U. S. DEPARTMENT OF COMMERCE NATIONAL BUREAU OF STANDARDS

RESEARCH PAPER RP912

Part of Journal of Research of the National Bureau of Standards, Volume 17, August 1936

LOAD DISTRIBUTION AND STRENGTH OF ELEVATOR CABLE EQUALIZERS

By Ambrose H. Stang and Leroy R. Sweetman

ABSTRACT

Tests to determine the equalizing ability and strength of four makes of elevator cable equalizers were made under conditions similar to but more severe than those encountered during ordinary use.

The cables were represented by jointed steel rods, hinged to allow freedom of motion in all directions. The middle rod of each assembly was equipped with 2-inch Tuckerman optical strain gages and calibrated as a dynamometer.

The distribution of load among the six shackles was determined for various amounts of movement of the shackles singly and in pairs. The limits of travel of the shackles were determined in each case.

CONTENTS

I. INTRODUCTION

Most elevator cars are supported by more than one wire rope and the safety of passengers depends to a large extent on the strength of the ropes. These supporting ropes are designed to carry a car with a liberal margin of safety, provided the load is equally distributed among the ropes. Although the ropes are of equal length when installed and the load on each rope is adjusted by means of threaded shackles to be as nearly uniform as possible when new cables are put in service, these loads do not remain uniform except in a very few instances. All wire ropes stretch appreciably under load, and, in addition, there is a gradual lengthening of the ropes under load, which may continue for months or even years. For ropes of the usual construction, this stretch amounts to about 1 percent of the length of the rope under loadings usually used in elevator practice. However, the stretch of two identical lengths of wire rope under the same loading will seldom be the same. This may be due to variations in the wires of which the strands are made, to variations in the tightness of the lay, to variations in the core, or to other causes. In the case of elevator ropes, the distance between the crosshead of the car and the cable anchorage on the counterweight remains substantially the same, with the result that the tendency of the ropes to stretch different amounts results in unequal forces on the ropes. The rope carrying the greatest load will deteriorate more rapidly than the others and also cause greater wear on its groove in the sheave. Wear of a groove decreases the effective diameter, resulting in slipping of the rope in that groove. This causes increased wear of both the rope and the groove, particularly of the sheaves which have V grooves, and this rope will need to be replaced when the other ropes may still have sufficient strength to carry their share of the total load. This unequal distribution of load among the wire ropes is obviously uneconomical and may become dangerous.

Devices designated as elevator cable equalizers have been designed to compensate for the unequal changes in length of the ropes and to equalize the loads on the ropes. The tests described in this paper were made to determine to what degree the loads are equalized and to determine the strength of the equalizers.

Two types of equalizers are manufactured in this country. For the first type, the equalizer is attached to the car only and tends to equalize the loads in the portion of the ropes between the car and the driving sheave. For the second type, the equalizer consists of two separate portions, one attached to the car and the other to the counterweight.

The tests reported in this paper deal only with elevator cable equalizers of the first type. For equalizers of the second type the distribution of the load on the cables under service conditions could not be determined satisfactorily by these methods; therefore equalizers of this type were not included in the program. The results give the load distribution for that portion of the cables between the car and the driving sheave. The load distribution for the portion of the cables between the driving sheave and the counterweight was not determined and cannot be estimated from the results of these tests.

II. ELEVATOR CABLE EQUALIZERS

Tests of four elevator cable equalizers were made. For convenience in this report they are designated as equalizers A, B, C, and D. Equalizer A was a multiple-lever type; equalizer B, a rack and pinion type; equalizer C, a multiple-lever type with roller bearings; and equalizer D a type having fixed sheaves and floating sheaves supported by a wire rope. Photographs of these equalizers are shown in figures 1, 2, 3, and 4, respectively.

Each equalizer was designed for six wire ropes, ⅝-in. diameter, traction steel.

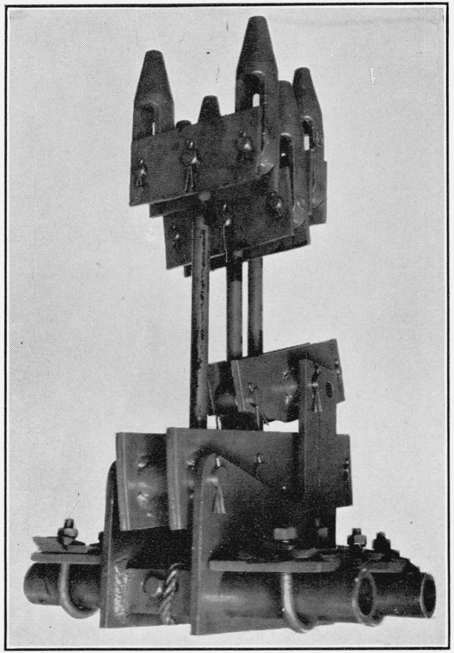

FIGURE 1.—*Elevator cable equalizer* A.

The failure of this equalizer during the strength test was due to the bending of the link indicated at F in figure 7.

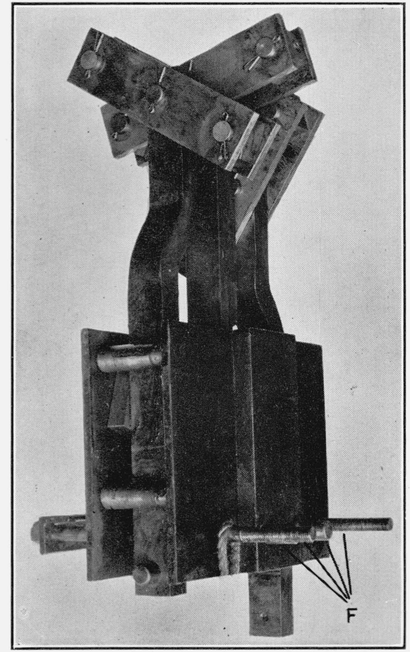

FIGURE 2.—*Elevator cable equalizer* B.

The failure of this equalizer during the strength test was due to the bending of the pins and bolts at F.

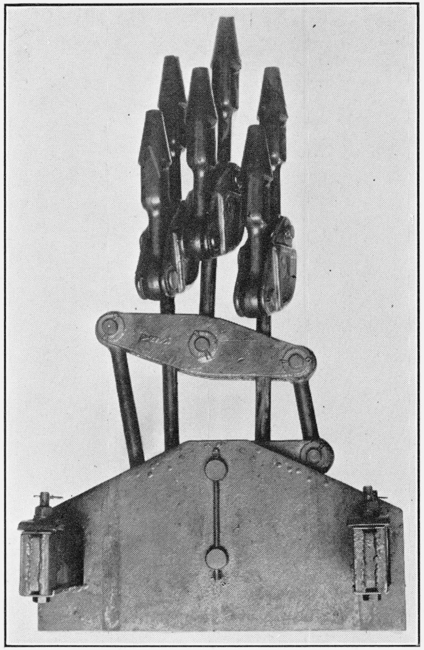

Figure 3.—*Elevator cable equalizer* C.

The failure of this equalizer during the strength test was due to tensile failure in the link indicated at F in figure 23.

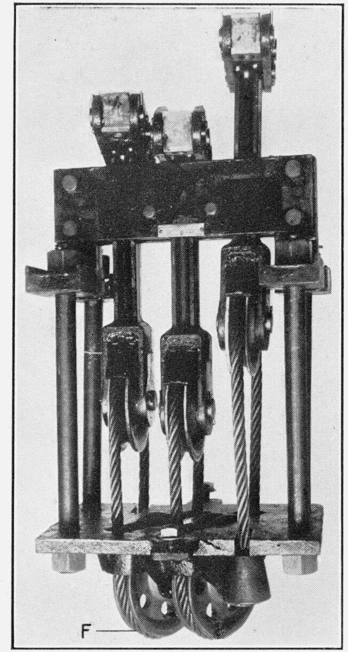

Figure 4.—*Elevator cable equalizer* D.

The failure of this equalizer during the strength test was due to the failure of the wire rope at F.

The distance between shackle centers on the singletrees was as follows:

Equalizer A	7 inches.
Equalizer B	9 inches.
Equalizer C	6 inches.
Equalizer D	6 inches.

III. METHOD OF TEST

1. TESTING MACHINE

The tests of the equalizers were made in a vertical, screw power, beam-and-poise type of testing machine having a capacity of 600,000 lb. using a poise which corresponded to a capacity of 300,000 lb.

2. LOAD DISTRIBUTION

(a) LOADING FIXTURES

The arrangement for determining the load distribution is shown in figure 5.

When installed on a car the equalizer is attached to the top of the car frame and the cables attached to the shackles extend upward to the sheave.

For convenience in making these tests this arrangement was reversed. Equalizer E was supported by two I-beams I, representing the car frame, which, in turn, were bolted to the fixed platen of the testing machine. Tension rod R was attached to each shackle. These rods passed down through a steel plate attached to the movable platen of the testing machine. The load was transmitted from each rod to this plate by a nut on the threaded lower end of the rod. Self-aligning ball thrust bearings were placed between the plate and the nuts of four of the rods.

(b) DESIGNATION OF SHACKLES

For convenience in this report, numbers were used as designations for the shackles and rods as shown diagrammatically in figures 7 to 30. The pairs of shackles 1 and 4, 2, and 5, and 3 and 6 were connected by a singletree.

(c) LOAD-MEASURING APPARATUS

The load on each shackle was measured with a special tension dynamometer. These dynamometers were steel drill rods, 0.5 in. in diameter and about 30 in. long, to which were attached at midlength two Tuckerman optical strain gages having a 2-in. gage length and placed diametrically opposite on the rod. Dynamometer rods R and gages G are shown in figure 5 below link-joints L, which are near the lower ends of shackles S. The dynamometers had been calibrated in a testing machine previous to use in this test. It was found that the strain in the drill rods, which produced a change of 1.0 division in the reading of the gages, corresponded to a load of 117 lb. Readings were estimated to 0.1 division or 11.7 lb.

(d) TESTING PROCEDURE

The procedure used in making the load-distribution determinations was as follows:

With no load on the equalizer, all of the shackle fulcrum pins were brought to the same horizontal plane by rotating the nuts below the plate. A load was then applied to the equalizer, gage readings were taken, and the load reduced to zero. Gage readings were again taken. The load on each shackle was calculated from the difference between the gage readings on the rod attached to the shackle.

These loads were obviously for a movement of zero inches of the shackles.

The load was again applied, and the nut at the bottom of one of the rods was rotated until this shackle had been lowered a predetermined distance, 0.2 in. The load on the equalizer had meantime been kept constant. Gage readings were taken, the load removed, and gage readings again taken. The load on each shackle was again calculated from the difference between the gage readings on the rod attached to the shackle. These loads were for a 0.2 in. movement of the shackle. This procedure was repeated with the same load for several positions of the shackle until the limit of travel of the shackle was reached. Shackle movements were made while the equalizer was under load.

When tested in this way there was little vibration of the shackles and the bearings in the equalizer. The differences in the loads on the shackles was therefore in all probability greater than would exist in an elevator installation where the relatively long ropes are attached to the shackles and the movement of the car causes considerable vibration.[1] It is believed, therefore, that the differences found in these tests were the maximum which would exist under the given conditions, and that under service conditions the differences might be somewhat less than these values. The test conditions were, however, the same for all the equalizers.

(e) PROGRAM

Load-distribution determinations were made by moving shackle 2, shackle 3, shackles 2 and 5 together, and shackles 3 and 6 together. It was not considered necessary to make tests to determine the load distribution for movements of shackle 1 or of shackles 1 and 4 together, since for each of the equalizers, shackles 1 and 4 were symmetrical with regard to their connections to the other parts of the equalizer, with shackles 3 and 6. The load distributions may be expected to be the same for both pairs of shackles.

For the tests to determine the load distribution when shackles 2 and 5 were moved together, the procedure was to move shackle 2 from, for example, the 1-inch position to the 2-inch position and then induce the same movement in shackle 5. Similarly, when shackles 3 and 6 were moved together, the movement of shackle 3 was completed and then that of shackle 6.

