[x_2 + h(t)\right] - W_1 = 0 \tag{1}$$

where

x_2 is the vertical displacement of masses m_1 and m_2

h is the height of the light

$\ddot{x}_2$ is the acceleration of masses m_1 and m_2

Other symbols are defined above.

If, as in the case of the B-47, the landing gear has dual wheels, equation (1) is modified to

$$(m_1+m_2)\ddot{x}_2 + 2k_2\left[x_2 + h(t)\right] - W_1 = 0. \tag{1a}$$

Equation (1a) would hold if both wheels ran over the light and were equally compressed. If only one wheel rolled over the light, equation (1) could be modified to:

$$(m_1+m_2)\ddot{x}_2 + k_2\left[x_2+h(t)\right] + k_2x_2 - W_1 = 0. \tag{1b}$$

At the time $t = 0$ when the airplane wheel would be at the edge of the light and before it had started to run over it, the deflection of the masses was taken as

$$x_2 = W_1\left(\frac{1}{k_2}\right) \tag{2}$$

With this initial value of displacement, the motion of the airplane was computed from equation (1) after replacing the second derivative by the following difference equation given in Appendix B of reference 2

$$\ddot{x}_t = \frac{1}{(\Delta t)^2}\left[2x_t - 5x_{t-\Delta t} + 4x_{t-2\Delta t} - x_{t-3\Delta t}\right] \qquad (3)$$

and defining h(t) by a particular shape of light.

In order to study what effect two proposed trapezoidal-shaped lights would have on the undamped response of an airplane taxying over them, the Elfaca and Westinghouse lights, figure 2, were chosen. The Elfaca is a long (149 inches) light with a rise in the center of one-half inch. See reference 3. The Westinghouse light, on the other hand, is 12-1/16 inches long with a center part 1-1/4 inches high. The load-deflection curves for the nose wheel tire of the F-86H airplane and for the main wheel tires of the B-47 airplane are given by figures 3 and 4, respectively.

3. RESULTS AND DISCUSSION

The time histories of the deflection of its nose wheel as the F-86H airplane is taxied at 110 mph over the Elfaca and Westinghouse lights are shown in figures 5 and 6, respectively. It will be noted that, for the Elfaca light, figure 5, the peak load (maximum deflection) occurs after the wheel has run over the light. The decay in the magnitude of the load is slow. While the peak load for the higher Westinghouse light, figure 6, is much greater than that for the Elfaca light, the magnitude of the loads occurring after the first peak is considerably less.

The time-history of the deflection of the main gear of the B-47, as computed by equation (1a), is given in figure 7. As in the case of the nose gear, the deflection of the tire after the first peak is nearly as great as the maximum deflection.

It should be remembered, however, that these peaks, the first one of which is due to taxying over a light, will no doubt be considerably reduced in magnitude by the damping action of the oleo. The first peak is relatively unaffected by the damping as can be seen from the comparison of the loads on the F-86H nose gear with damping considered, reference 1, and no damping. The loads corresponding to the maximum deflections are given in table 2.

A first approximation to the deflection of the tire to be expected by running over an obstruction would be to add the deflection under static load to the maximum height of the obstruction. While this gives a value of tire deflection that is too high, it would indicate whether bottoming of the tire might be a problem.

4. CONCLUSIONS

The analysis made in the paper would be indicative of the loads on an airplane landing gear if there was no relative motion in the oleo strut. This is a condition that would occur many times during the taxying of the airplane but only for very short periods of time. Although this analysis might give a fairly accurate value of the maximum load to be expected if an airplane were taxied over a protruding runway light, it does not give a true picture of the response of either the airplane mass or of the tire. Damping in the oleo strut should be considered.

