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16. ABSTRACT

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COMPARISON OF DEFLECTOMETER AND DYNAFLECT FOR ASPHALT CONCRETE OVERLAY DESIGN

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January 31, 1968

Overlay design of distressed highway pavements in California has been accomplished since 1960 utilizing pavement deflection analysis[1]*. The method of obtaining deflection measurements was originally by permanently installed gage units and later simplified by development of the manually operated Benkelman beam and the traveling deflectometer. At the present time a new deflection measuring device is being evaluated. This device, which is known as the "Dynaflect" was developed in 1965 by the Lane-Wells Highway Products Company of Houston, Texas. The "Dynaflect" (Figure 1) is a small, self-contained trailer-mounted, electro-mechanical apparatus which can be towed behind a passenger vehicle and operated by the driver from inside the tow vehicle. In October, 1966, the Materials and Research Department of the California Division of Highways began the evaluation of this device under a two year cooperative research study with the U. S. Department of Transportation, Bureau of Public Roads.

The "Dynaflect" system is composed of a dynamic force generator which consists of a pair of unbalanced flywheels which revolve counter to one another at eight cycles per second, a set of five motion sensing devices and a motion measuring instrument. A tow vehicle with a 12 volt electrical system is utilized to make the unit operational. By means of a hydraulic system, the trailer is lifted off the pavement surface and a pair of steel test wheels spaced 20 inches apart are brought down into contact with the pavement to support the trailer unit (Figure 2). Utilizing the static weight of the trailer which is 1,600 pounds and the dynamic force generator, a 1,000 pound peak to peak eight cycles per second oscillatory load is produced onto the pavement surface. The actual load on the surface varies from 1100 to 2100 pounds. The resultant amplitude of motion is sensed by a set of five geophones which are also brought into contact with the pavement. They are located along the tongue of the trailer at one foot intervals

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*References are listed on the concluding page of this section of the PROCEEDINGS.

out from the center of loading. When the trailer is in a stopped position, resulting amplitudes of vibration produced by the oscillatory loading are read as deflection measurements by means of a deflection measuring gage on the control box (Figure 3) located in the tow vehicle. It is possible to read deflections as high as 30 thousandths of an inch and as low as 0.01 thousandth of an inch. It is not only possible to measure the maximum deflection under the loading but also the shape of the deflected basin which is produced.

The trailer may be moved short distances between readings at slow speed on the steel test wheels. However, at highway speeds these steel test wheels must be raised and the pneumatic trailer wheels lowered.

This device was first demonstrated to the California Division of Highways in the fall of 1965, and the resulting Dynaflect data was compared to that obtained with the traveling deflectometer over several roadways. A reasonably good correlation was found to exist although insufficient information was obtained to warrant a definite conclusion. The Dynaflect did appear to have various potential uses. Because of the relatively light loadings involved, it could possibly be used to obtain deflection measurements on unsurfaced roadbeds during various stages of construction. This has not been possible with the traveling deflectometer or the Benkelman beam due to distortion and up-thrust between the loaded dual wheels of the test vehicle. This device also presented the possibility of locating weak spots on subgrades on going construction projects for corrective treatment prior to completion of the structural section. Its greatest potential use would be for obtaining deflection measurements on distressed roadways for the purpose of determining necessary overlay repairs or maintenance treatments. Because of the many possible potential uses for this equipment, the Materials and Research Department undertook the present Dynaflect evaluation program.

The first phase of this evaluation involved a familiarization program to determine its capabilities. The second phase involved various studies to determine how well deflection measurements obtained with the Dynaflect correlated to those made by the Benkelman beam and traveling deflectometer. The repeatability of these measurements was also checked. A considerable amount of data has also been collected on the shape and slope of deflected basins. This appears to be a good approach to the evaluation of cement treated bases to determine an indication of slab strength.

The most important aspect of this study was to determine if the Dynaflect is an acceptable deflection measuring device.

A preliminary correlation established after four months of evaluation indicated that the relationship to Benkelman beam deflection under a 15,000 pound axle load could be described by the logarithmic function Log Y equals Log A + B Log X. This data (Figure 4) represented a total of 340 different test measurements over 38 test sections using the Dynaflect in conjunction with the manually operated Benkelman beam at the same test locations. This produced a coefficient of correlation of 0.98 and a standard error of ± 0.003" to ± 0.005" in terms of Benkelman beam deflection. This preliminary correlation suggests that the Dynaflect is an acceptable deflection measuring tool. However, this data was obtained over a limited number of roadways, and additional data was necessary to make a firm conclusion. Further study revealed that the relationship of Dynaflect deflections to those obtained with either Benkelman beam or traveling deflectometer is linear rather than logarithmic. Work done by other agencies also suggests a linear correlation.[2,3,4]

Since the majority of California's deflection work is accomplished with the traveling deflectometer, I will confine the remainder of this discussion to the correlation and comparison of this equipment to the Dynaflect.

As you may be aware, the deflectometer is an automatic deflection measuring device which was developed by the California Division of Highways between 1955 and 1960 and is based on the Benkelman beam principle (Figure 5). It combines a truck-trailer unit with two probes for simultaneous deflection measurements under both sets of dual wheels. The device is electro-mechanical and is capable of measuring pavement deflections at 14-1/2 foot intervals while traveling steadily at 1/2 mile per hour. The deflectometer carries a 15,000 pound single axle load and requires a crew of three men.

Deflection measurements obtained with the Dynaflect in conjunction with the traveling deflectometer over identical test locations produced the correlation plot which is shown on Figure 6. This data was obtained over 140 different test sections and produced a coefficient of correlation of 0.92 and a standard error of ± 0.010" in terms of traveling deflectometer deflection. This correlation represents various soil conditions, structural sections, pavement surface temperatures and asphaltic concrete surface conditions, varying from uncracked to considerable distress.

This data suggests a good correlation between deflection measurements obtained with the Dynaflect and those obtained by traveling deflectometer. However, the overall standard error of ± 0.010" in terms of deflectometer deflection is considered poor. This standard error is reduced to ± 0.007" for measurements below 0.050" deflectometer deflection because the spread of data in this range is narrower due to better correlation results on uncracked pavements. This lower deflection range (below 0.050") is more representative of distress roadways which are subject to asphaltic concrete overlay repair. Roads with deflection levels above this range generally require more extensive treatment.

Repeatability tests made in conjunction with correlation work indicate that the Dynaflect can repeat an equivalent deflectometer deflection measurement to within ± 0.001" and the traveling deflectometer can only repeat itself within certain deflection levels to within ± 0.005". Most of the variations in traveling deflectometer measurements were at the higher deflection levels and are due to surface distortion and up-thrust between the dual tires of the test vehicle. This, therefore, suggests the advantages of the Dynaflect principle of deflection measurement.

Although the Dynaflect did not correlate as well to our present equipment as initially indicated by preliminary Benkelman beam studies, it is still considered acceptable for work on pavement distress investigational studies of limited scope. It particularly lends itself to city and county work because of its mobility.

During the last year, 15 projects representing 90 different roadways have been subject to deflection study for purposes of recommending reconstruction utilizing the Dynaflect and a preliminary correlation curve which was developed with Benkelman beam data. On these projects, the Dynaflect was used either as a supplemental deflection measuring tool along with the traveling deflectometer, or it was used exclusively on small projects or projects in remote locations.