The four sets of load-distribution determinations were made with the following loads on the equalizers: for equalizer A, at 6,000, 12,000, and 18,000 lb; these loads corresponded to an average load

[1] G. P. Boomsliter, Acceleration Stresses in Hoisting Ropes. Research Bulletin 2, Engineering Experiment Station, University of West Virginia, Morgantown, W. Va.

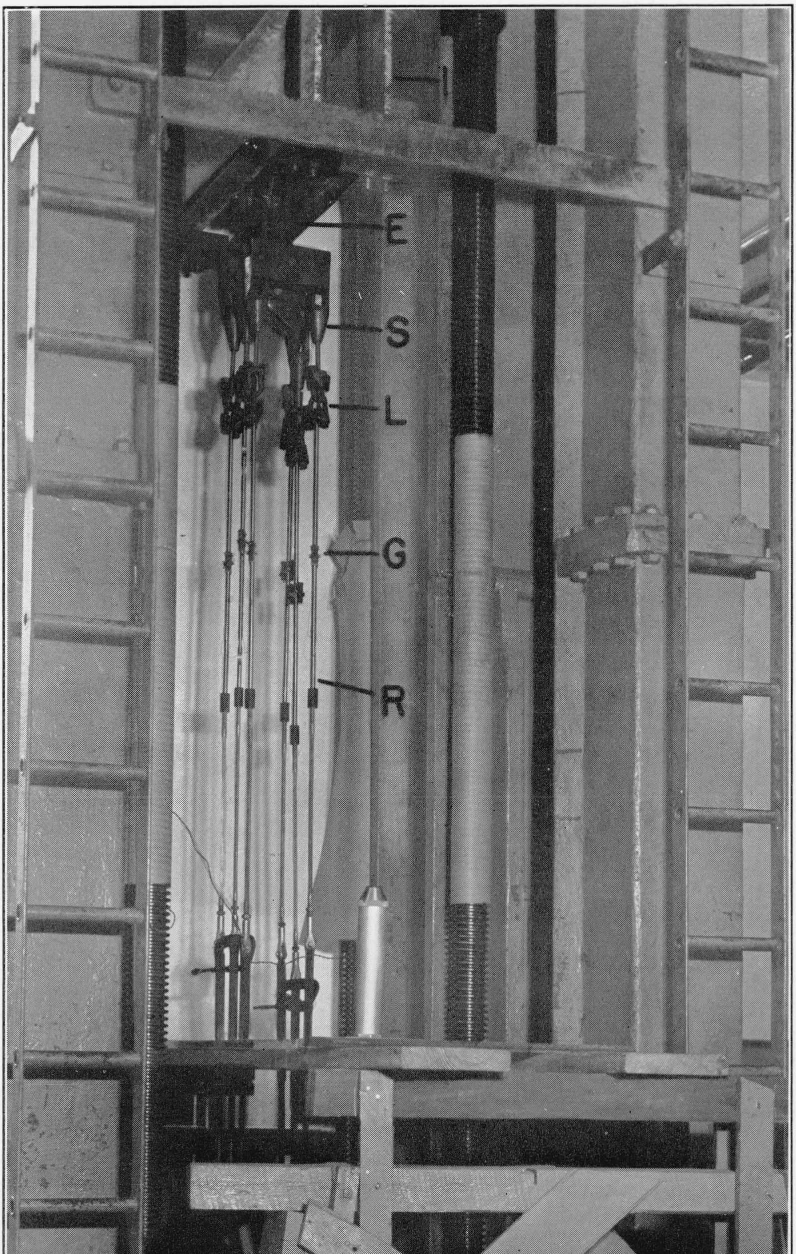

FIGURE 5.—*Elevator cable equalizer* A *in the testing machine for the load-distribution test.*

Note the Tuckerman optical strain gages on the dynamometer rods and the autocollimator on the platform.

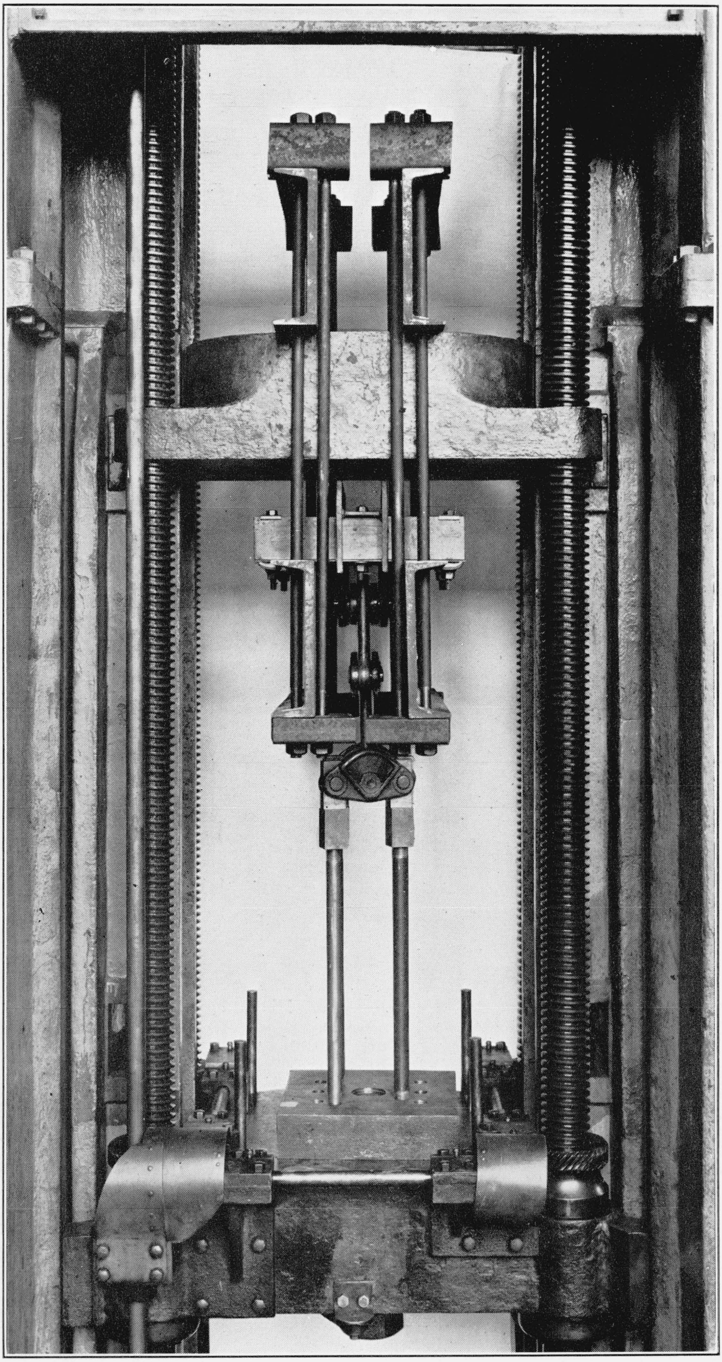

FIGURE 6.—*Elevator cable equalizer* C *in the testing machine for the strength test.*

on each shackle of 1,000, 2,000, or 3,000 lb. For equalizers B, C, and D, at 12,000 lb corresponding to an average load on each shackle of 2,000 lb.

(f) ACCURACY

When the total load on the equalizer was 6,000 lb, the sum of the loads on the six shackles as determined by the gage readings of the dynamometer rods did not differ by as much as 3 percent from the load indicated by the testing machine. When the total load on the equalizer was either 12,000 or 18,000 lb, the sum of the loads on the shackles did not differ by more than 1 percent from the load indicated by the testing machine.

3. STRENGTH

After the tests to determine the ability of the device to equalize the loads on the different shackles were completed, the strength of the equalizers was determined. For this test the shackles were removed and fixtures, as shown in figure 6, were attached to the shackle fulcrum pins and to the movable platen of the testing machine.

IV. RESULTS OF THE TESTS, WITH DISCUSSION

1. LOAD DISTRIBUTION

The results of the load-distribution tests are given in figures 7 to 30, inclusive. A diagrammatic sketch of the mechanism of the equalizers is given on each figure. The shackle or shackles moved are indicated by arrowheads.

The different loads of 6,000, 12,000, and 18,000 lb used for the tests of equalizer A did not appear to change the character of the load-distribution curves for this equalizer. For this reason, tests of the other equalizers were made only for a 12,000-lb load.

Although there are some exceptions to each of the following statements, the results of the tests, as indicated by the load-distribution curves, may be summarized as follows:

The shackle which was moved while under load took more than its share of the load, beginning with a very small movement. In general, the load on the shackle increased slowly with increase in movement and then more rapidly as the limit of travel of the shackle was approached.

If the movement was confined to a single shackle, the other shackle on the same singletree at first took more than its share of the load but generally not as much as the shackle which was moved. As the limit of travel of the moved shackle was approached, the other shackle of the pair took less and less load, apparently transferring its share of the load to the moved shackle. The load on the other four shackles was approximately constant.

If two of the shackles were moved, the shackle moved last sustained a greater load than the shackle first moved and both took more than the average load.

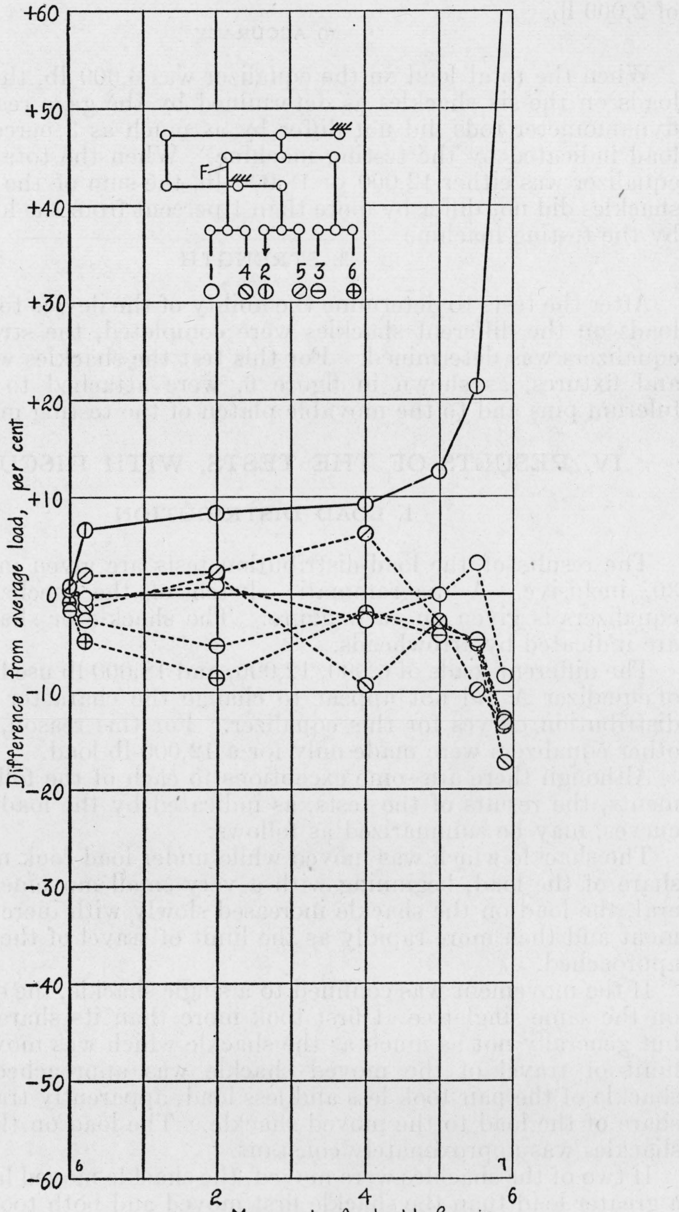

FIGURE 7.—*Load distribution for elevator cable equalizer* A *as shackle 2 was moved.*

Total load 6,000 lb. Link F failed during the strength test.