For the Director,

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Washington, D. C.
November 1957

REFERENCES

1. Kroll, Wilhelmina D.
Landing Gear Loads Resulting from Taxying an Airplane over a Projecting Runway Light
NBS Report 4574, March 1956
NBS Project 0201-20-2331, NBS Lab. No. 6.4/295, PR-1

2. Houbolt, John C.
A Recurrence Matrix Solution for the Dynamic Response of Aircraft in Gusts
NACA TN 2060, March 1950

3. Anonymous
Elfaca Flush Airfield Lighting
Structural Concrete Products Corp. 10 East 40th Street, New York 16, N. Y.
September 18, 1956

Table 1. Data for F-86H and B-47 airplanes

F-86H Airplane -- Nose Wheel

Weight attributed to nose wheel, $W_1 = 1811$ lb
At time $t = 0$ and for weight supported by nose wheel,

$$x_2 = 0.665 \text{ in.}$$

Velocity, 110 mph or 1936 in./sec.

B-47 Airplane -- Rear Main Gear

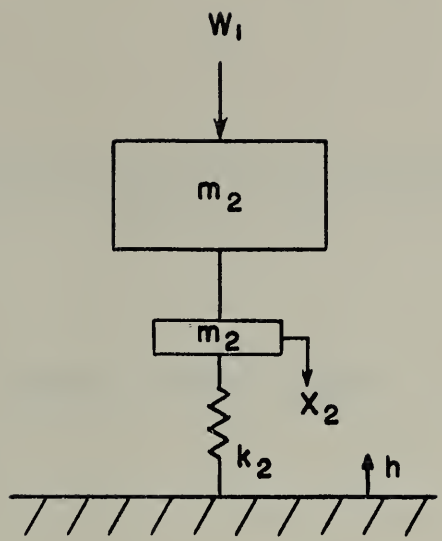
Weight attributed to rear main wheel, $W_1 = 108{,}200$ lb
At time $t = 0$ and for weight supported by rear main wheel

$$x_2 = 4.10 \text{ in.}$$

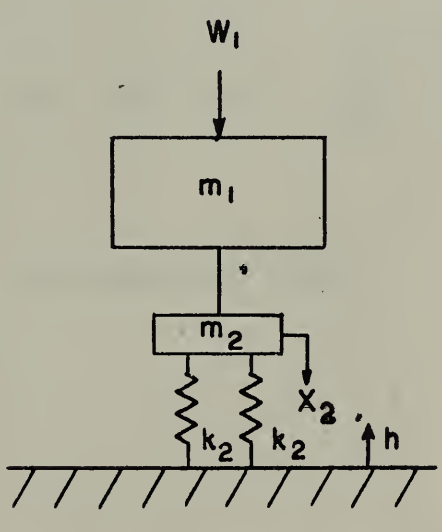
Velocity, 110 mph or 1936 in./sec.

Table 2. Maximum loads on landing gears from taxying over a runway light

Landing gear	Light	Max. deflection in.	Max. load, lb.	Max. load (ref. 1), lb.
F-86H nose	Elfaca	1.071	3580	-
F-86H nose	Westinghouse	1.912	7370	7200
B-47 rear main	Elfaca	4.587	62,000	-