The same test procedure is followed with the Dynaflect as with the traveling deflectometer with exception of a conversion to standard deflection level. It is just a matter of converting the evaluated 80 percentile Dynaflect deflection level for a particular test section to an equivalent deflectometer deflection utilizing Figure 6 and following the overlay design procedure which was presented to the 9th Annual University of the Pacific Highway and Public Works Conference in March 1966[5].

Prior to making deflection measurements on a particular project, information is obtained on structural section, traffic volume, foundation and drainage conditions, and unusual occurrences during construction which may have had an effect upon the performance of the roadway. From this and visual examination of the project, test sections considered to be representative are selected. Approximately 1000 feet per centerline mile is tested on each project. Dynaflect measurements are generally obtained at 0.01 mile intervals in the most severely distressed wheel track of each test section. This is usually the outer wheel track. Deflection test data is separated into the categories of fill, cut, cracked, and uncracked. Examination of average deflections for each of these categories can frequently indicate the nature or cause of early pavement distress and the practicability of utilizing more than one type of corrective treatment.

The mean deflection and the evaluated deflection level for each test section is determined by combining all individual readings. (The evaluated deflection level is the point at which 20% of the readings are higher and 80% are lower). Usually a large discrepancy between the evaluated and mean deflection levels indicates a disproportionate influence of a few high readings so that the mean value may be more realistic as the basis for the design of reconstruction.

As a means of comparison, various distressed roadways were tested with the Dynaflect and also the traveling deflectometer and recommendations for corrective overlay treatments were made based on deflectometer data. Dynaflect measurements were obtained at 0.01 mile intervals and converted to deflectometer deflection by use of Figure 6. Traveling deflectometer readings were obtained at 14-1/2 foot intervals and converted to 100 foot mean deflection measurements for simplicity. Deflection profiles of four selected test sections on three different projects are presented on Figures 7 through 10. From these deflection studies, the mean and evaluated 80 percentile deflections can be compared for both types of measurement.

These projects present typical examples of how both types of measurement and corrective treatment might be expected to vary during actual investigational work. Figures 7 and 8 indicate close agreement between calculated mean and evaluated 80 percentile deflection levels by both methods, suggesting no variation in design overlay thickness.

The two deflection profiles on Figure 9 produced the same calculated mean deflection level (0.029"), but yielded different evaluated 80 percentile design deflection levels (0.035" by traveling deflectometer and 0.042" by Dynaflect). This particular roadway was in good condition and carried a high volume of traffic. An asphaltic concrete contact blanket was not applicable, as it would bond to the existing surfacing to form a thicker pavement section requiring a much lower tolerable deflection level. A blanket repair would not provide a sufficient reduction in the existing deflection level because the resulting deflections would never approach the tolerable limit required for the thicker pavement. A cushion course overlay was therefore recommended by deflectometer design and consisted of 0.50' of Class 2 aggregate base surfaced with 0.35' asphaltic concrete. The 0.042" evaluated deflection level produced by the Dynaflect would not have altered this recommended repair. However, if the surfacing had been cracked to the extent that a contact blanket could be utilized, Dynaflect measurements would have produced approximately a 50% over design.

Figure 10 shows the amount of variation which might occur at extreme deflection levels. This particular project produced an evaluated 80 percentile deflection level of 0.090" by Dynaflect and 0.073" by traveling deflectometer. Both deflection levels indicate the need for a major corrective treatment. Assuming that a 0.30' asphaltic concrete surfacing is utilized in a cushion overlay repair, a tolerable deflection level of 0.020" is indicated by Figure 11* (TI 8.0). This suggests the need for the following reductions in deflection level:

$$\frac{0.090'' - 0.020''}{0.090''} \times 100 = 78\% \text{ (Dynaflect)}$$

$$\frac{0.073'' - 0.020''}{0.073''} \times 100 = 73\% \text{ (deflectometer)}$$

Figure 12*, indicates a need for an increase in gravel equivalences of 20.5" by Dynaflect and 18.5" by deflectometer. This would yield a slight over design by Dynaflect measurement.

The examples that I have just presented verify that the Dynaflect is a reliable as well as an economical deflection tool that can be used in determining asphaltic concrete overlay and maintenance requirements. It does, however, generally yield a conservative design when compared to that determined by the traveling deflectometer.

The Materials and Research Department's evaluation of the Dynaflect will be concluded in July with the completion of a research report. Future research is anticipated for the Dynaflect to determine other possible field applications.

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*Basic criteria used by California Division of Highways for recommending reconstruction of distressed roadways by deflection analysis.

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1. "Flexible Pavement Maintenance Requirements as Determined by Deflection Measurements", Ernest Zube and Raymond Forsyth, Presented at the 45th Annual Meeting of the Highway Research Board, January, 1966.

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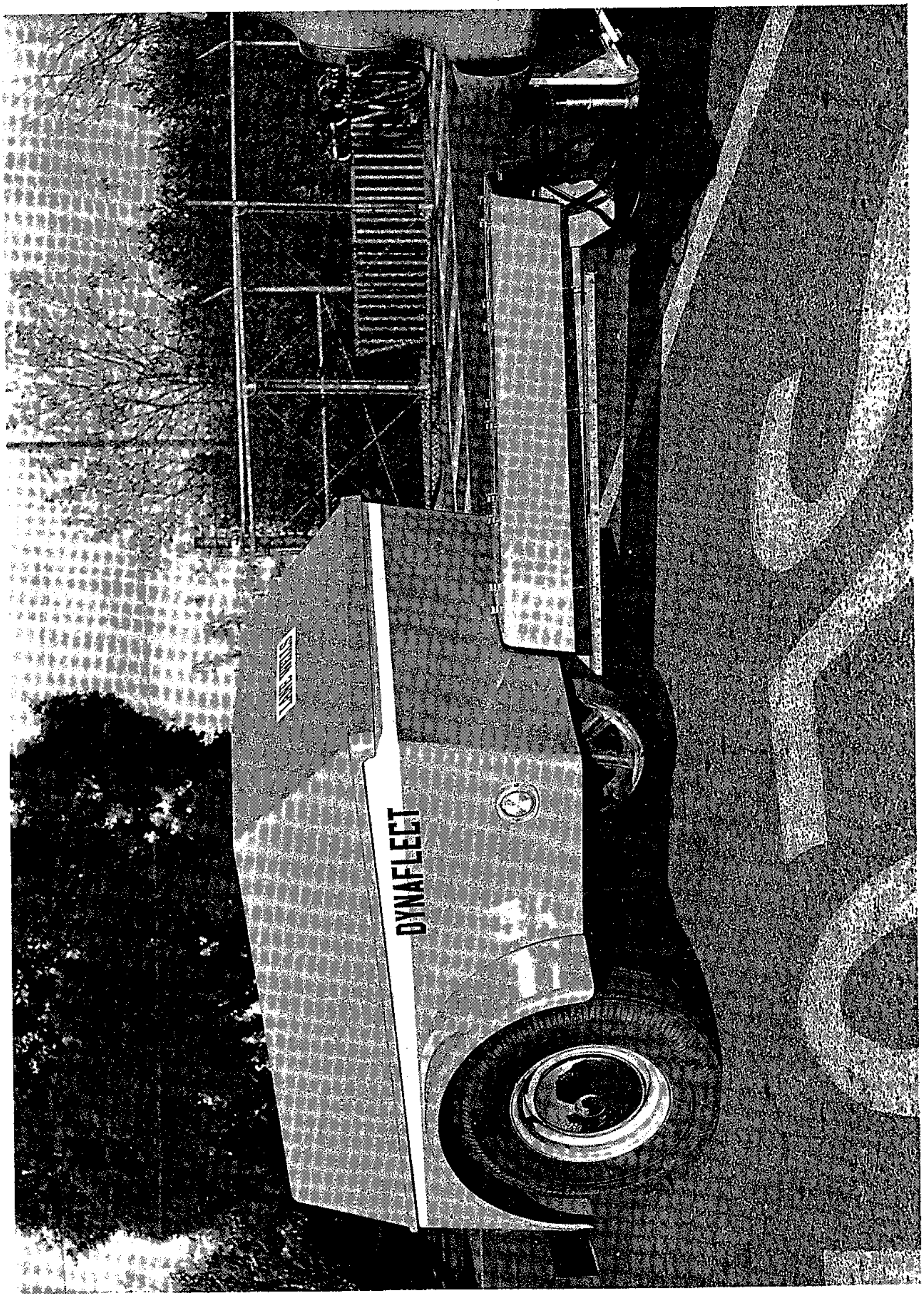
3. "Use of Texas Dynaflect Apparatus on Minnesota Test Sections (1966)", Investigation 183, Special Report 1, November, 1966, Eugene L. Skok, Jr., Department of Civil Engineering, University of Minnesota, Minneapolis, Minnesota.