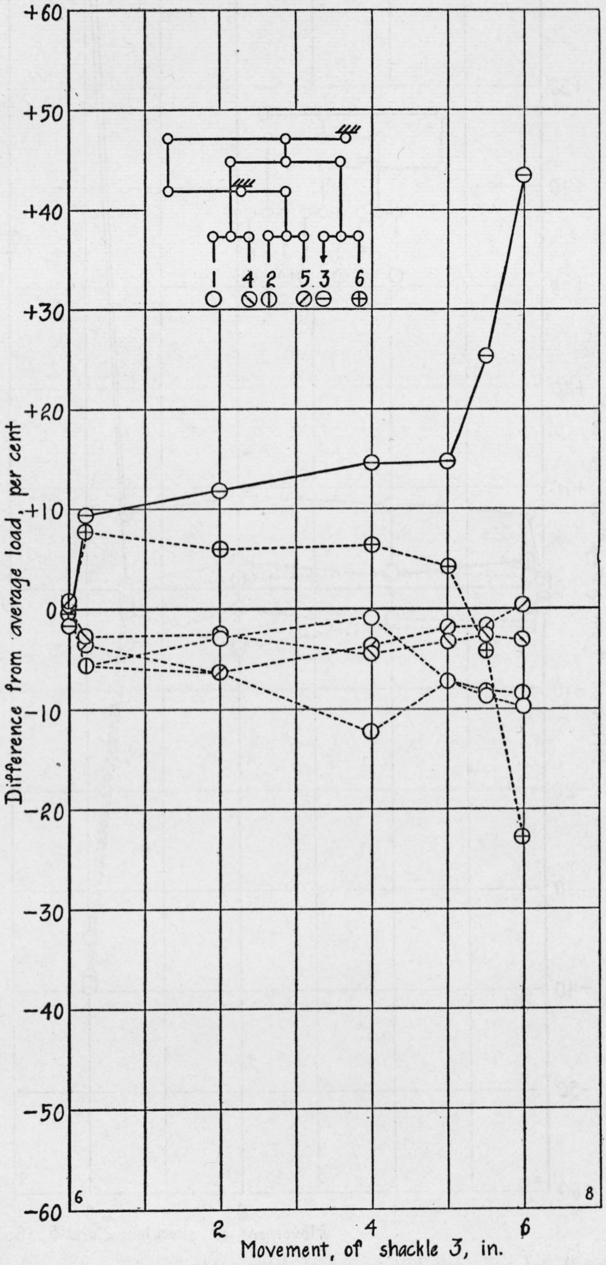

FIGURE 8.—*Load distribution for elevator cable equalizer* A *as shackle 3 was moved.*

Total load 6,000 lb.

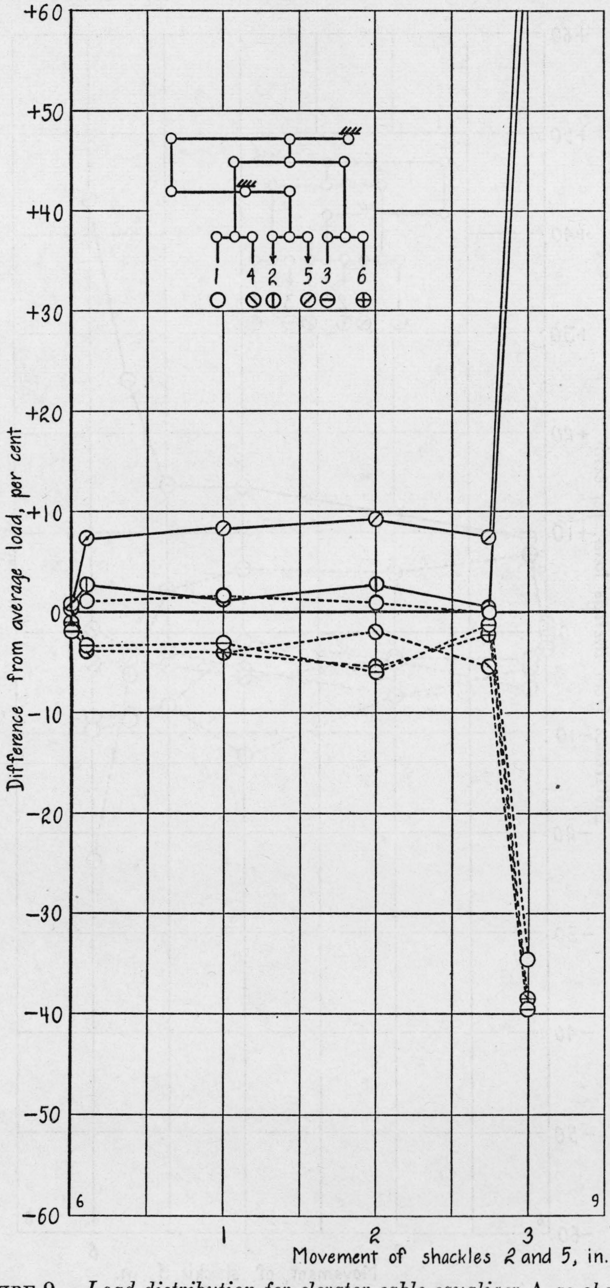

Figure 9.—*Load distribution for elevator cable equalizer A as shackles 2 and 5 were moved.*

Load 6,000 lb.

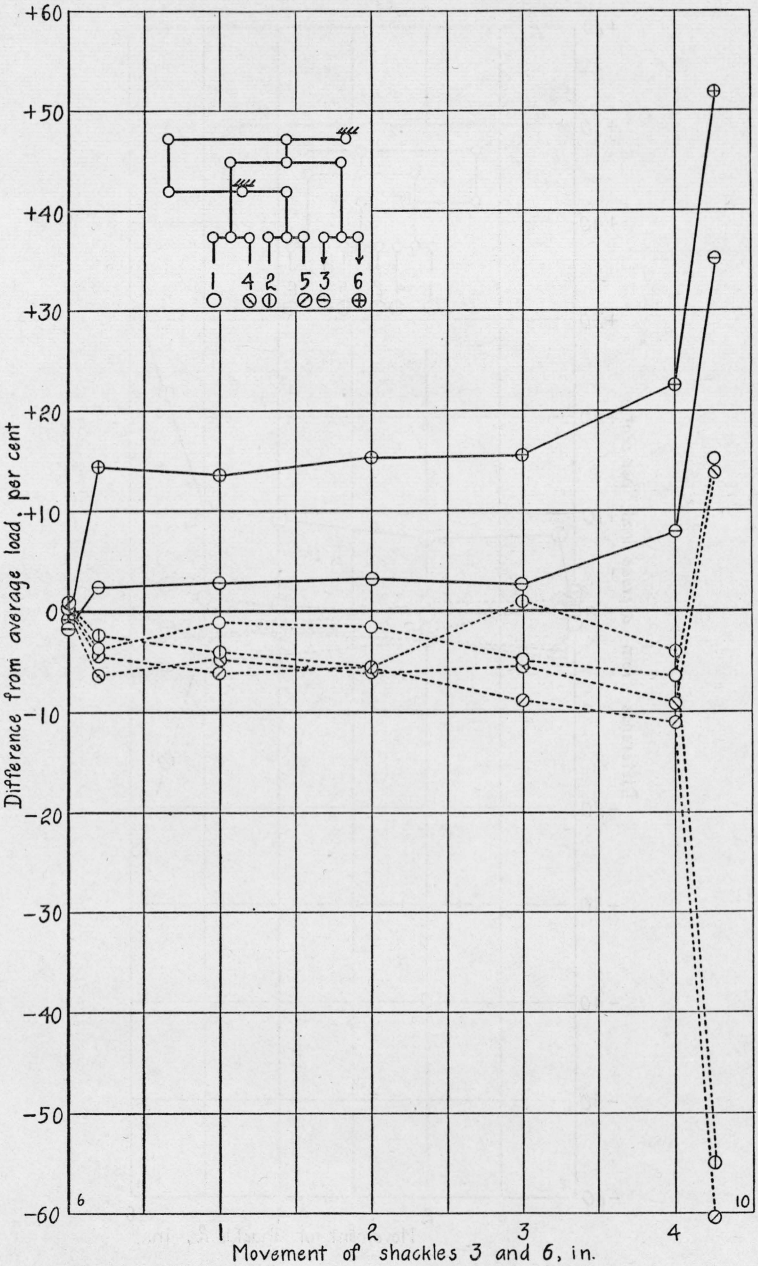

FIGURE 10.—*Load distribution for cable elevator equalizer A as shackles 3 and 6 were moved.*

Load 6,000 lb.

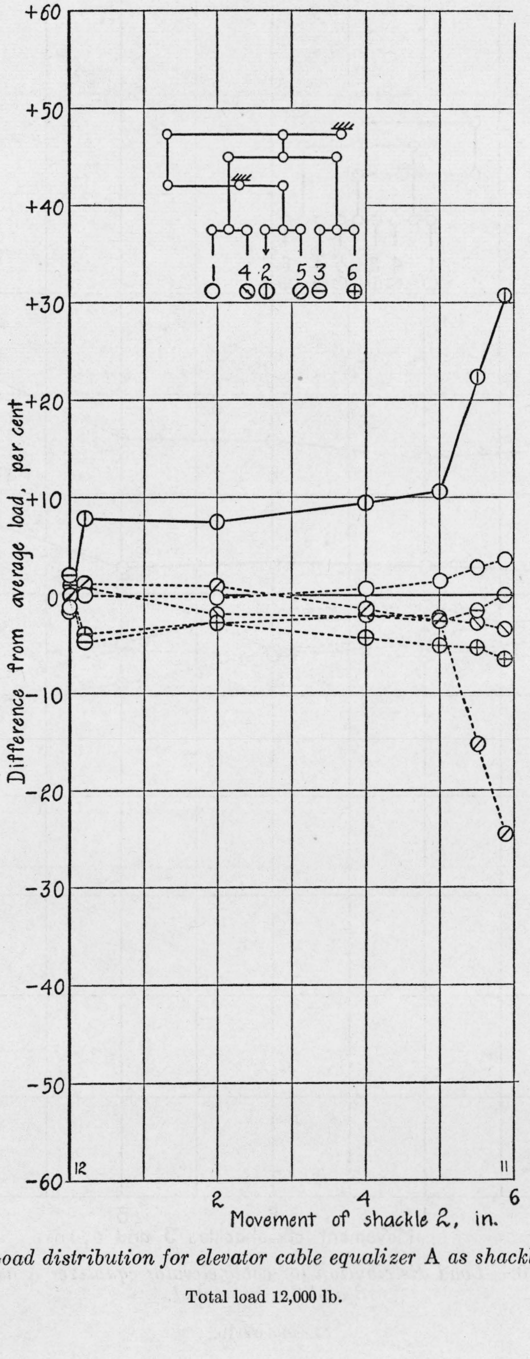

FIGURE 11.—*Load distribution for elevator cable equalizer A as shackle 2 was moved.*

Total load 12,000 lb.