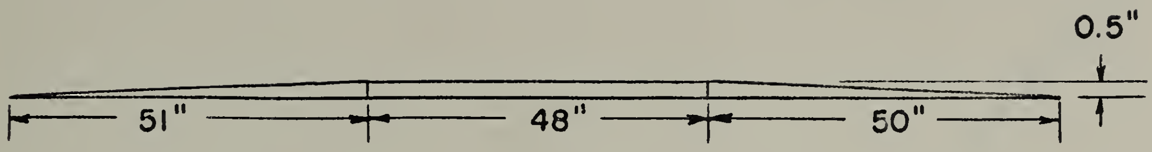


(a) With single wheel attached to each oleo strut

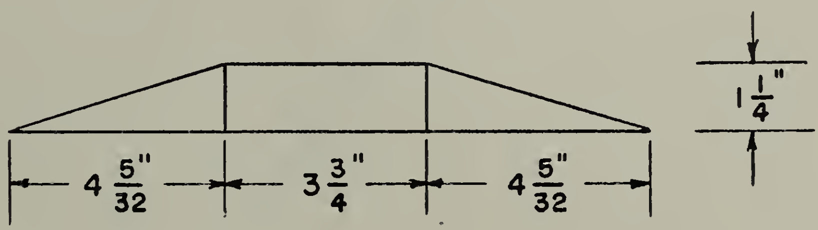


(b) With two wheels attached to each oleo strut

Fig. 1 Representations of airplane



(a) Model C Elfaca Light



(b) Westinghouse Light

Fig. 2 Runway light shapes used in analysis

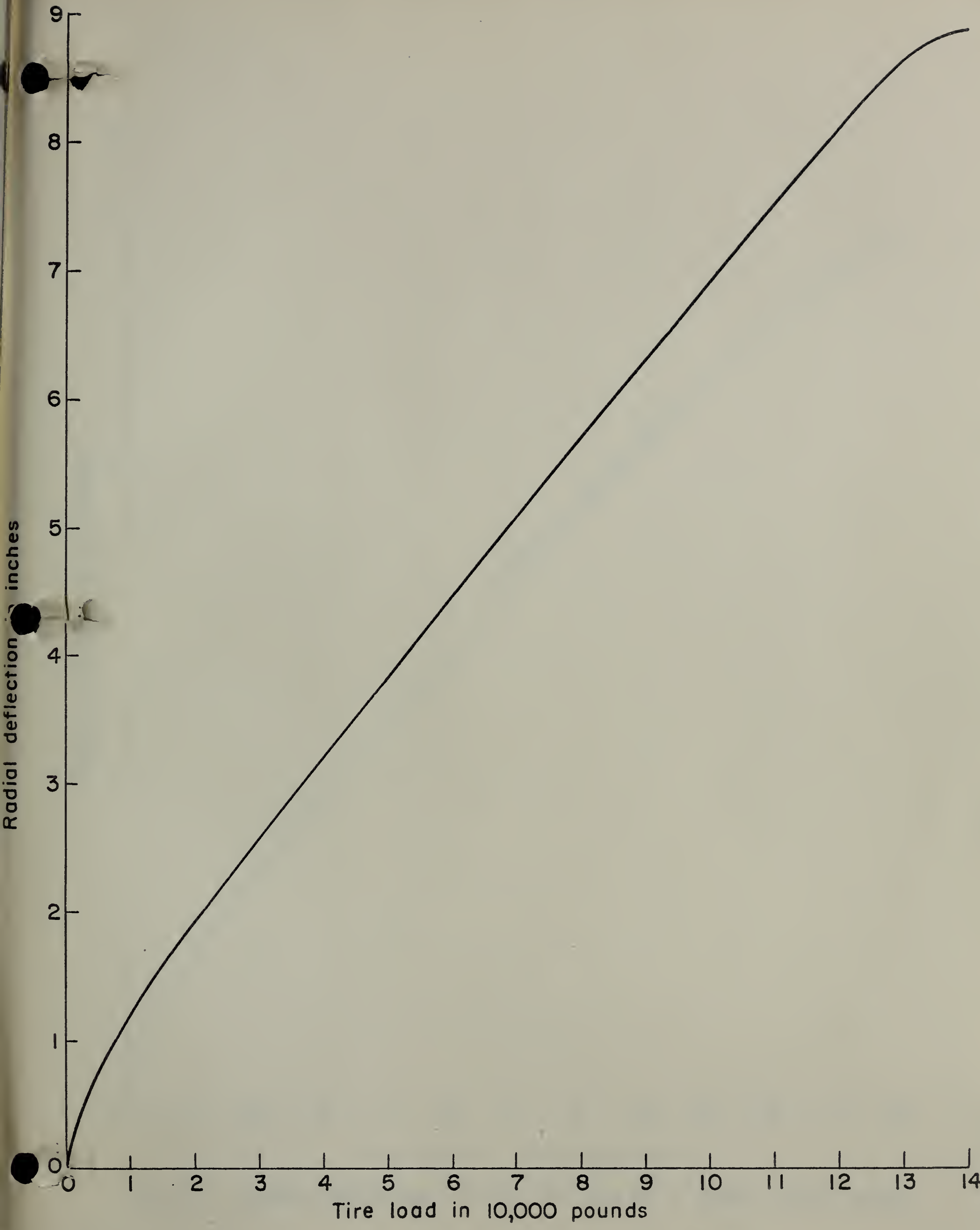


Fig. 3 Load-deflection curve for tire of B-47 rear main gear.