4. "Evaluation of a Dynamic Deflection Determination System (Lane-Wells Dynaflect)", Technical Report 4, October, 1966, R. W. Culley, Materials Research Engineer, Saskatchewan Department of Highways, Regina, Saskatchewan, Canada.

5. "Use of Deflection Data for Road Repairs and Improvements", Raymond A. Forsyth, Proceedings of the 9th Annual Highway and Public Works Conference, University of the Pacific, March, 1966, pages 81-89.

FIGURE 1



DYNAFLECT IN HIGHWAY TRAVEL POSITION

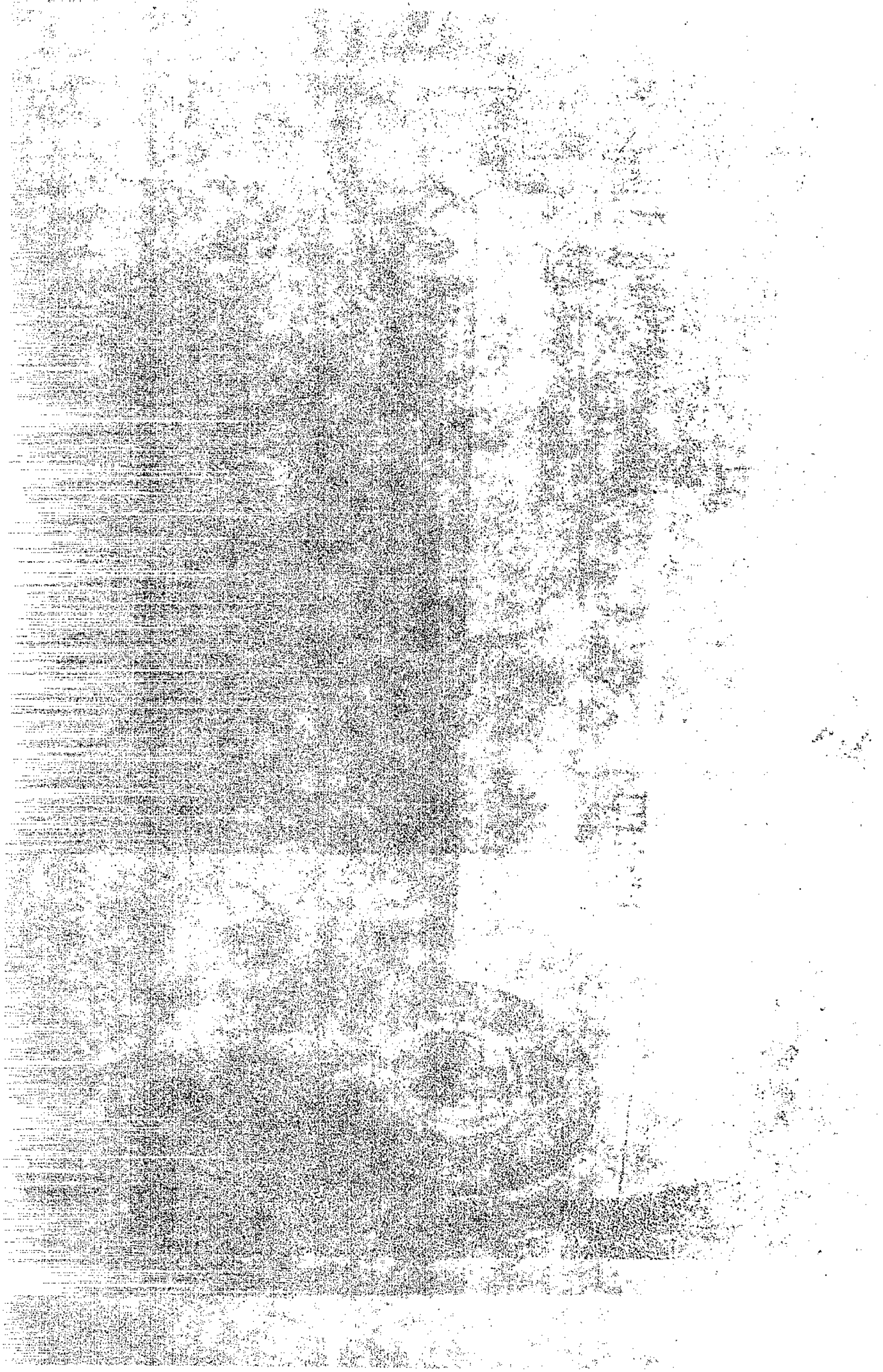
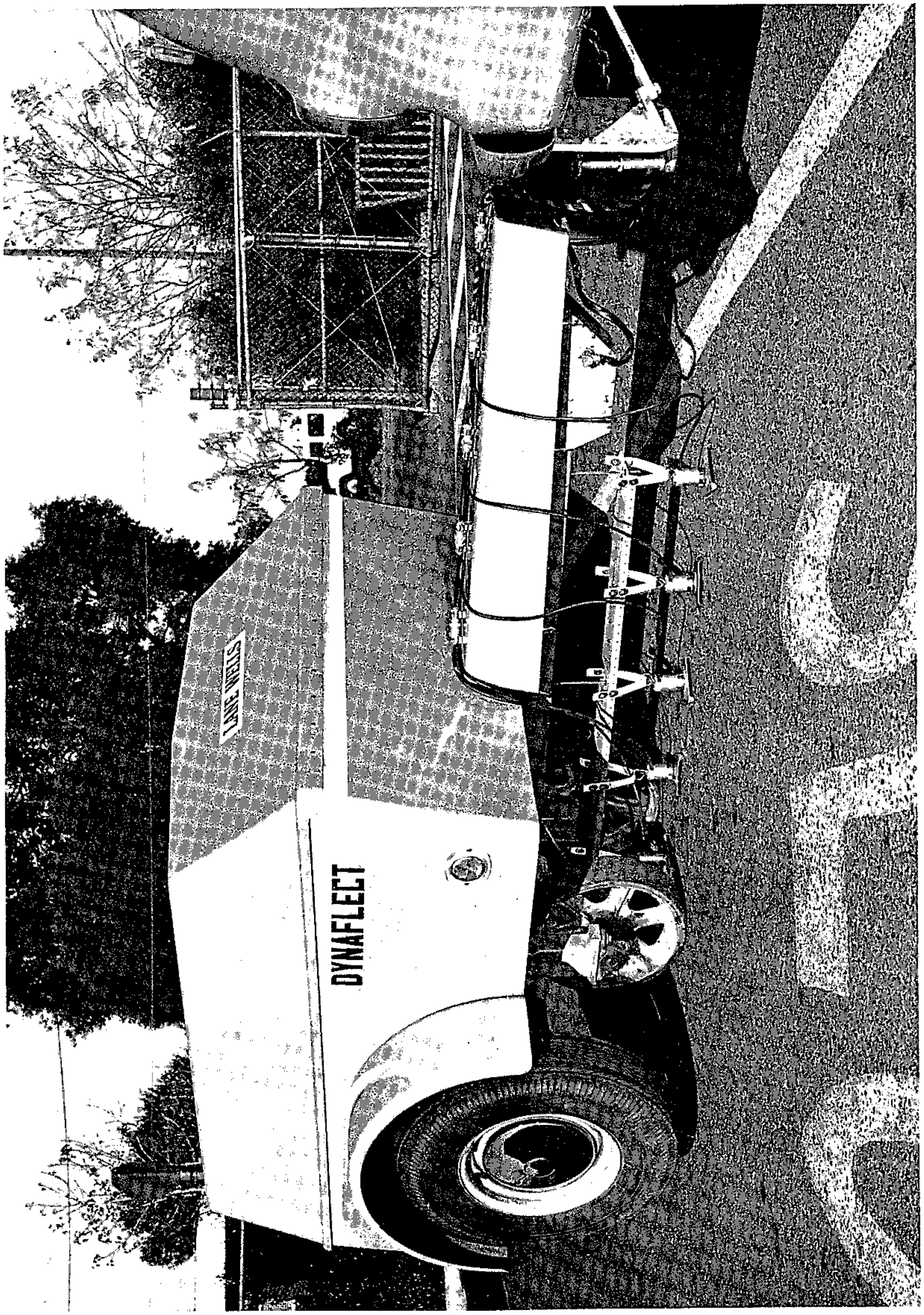
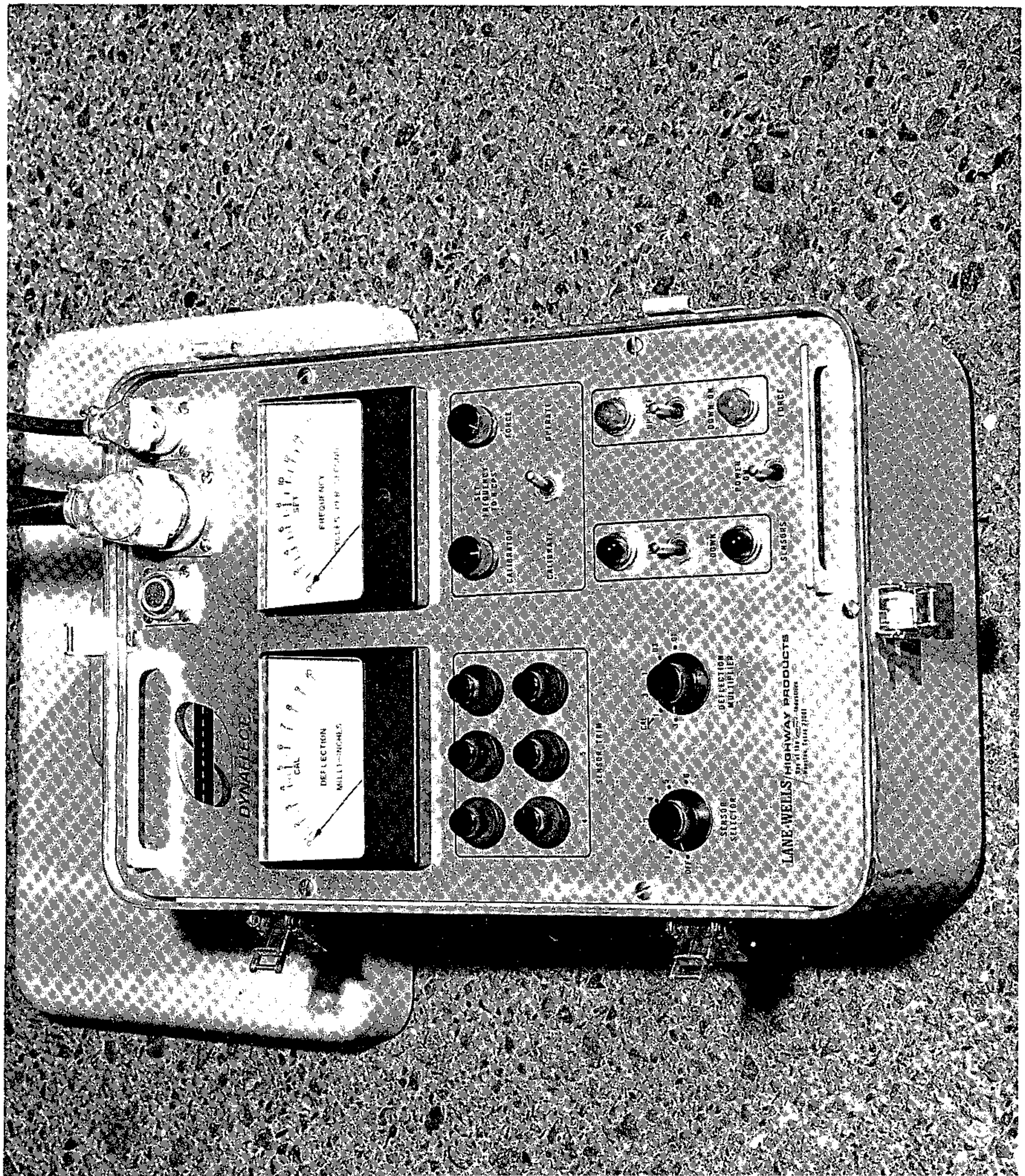