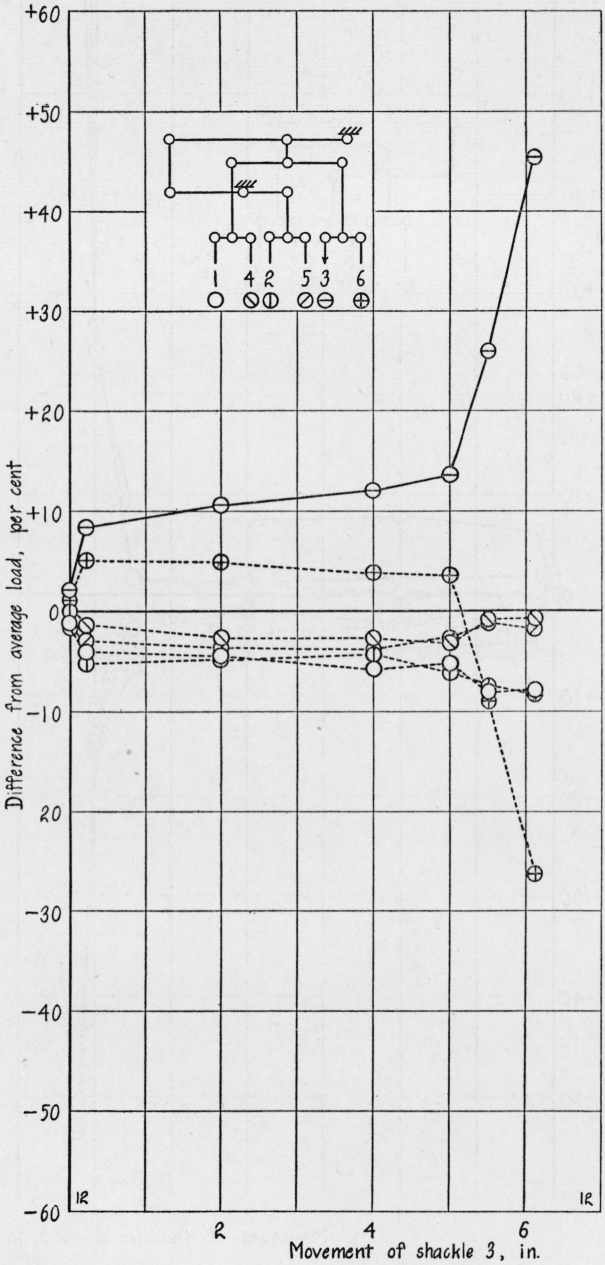

FIGURE 12.—*Load distribution for elevator cable equalizer* A *as shackle 3 was moved.*

Total load 12,000 lb.

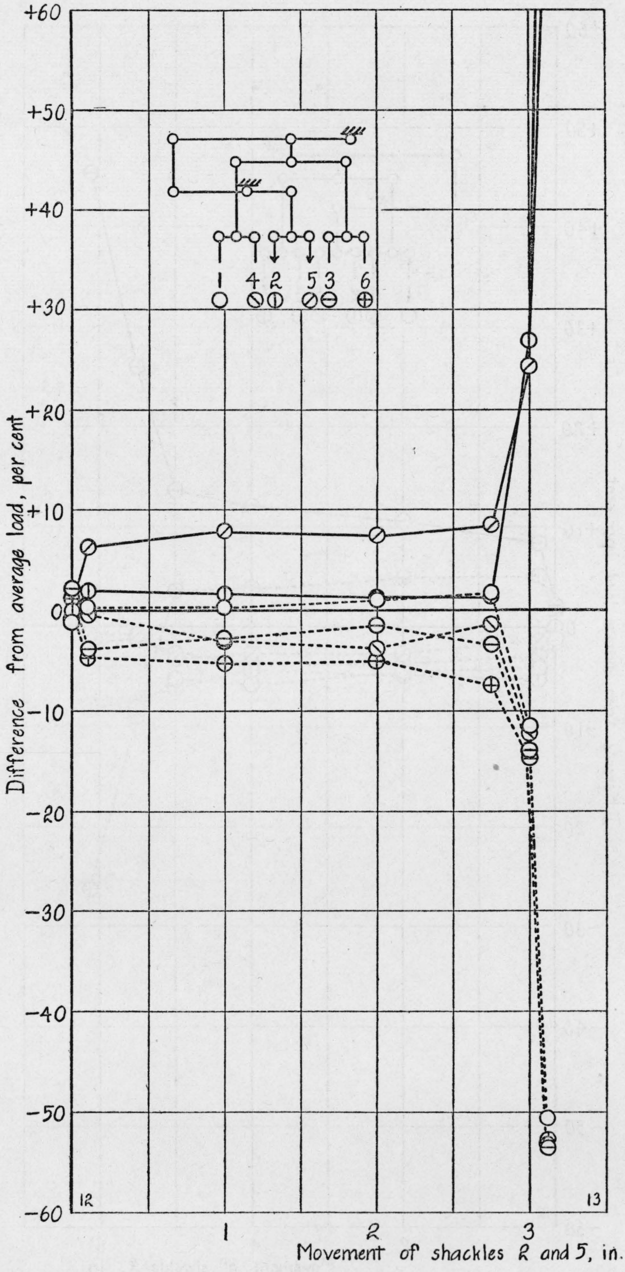

Figure 13.—*Load distribution for elevator cable equalizer* A *as shackles 2 and 5 were moved.*

Total load 12,000 lb.

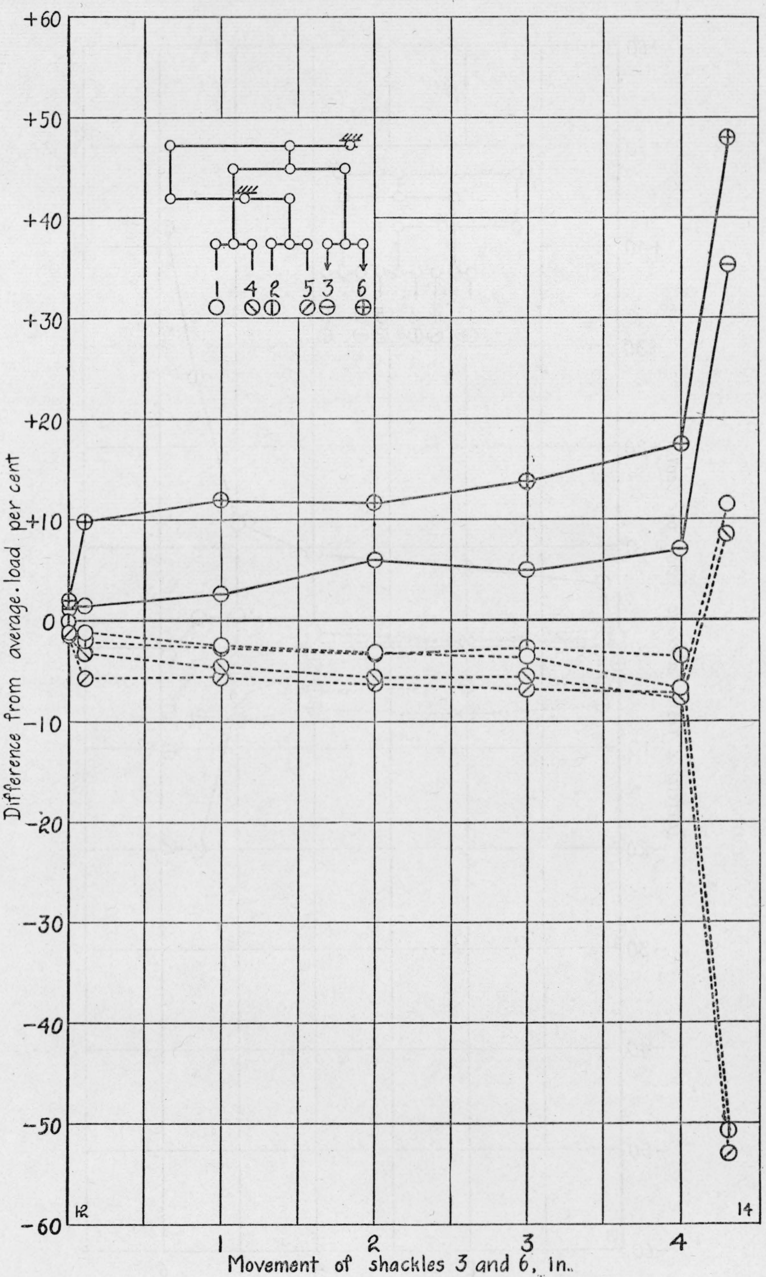

FIGURE 14.—*Load distribution for elevator cable equalizer* A *as shackles 3 and 6 were moved.*

Total load 12,000 lb.

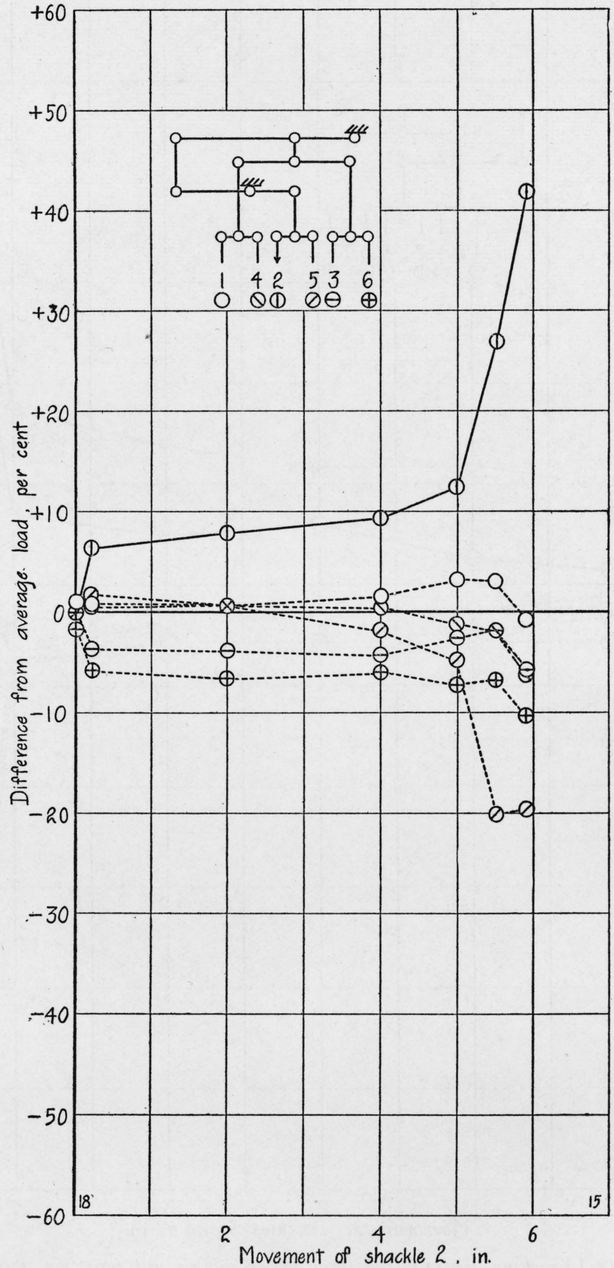

FIGURE 15.—*Load distribution for elevator cable equalizer* A *as shackle 2 was moved.*

Total load 18,000 lb.

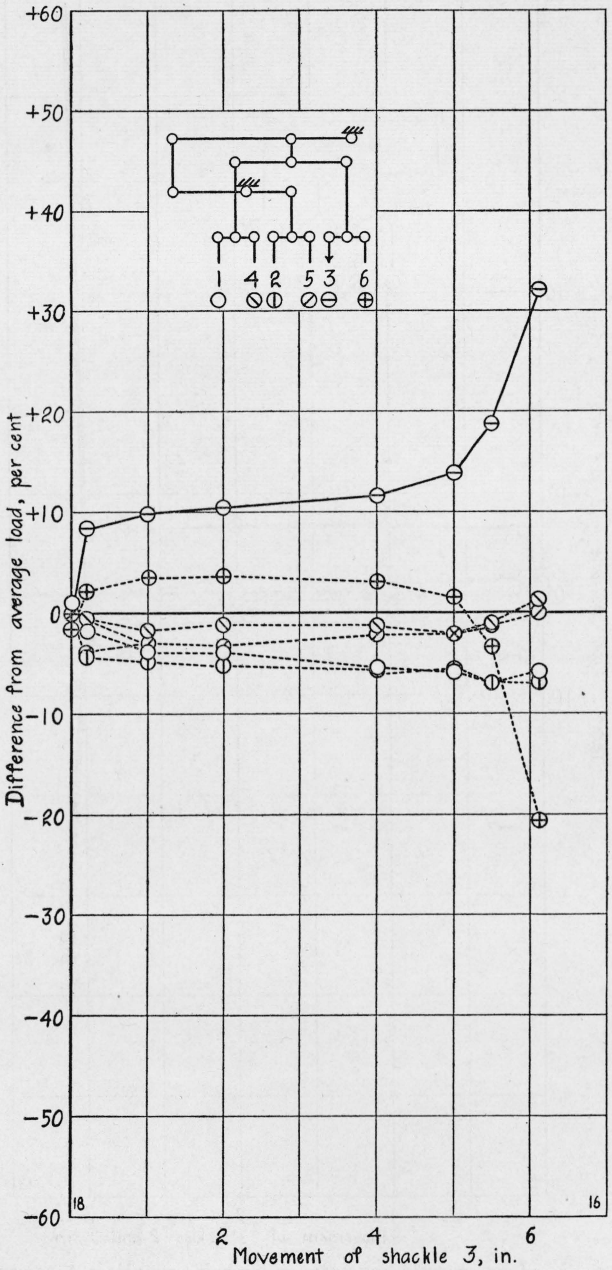

FIGURE 16.—*Load distribution for elevator cable equalizer* A *as shackle 3 was moved.*

Total load 18,000 lb.