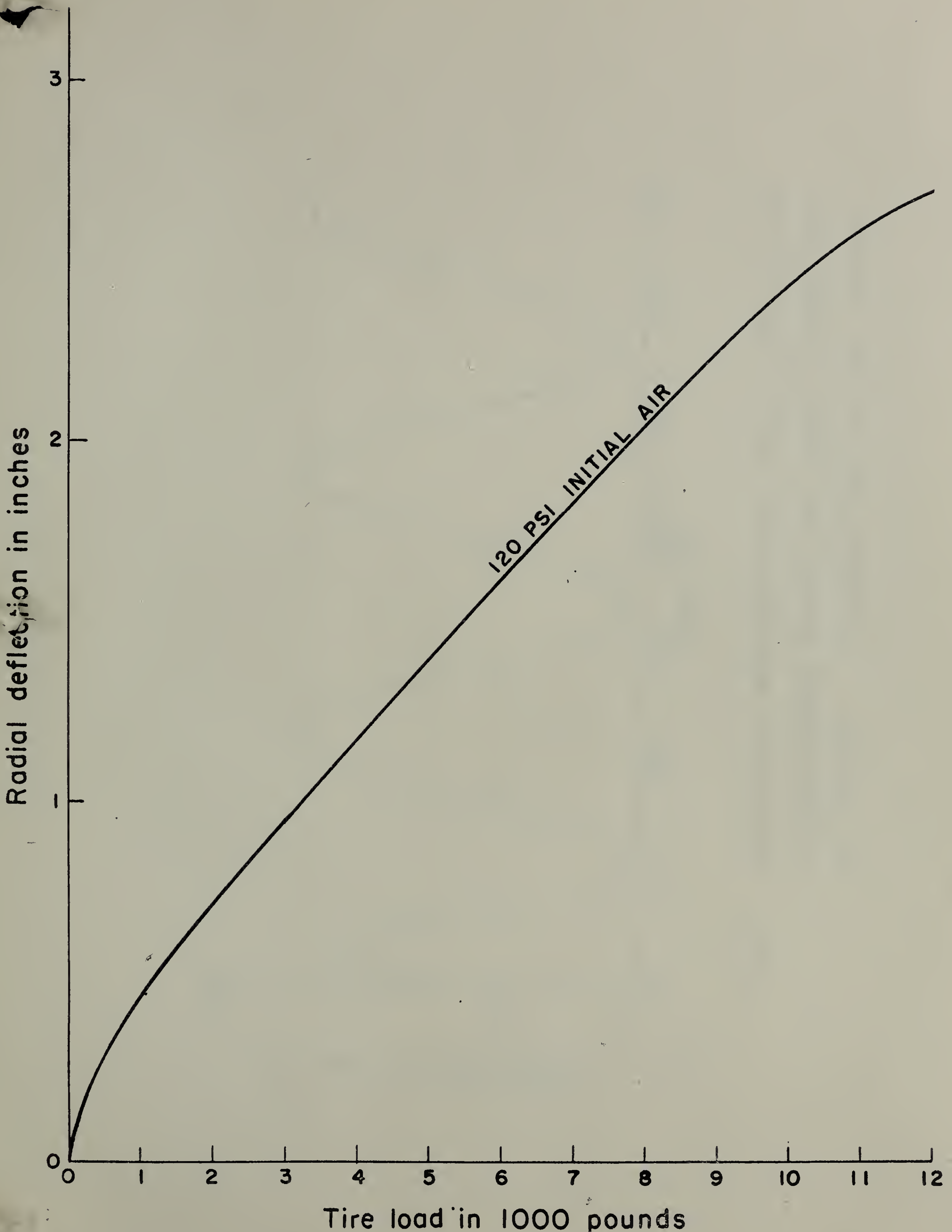


Fig. 4 Load-deflection curve for tire of F-86H nose wheel.