Figure 2



DYNAFLECT IN TEST POSITION WITH FORCE WHEELS AND GEOPHONES DOWN

FIGURE 3



DYNAFLECT CONTROL BOX

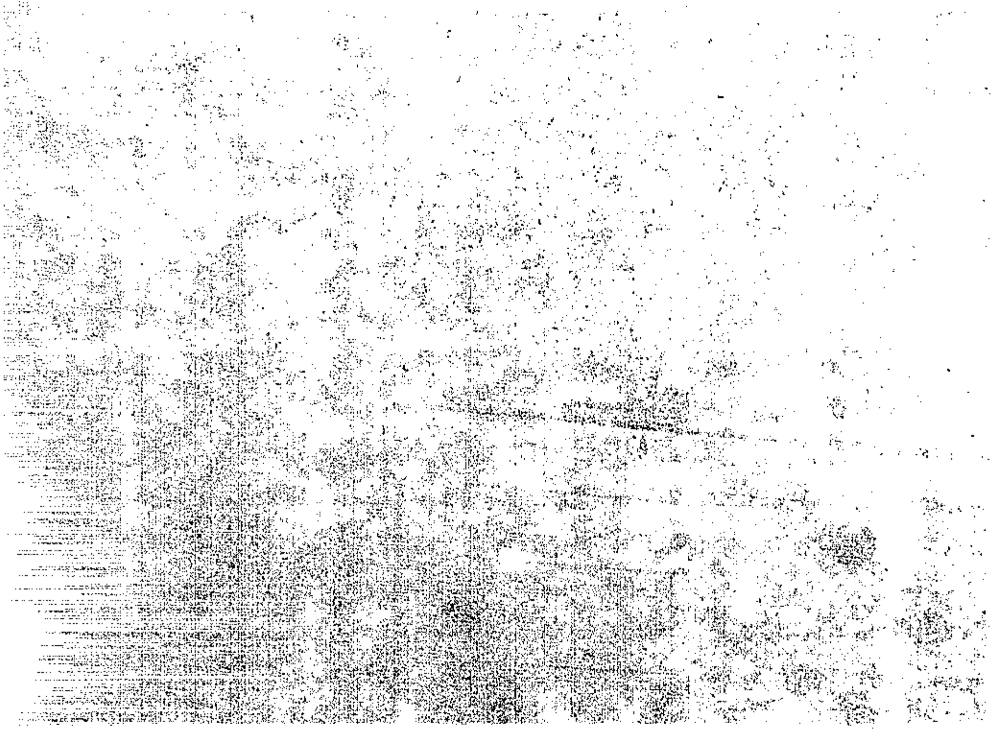


FIGURE 4

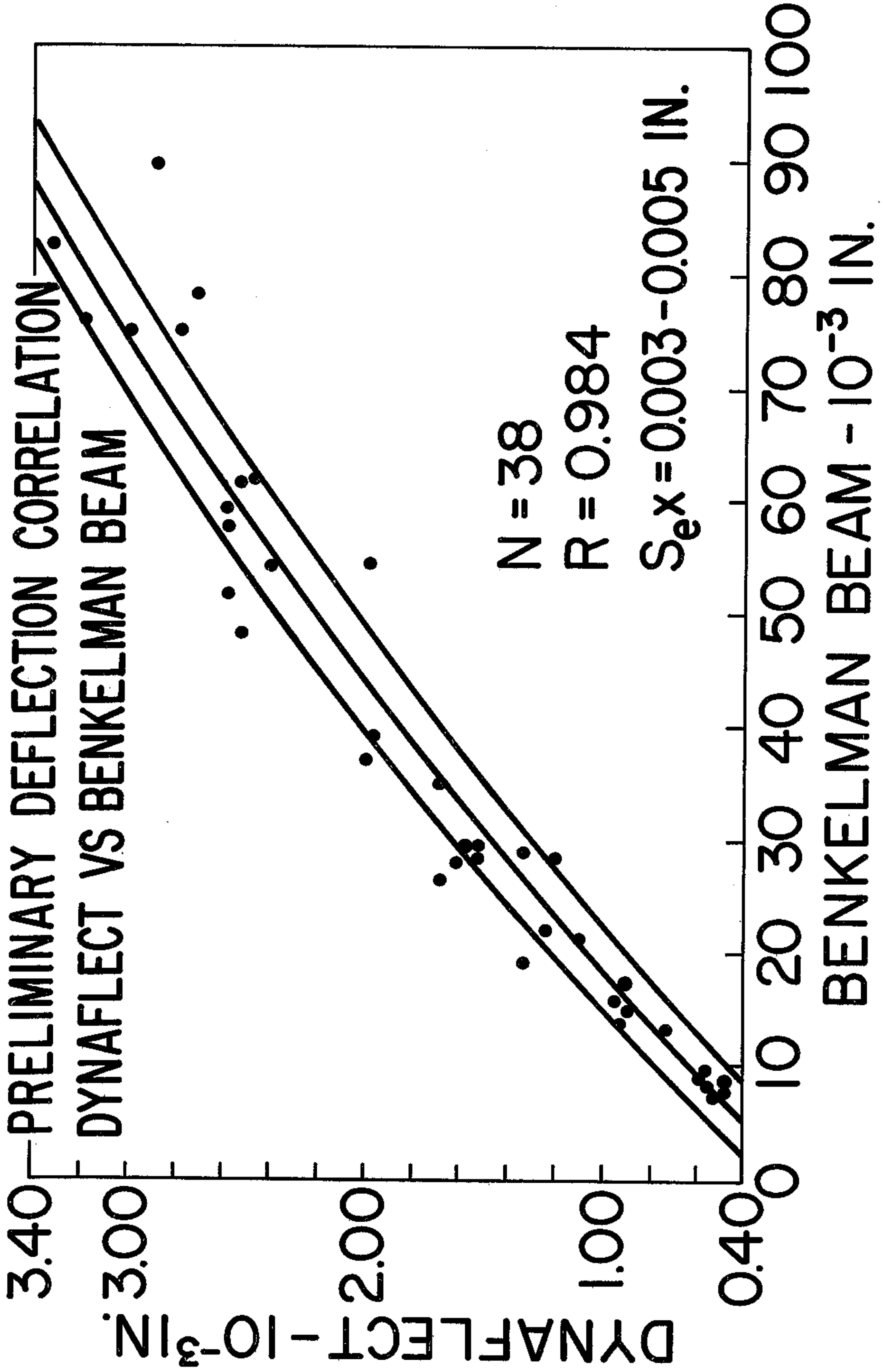
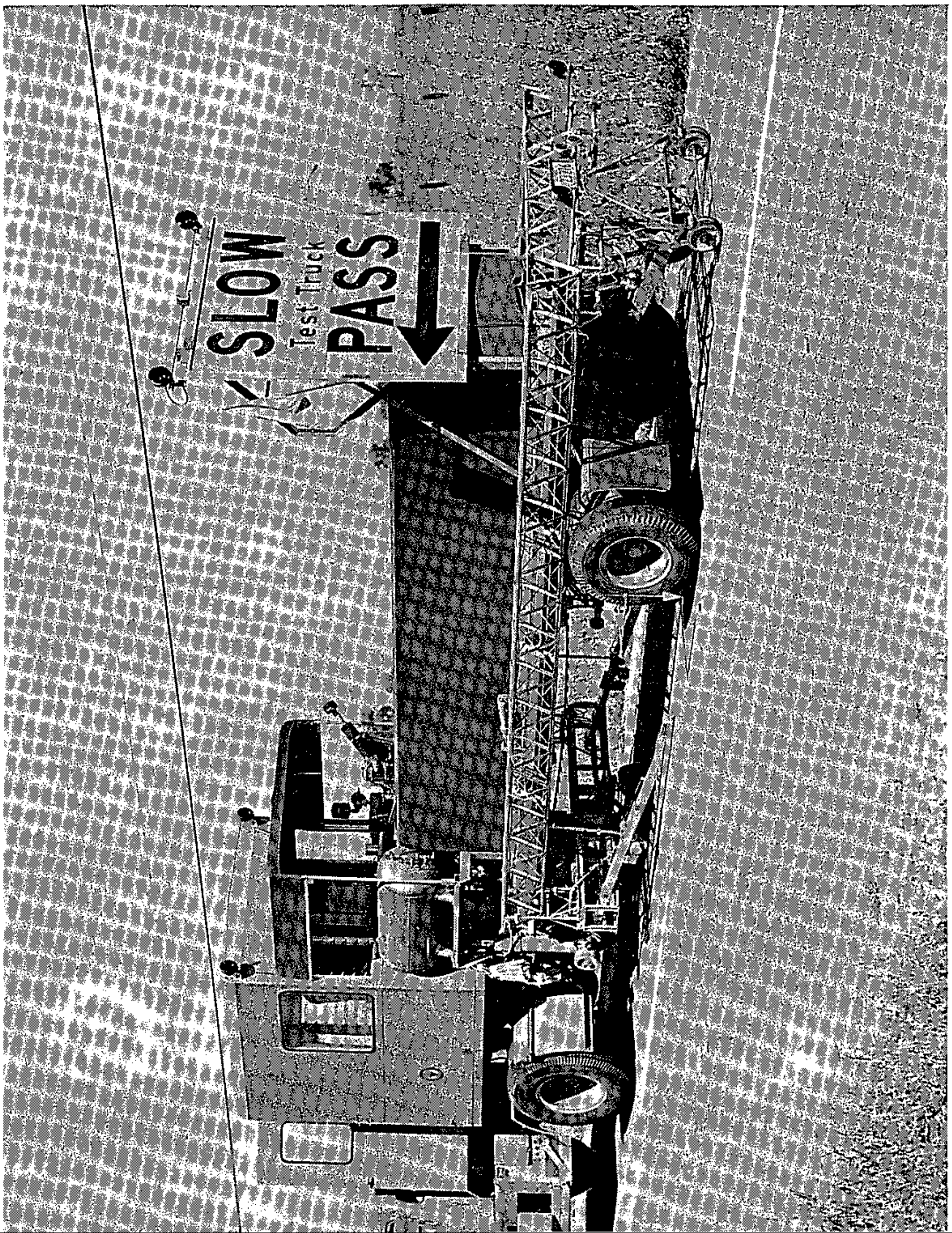