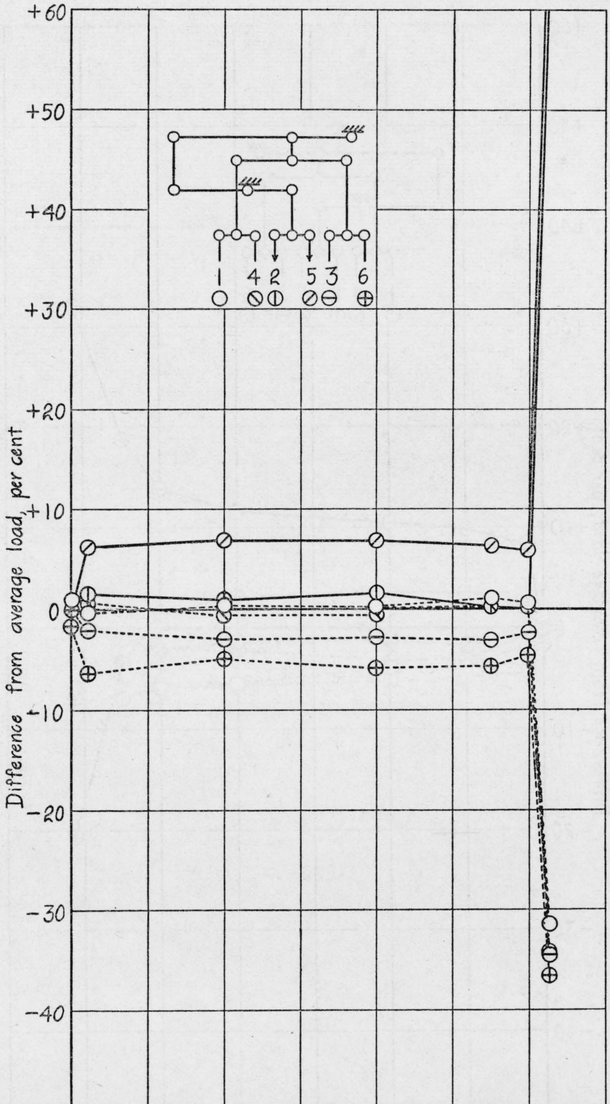

FIGURE 17.—*Load distribution for elevator cable equalizer* A *as shackles 2 and 5 were moved.*

Total load 18,000 lb.

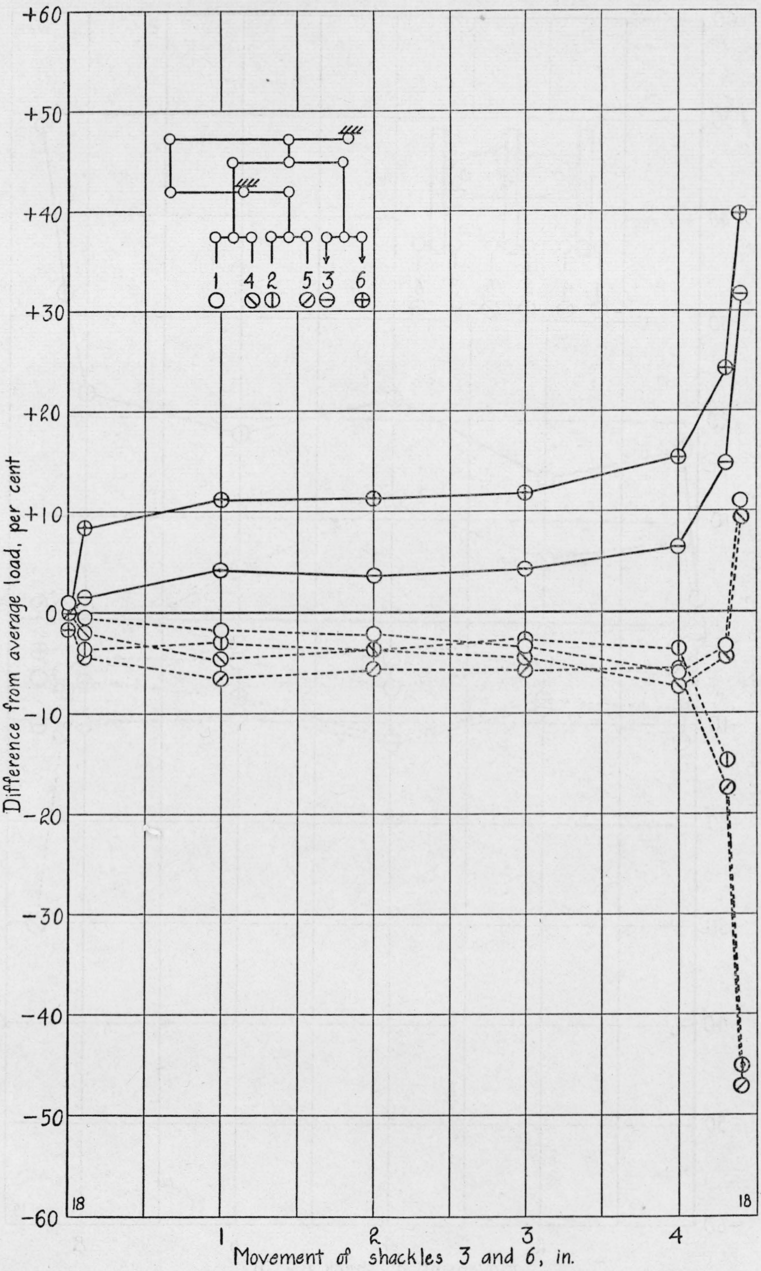

FIGURE 18.—*Load distribution for elevator cable equalizer* A *as shackles 3 and 6 were moved.*

Total load 18,000 lb.

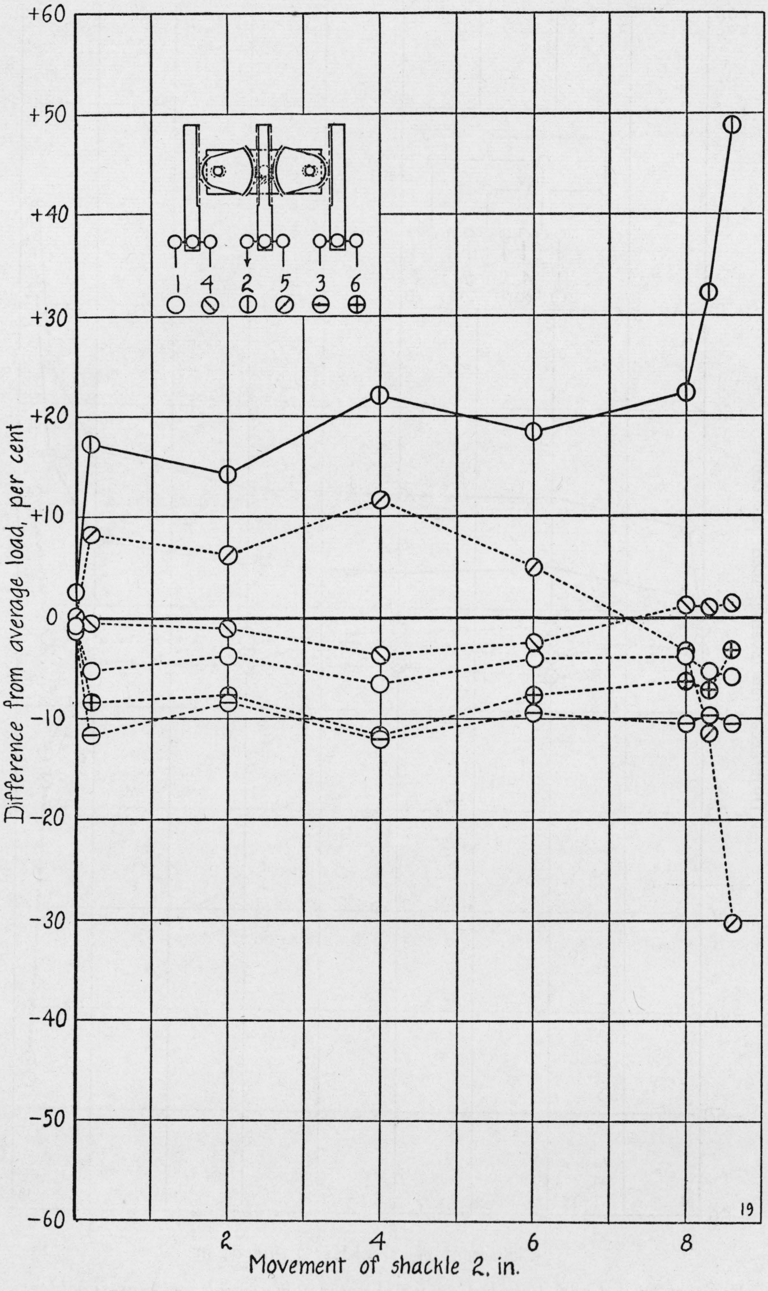

FIGURE 19.—*Load distribution for elevator cable equalizer* B *as shackle 2 was moved.*

Total load 12,000 lb.

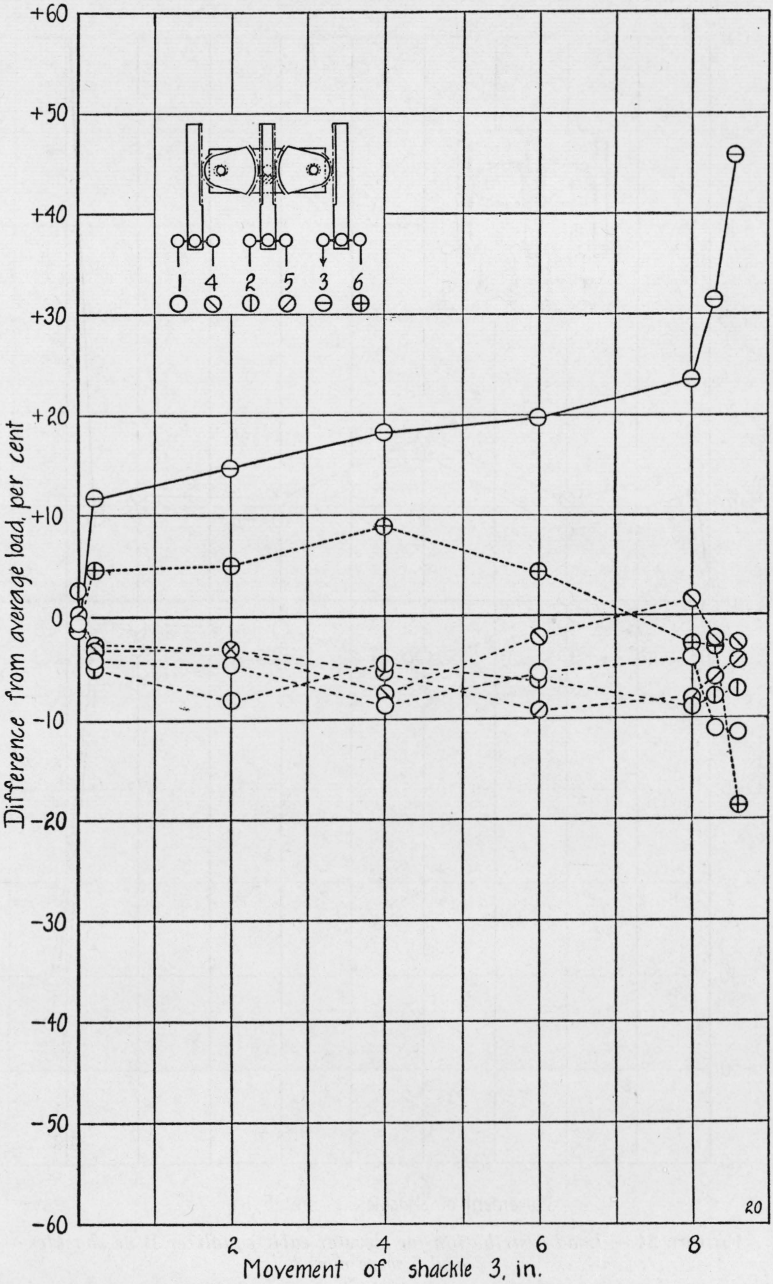

FIGURE 20.—*Load distribution for elevator cable equalizer* B *as shackle 3 was moved.*

Total load 12,000 lb.