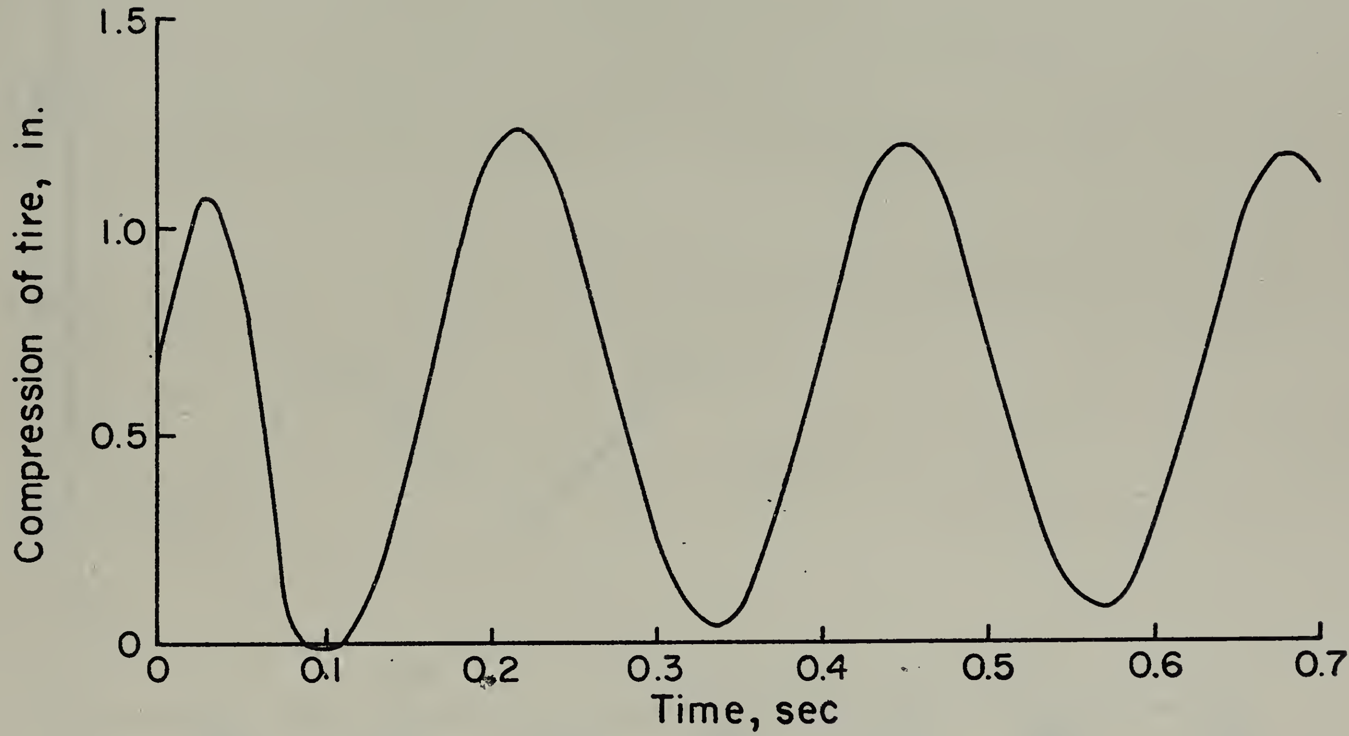


Fig. 5 *Time history of compression of nose wheel tire of F-86 airplane taxying over model C Elfaca light at 110 mph. Maximum height of light = 0.50 in.*