PRELIMINARY DEFLECTION CORRELATION
DYNAFLECT VS BENKELMAN BEAM
N = 38
R = 0.984
$S_e x$ = 0.003-0.005 IN.
BENKELMAN BEAM - 10^{-3} IN.
DYNAFLECT - 10^{-3} IN.
0
10
20
30
40
50
60
70
80
90
100
0.40
1.00
2.00
3.00
3.40

Figure 5



TRAVELING DEFLECTOMETER

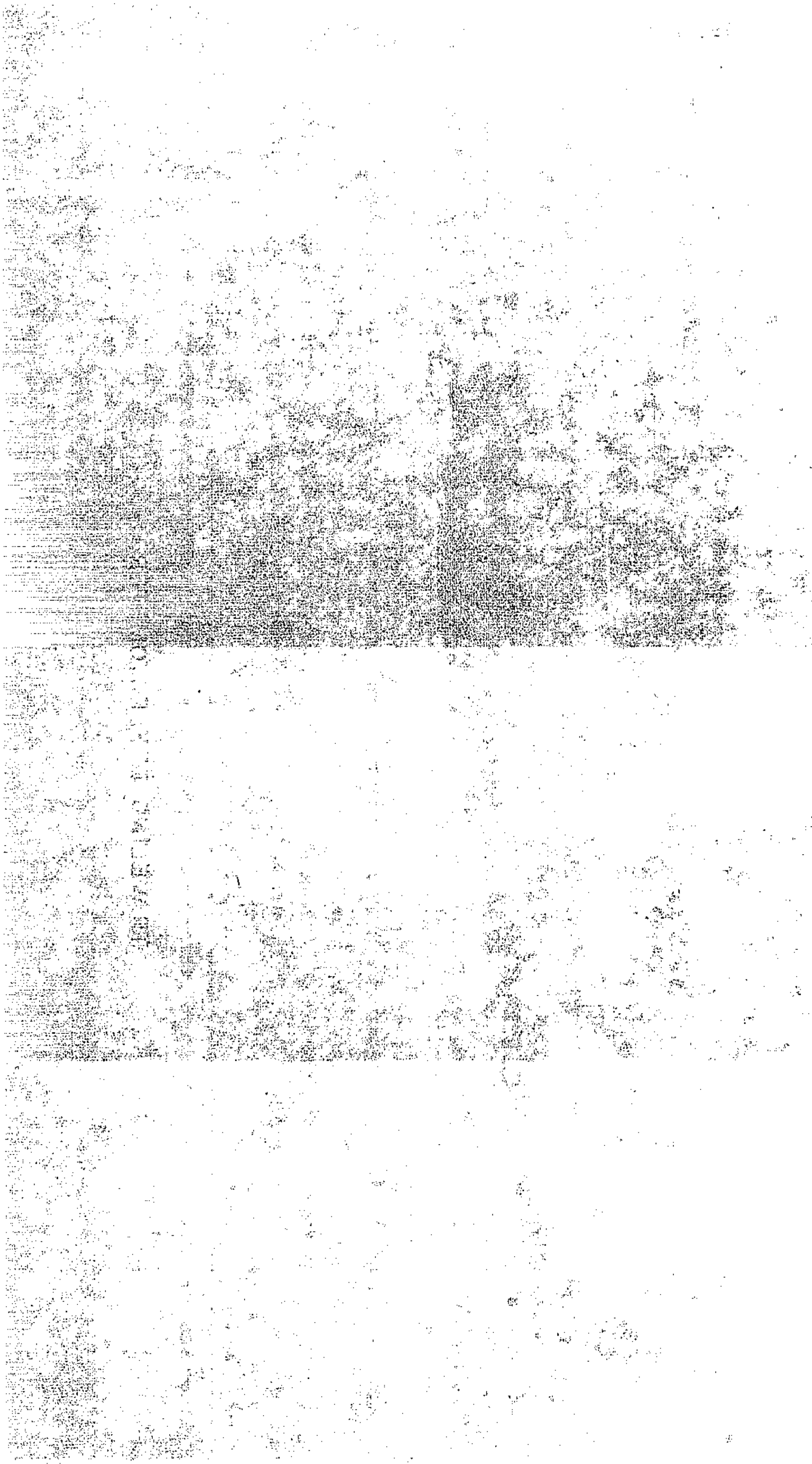
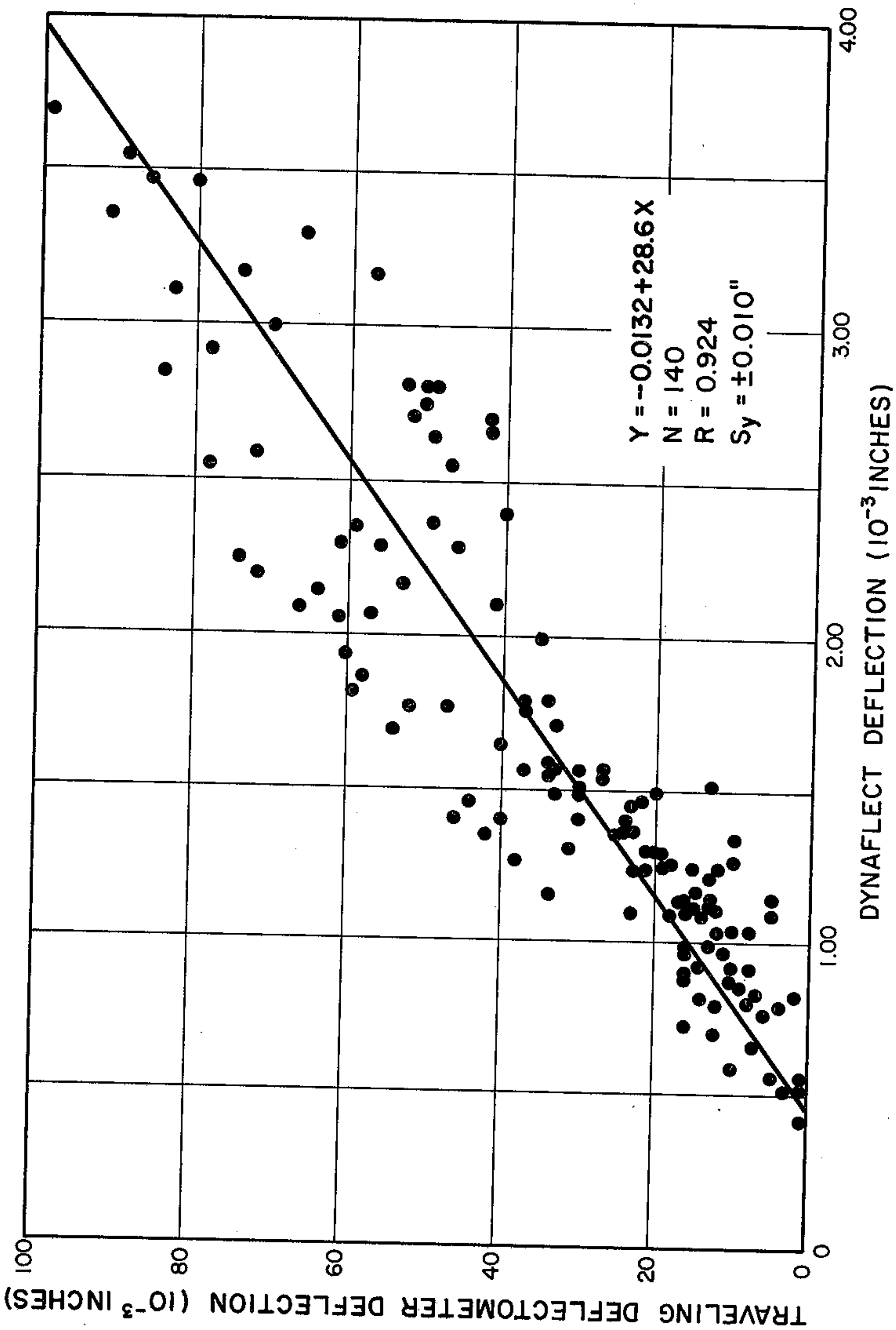
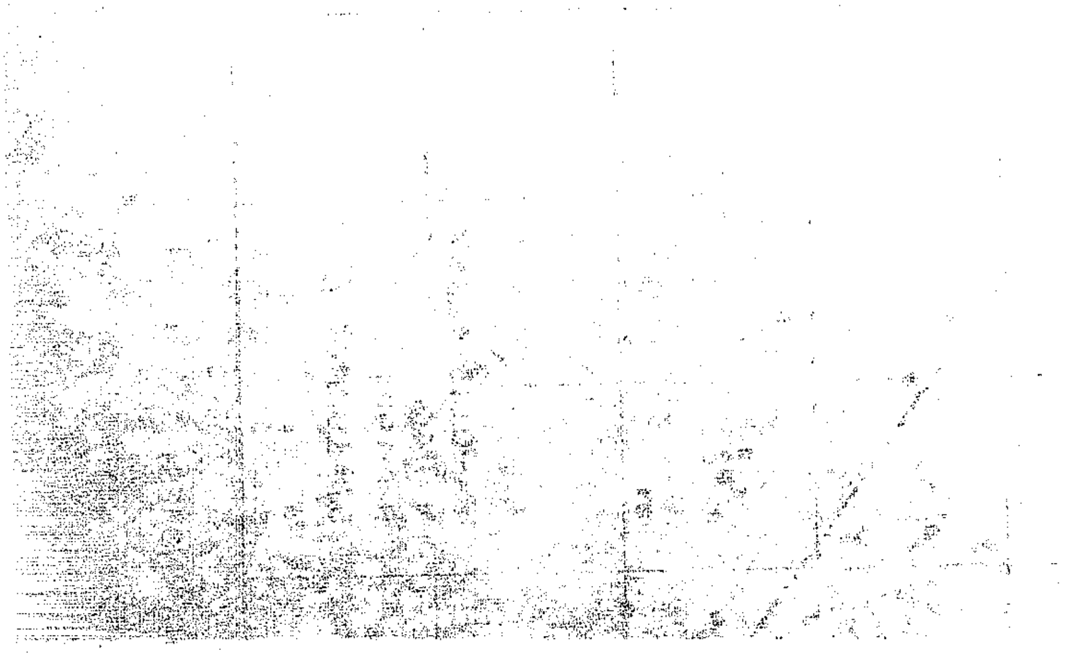