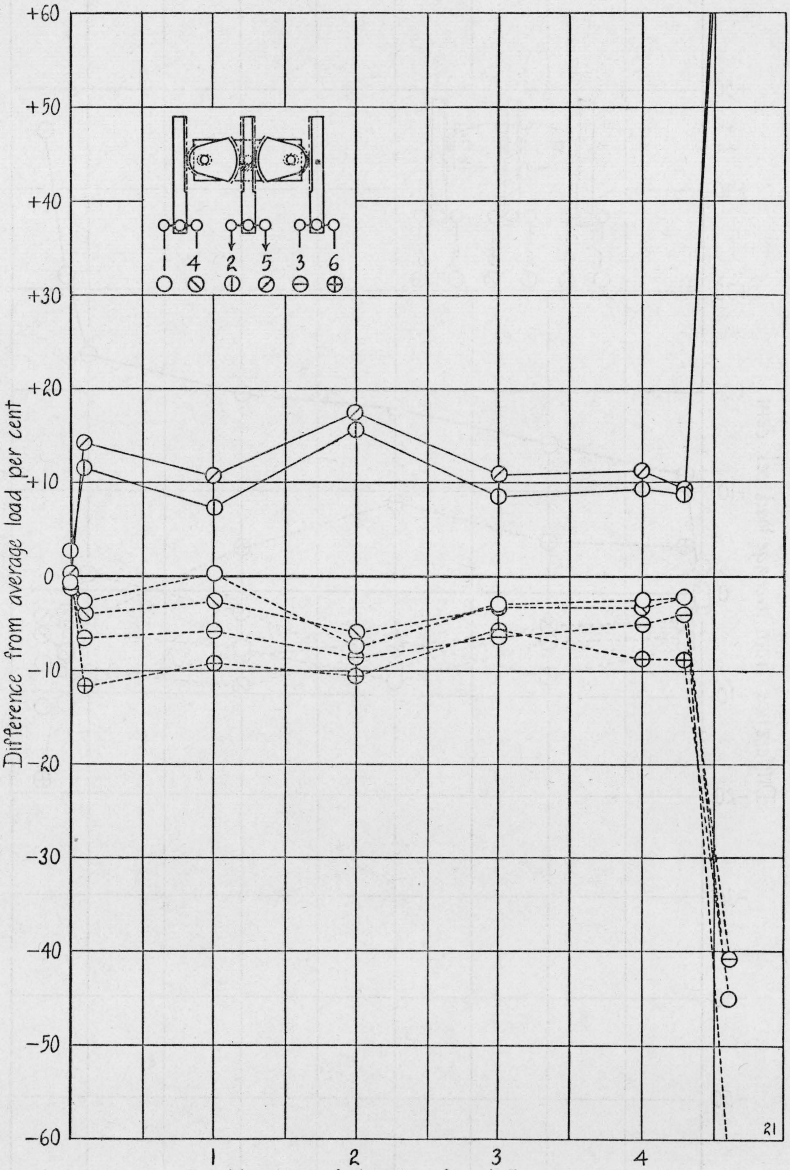

FIGURE 21.—*Load distribution for elevator cable equalizer* B *as shackles 2 and 5 were moved.*

Total load 12,000 lb.

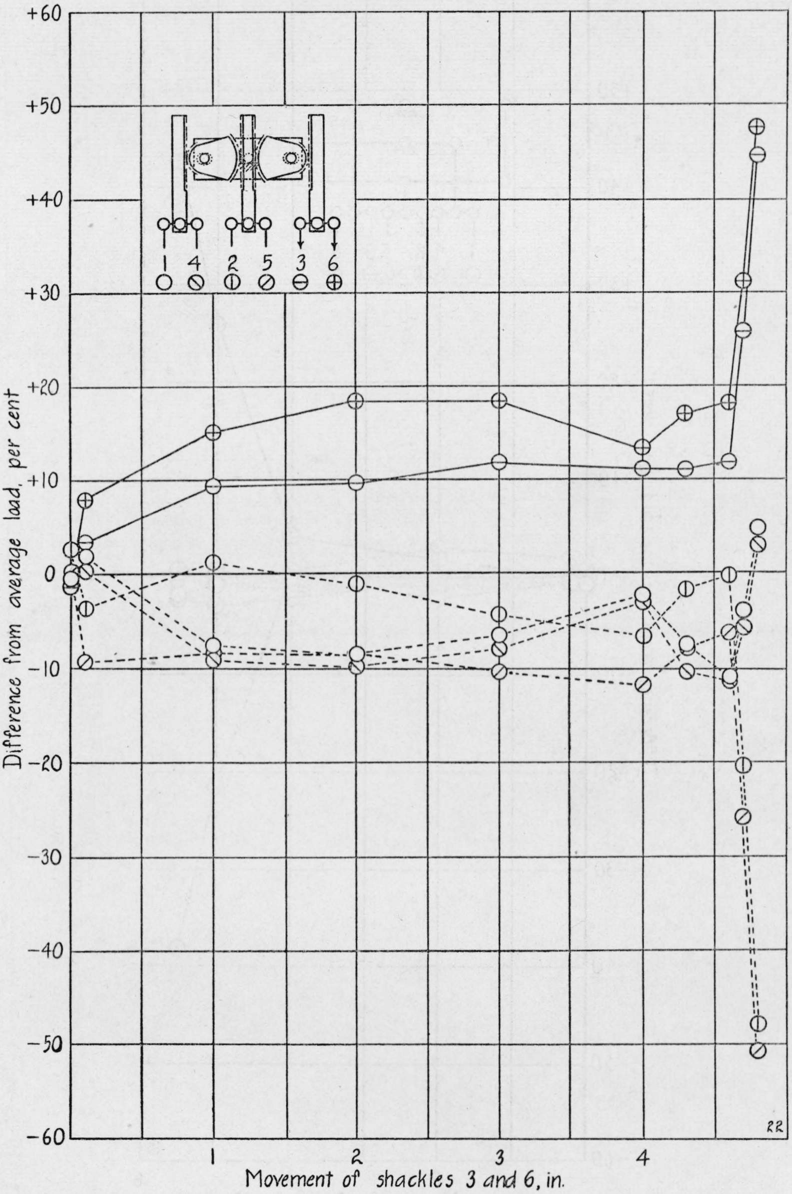

FIGURE 22.—*Load distribution for elevator cable equalizer* B *as shackles 3 and 6 were moved.*

Total load 12,000 lb.

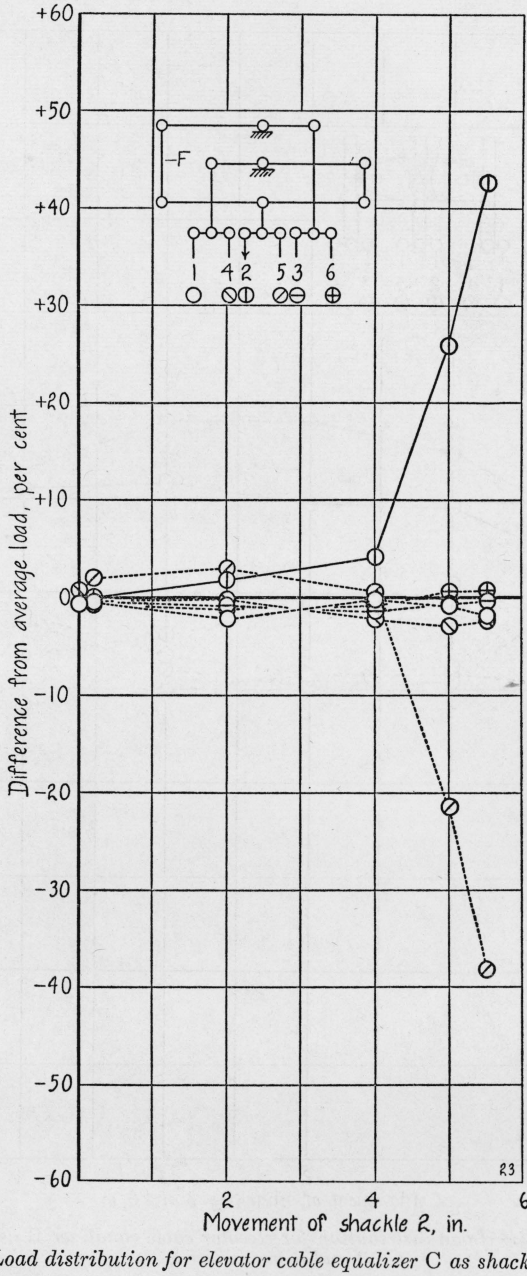

FIGURE 23.—*Load distribution for elevator cable equalizer* C *as shackle 2 was moved.*

Total load 12,000 lb. Link F broke during the strength test.

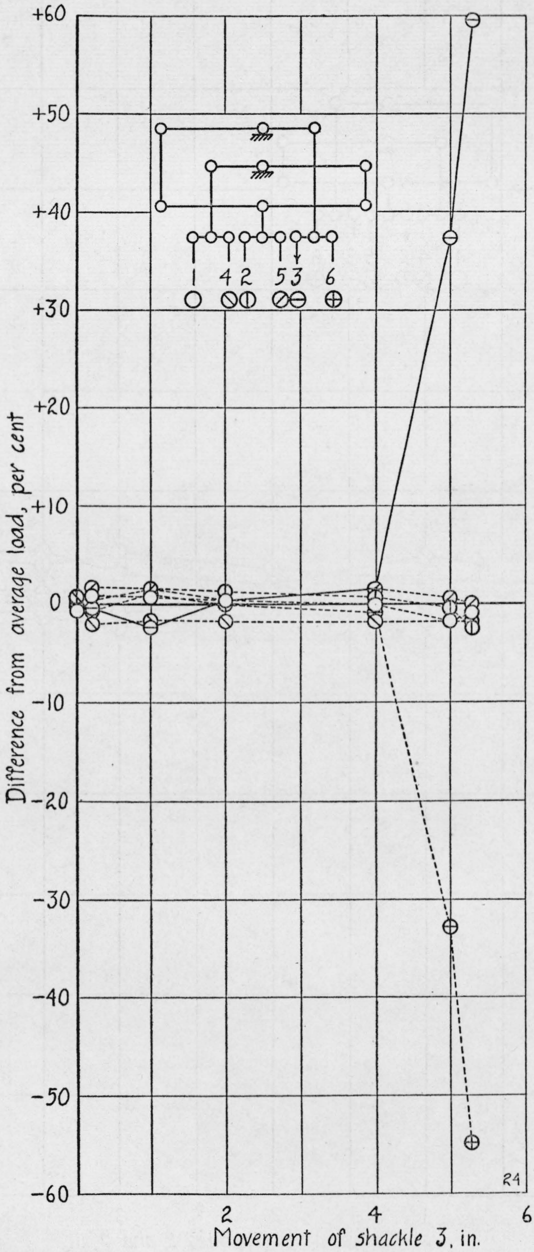

FIGURE 24.—*Load distribution for elevator cable equalizer* C *as shackle 3 was moved.*

Total load 12,000 lb.