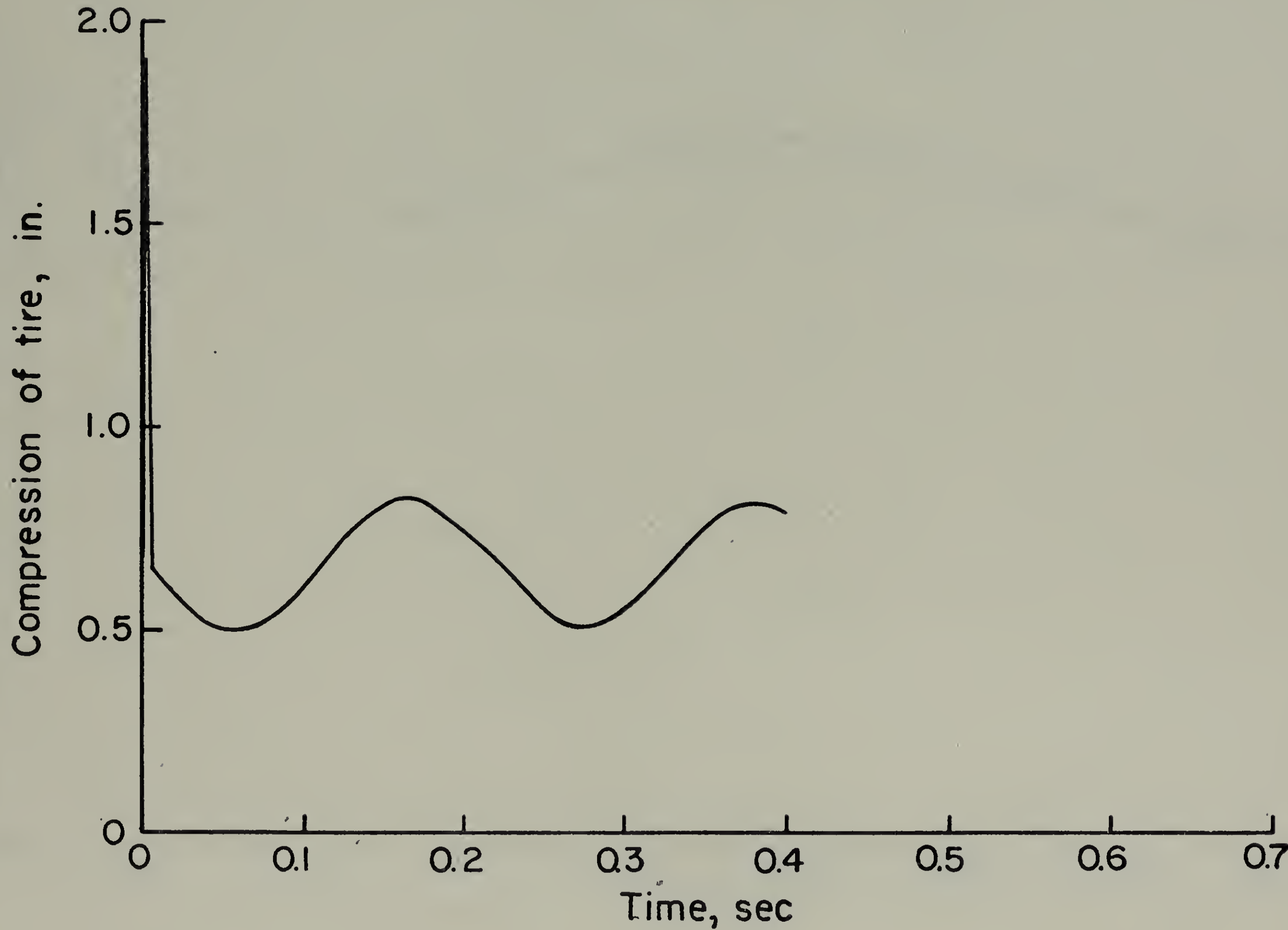


Fig. 6 Time history of compression of nose wheel tire of F-86 airplane taxying over Westinghouse light at 110 mph. Maximum height of light = 1.25 in.