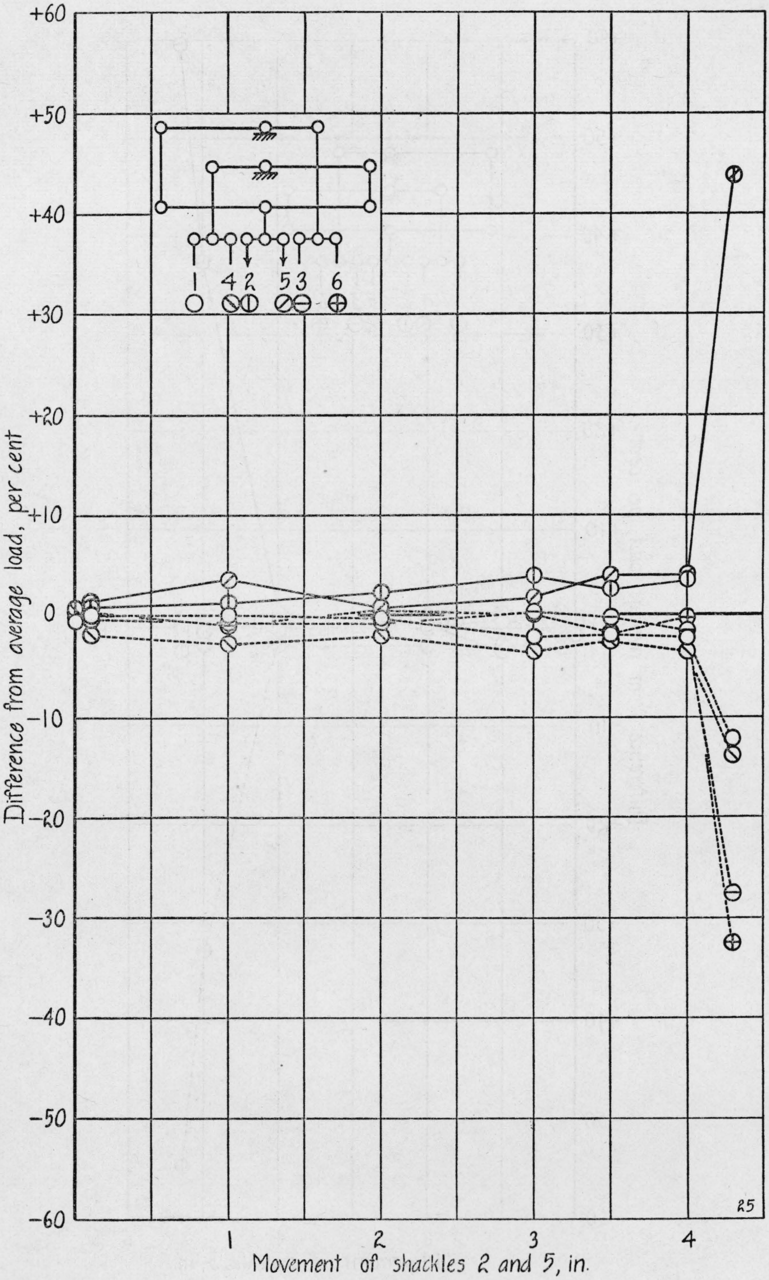

FIGURE 25.—*Load distribution for elevator cable equalizer* C *as shackles 2 and 5 were moved.*

Total load 12,000 lb.

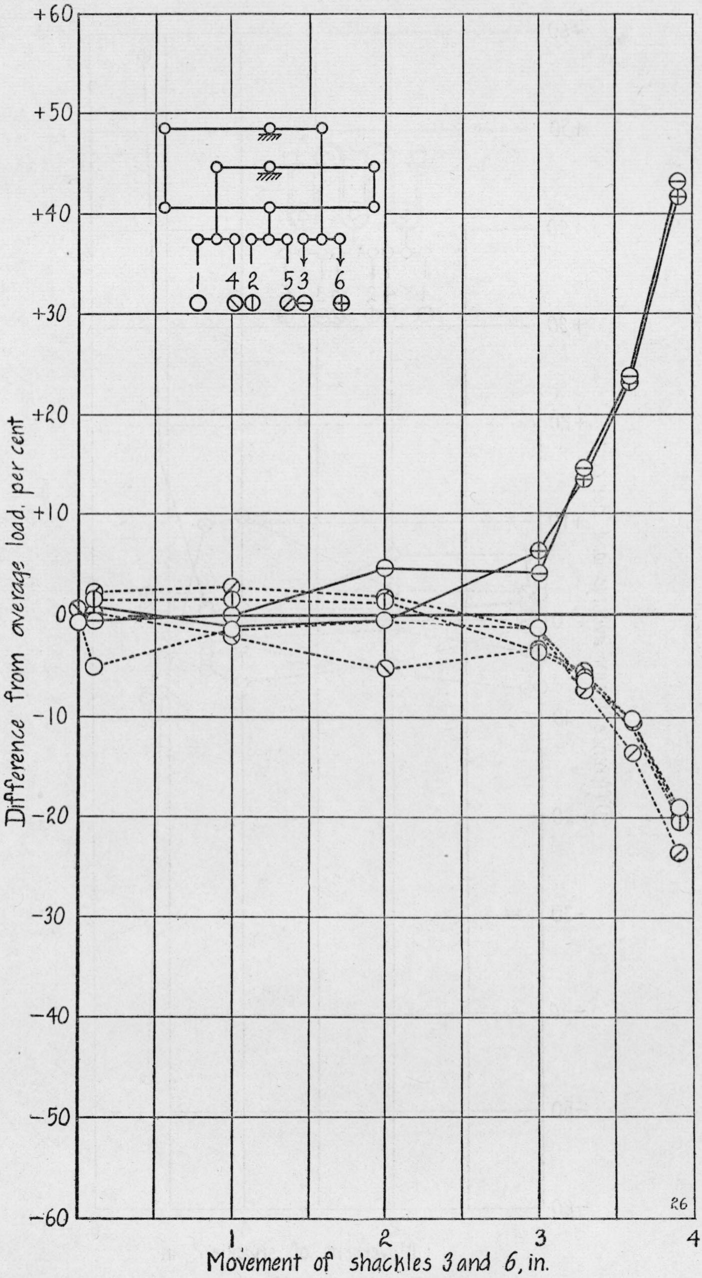

FIGURE 26.—*Load distribution for elevator cable equalizer* C *as shackles 3 and 6 were moved.*

Total load 12,000 lb.

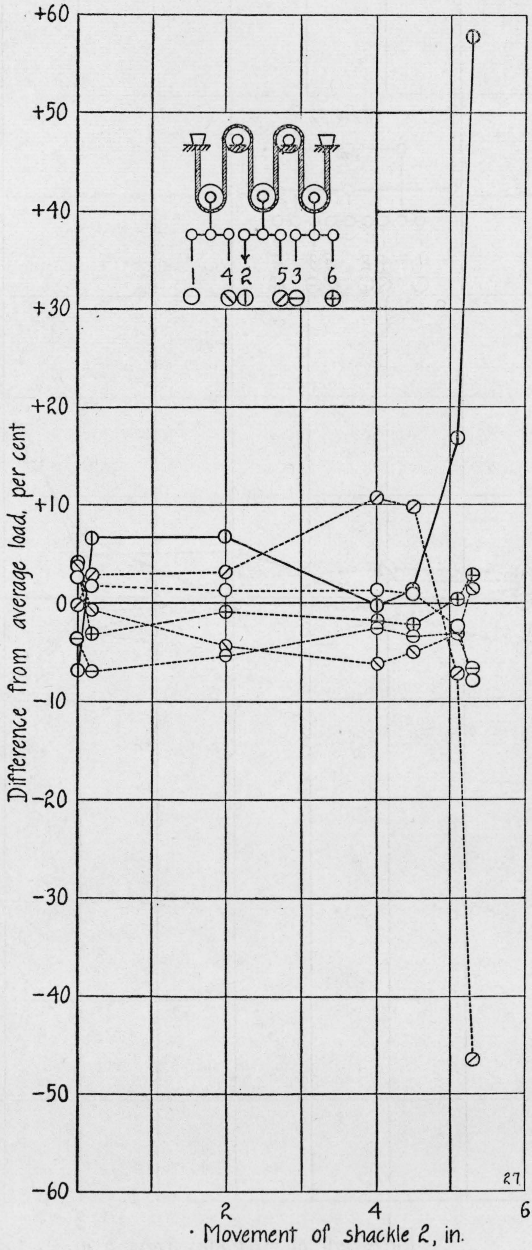

FIGURE 27.—*Load distribution for elevator cable equalizer* D *as shackle 2 was moved.*

Total load 12,000 lb.

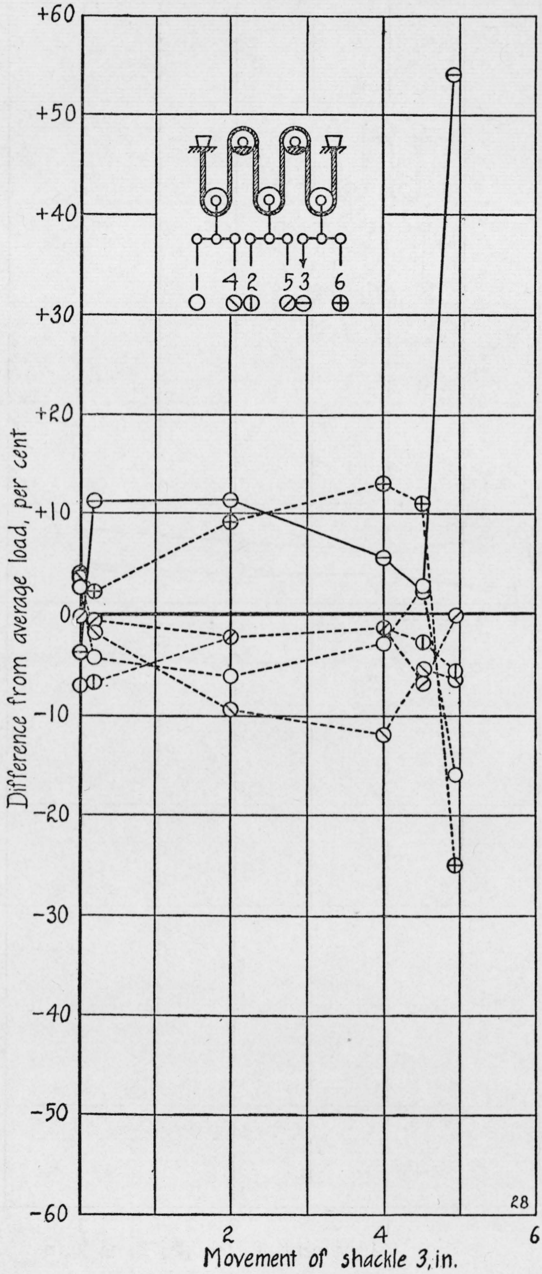

FIGURE 28.—*Load distribution for elevator cable equalizer* D *as shackle 3 was moved.*

Total load 12,000 lb.