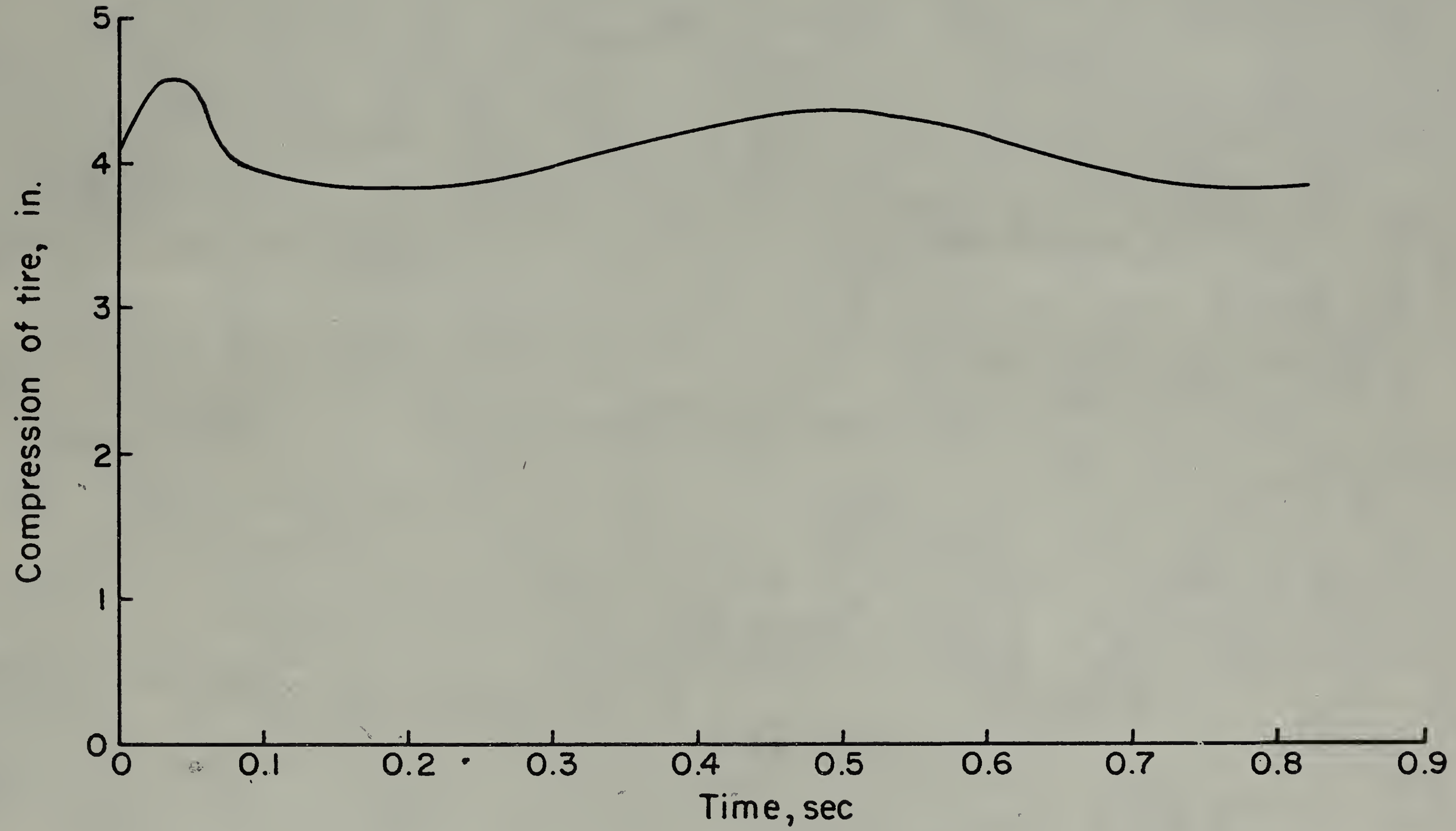


Fig. 7 *Time history of compression of main wheel tire of B-47 airplane taxying over model C Elfaca light at 110 mph. Maximum height of light = 0.50 in.*