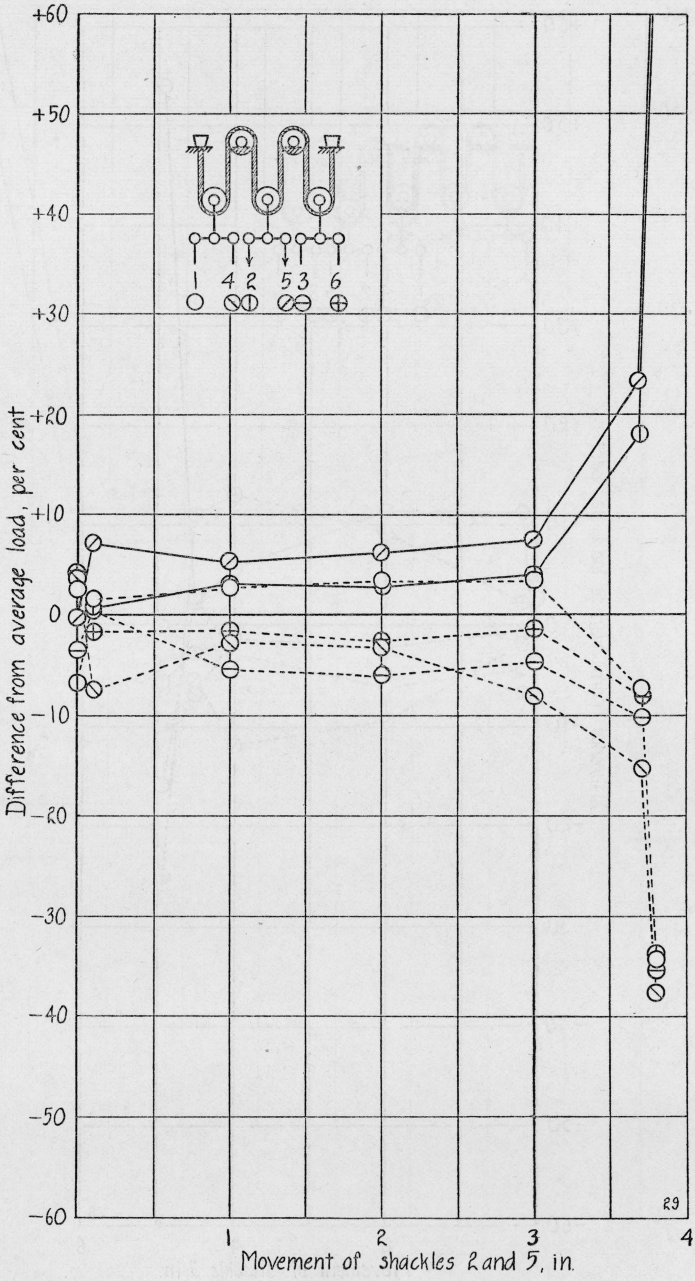

FIGURE 29.—*Load distribution for elevator cable equalizer D as shackles 2 and 5 were moved.*

Total load 12,000 lb.

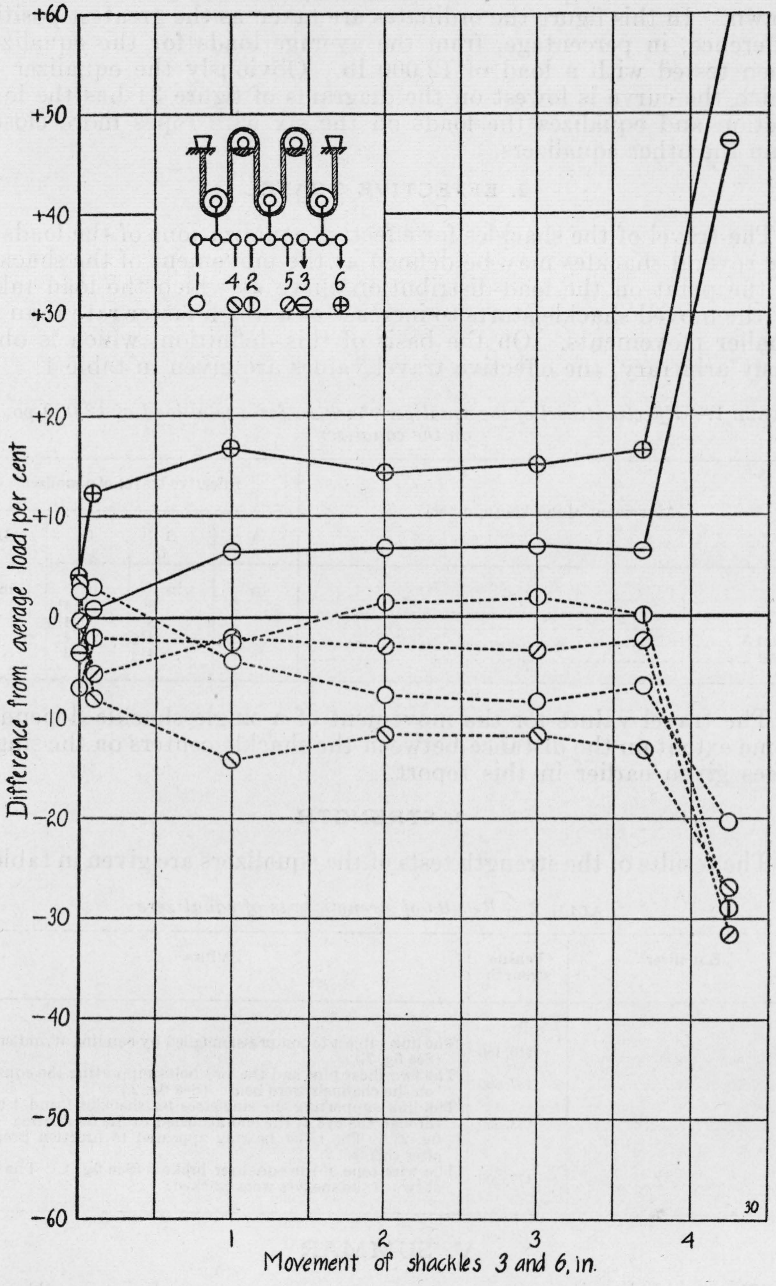

FIGURE 30.—*Load distribution for elevator cable equalizer* D *as shackles 3 and 6 were moved.*

Total load 12,000 lb.

To obtain a comparison of the four equalizers, figure 31 has been drawn. In this figure the ordinates are taken as the greatest positive difference, in percentage, from the average loads for the equalizers when tested with a load of 12,000 lb. Obviously the equalizer for which the curve is lowest on the diagrams of figure 31 has the least friction and equalizes the loads on the six wire ropes more closely than the other equalizers.

2. EFFECTIVE TRAVEL

The travel of the shackles for effective equalizations of the loads on the several shackles may be defined as the movement of the shackles to the point on the load-distribution curve at which the load taken by the moved shackle starts to increase at a much faster rate than for smaller movements. On the basis of this definition, which is obviously arbitrary, the effective travel values are given in table 1.

TABLE 1.—*Effective travel of the equalizer shackles, for a total load of 12,000 pounds on the equalizer*

Movement of shackle (number)	Effective travel of equalizer:			
	A	B	C	D
	in.	in.	in.	in.
2	5	8	4¼	5
3	5	8	4½	4½
2 and 5	2¾	4¼	4	3½
3 and 6	4	4½	3	3¾

The travel values for the movement of a single shackle depend to some extent on the distance between the shackle centers on the singletrees given earlier in this report.

3. STRENGTH

The results of the strength tests of the equalizers are given in table 2.

TABLE 2.—*Results of strength tests of equalizers*

Equalizer	Tensile strength	Failure
	lb.	
A	119,150	The link subject to compression failed by bending at midlength. (See fig. 7.)
B	137,800	The two shear pins and the two bolts supporting the equalizer on the channels were bent. (See fig. 2.)
C	133,950	The link supporting the singletree for shackles 1 and 4 broke through the eye at the end attached to the doubletree. (See fig. 23.) The roller bearing appeared to function properly after this test.
D	177,200	The wire rope of the equalizer broke. (See fig. 4.) The hubs of two of the sheaves were cracked.

V. SUMMARY

The load-distribution curves, especially those of figure 31, the effective travel values of table 1, and the breaking-strength values of table 2 afford bases for comparisons of the four equalizers.

Equalizer C, for shackle movements within the travel limits given in table 1, equalized the loads on the shackles more closely than the

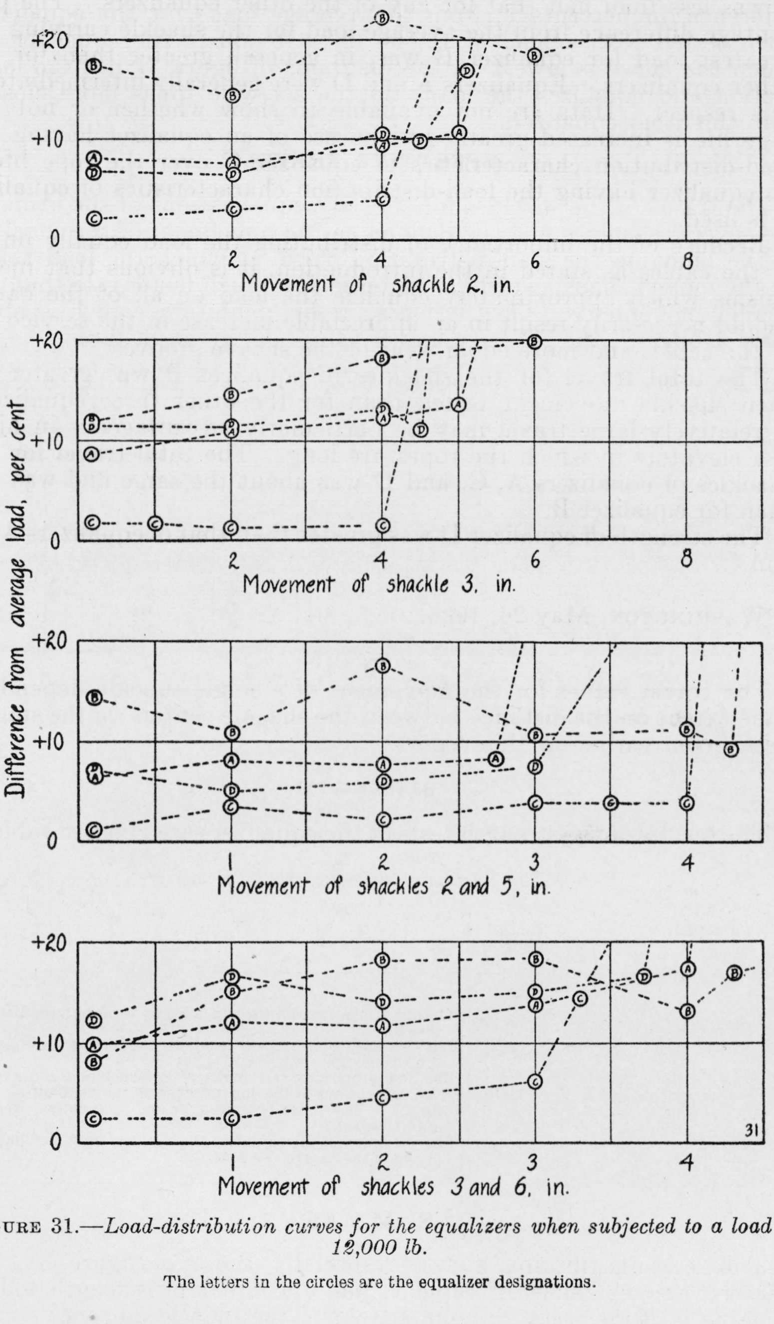

FIGURE 31.—*Load-distribution curves for the equalizers when subjected to a load of 12,000 lb.*

The letters in the circles are the equalizer designations.

other equalizers. In most cases, the percentage difference from the average load for the shackle carrying the greatest load for equalizer C was less than half that for any of the other equalizers. The percentage difference from the average load for the shackle carrying the greatest load for equalizer B was, in general, greater than for the other equalizers. Equalizers A and D were generally intermediate in this respect. Data are not available to show whether or not the rope life is increased greatly by the use of an equalizer having the load-distribution characteristics of equalizer C over the rope life if an equalizer having the load-distribution characteristics of equalizer B is used.

Because of the importance of distributing the load equally on all of the cables as stated in the introduction, it is obvious that mechanisms which approximately equalize the load on all of the cables should necessarily result in an appreciable increase in the service life of the cables and more equal wear of the sheave grooves.

The total travel for the shackles of equalizer B was greater for each shackle movement tested than for the other three equalizers. A relatively large travel may be particularly advantageous in high-rise elevators in which the ropes are long. The total travel for the shackles of equalizers A, C, and D was about the same and was less than for equalizer B.

The strength of equalizer D was greater than that of equalizers A, B, and C.

WASHINGTON, May 26, 1936.

○