FIGURE 6

COMPARISON OF DYNAFLECT AND TRAVELING DEFLECTOMETER





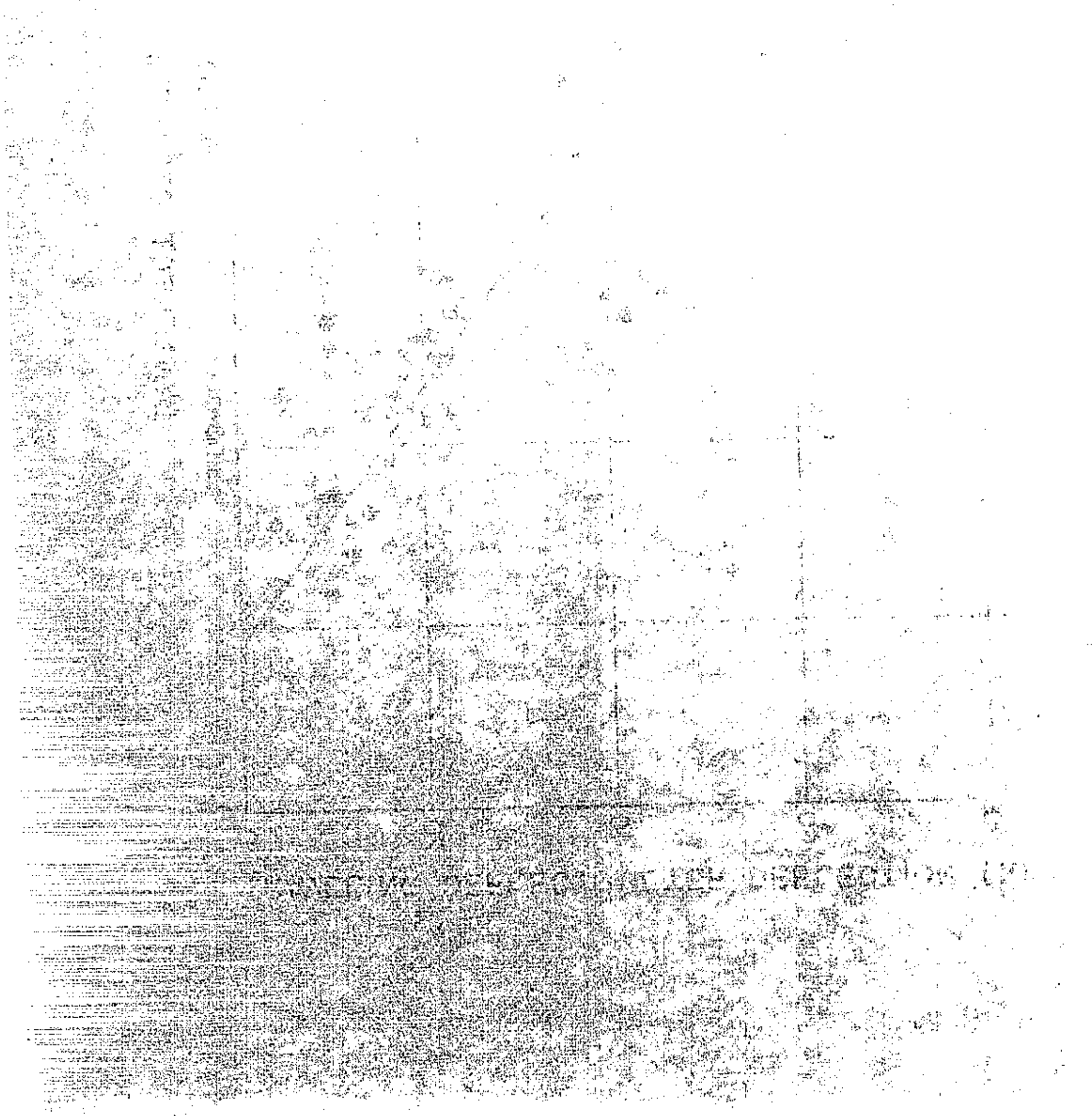
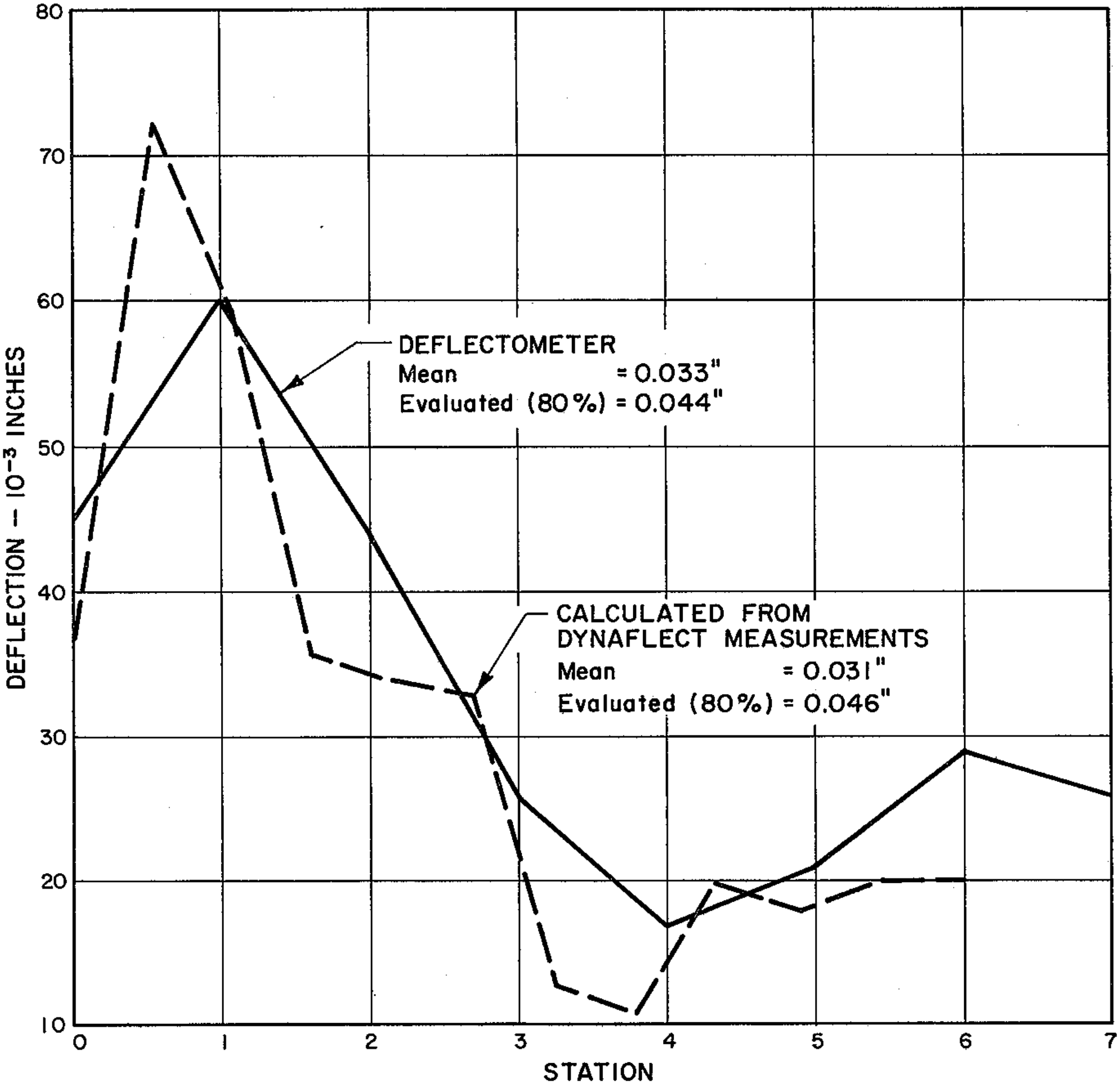
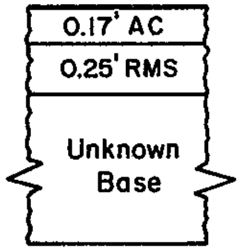


FIGURE 7

COMPARISON OF MEASURED DEFLECTION BY DEFLECTOMETER AND DYNAFLECT

ROAD 07-LA-60-18.7/22.8-OWT
TRAFFIC INDEX = 9.0





EXISTING STRUCTURAL SECTION

COMPARISON OF MEASURED DEFLECTION BY DEFLECTOMETER AND DYNAFLECT

ROAD 08-Riv-395 PM 8.4/20.3
TRAFFIC INDEX = 10.0

EXISTING
STRUCTURAL SECTION

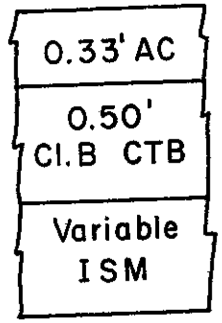
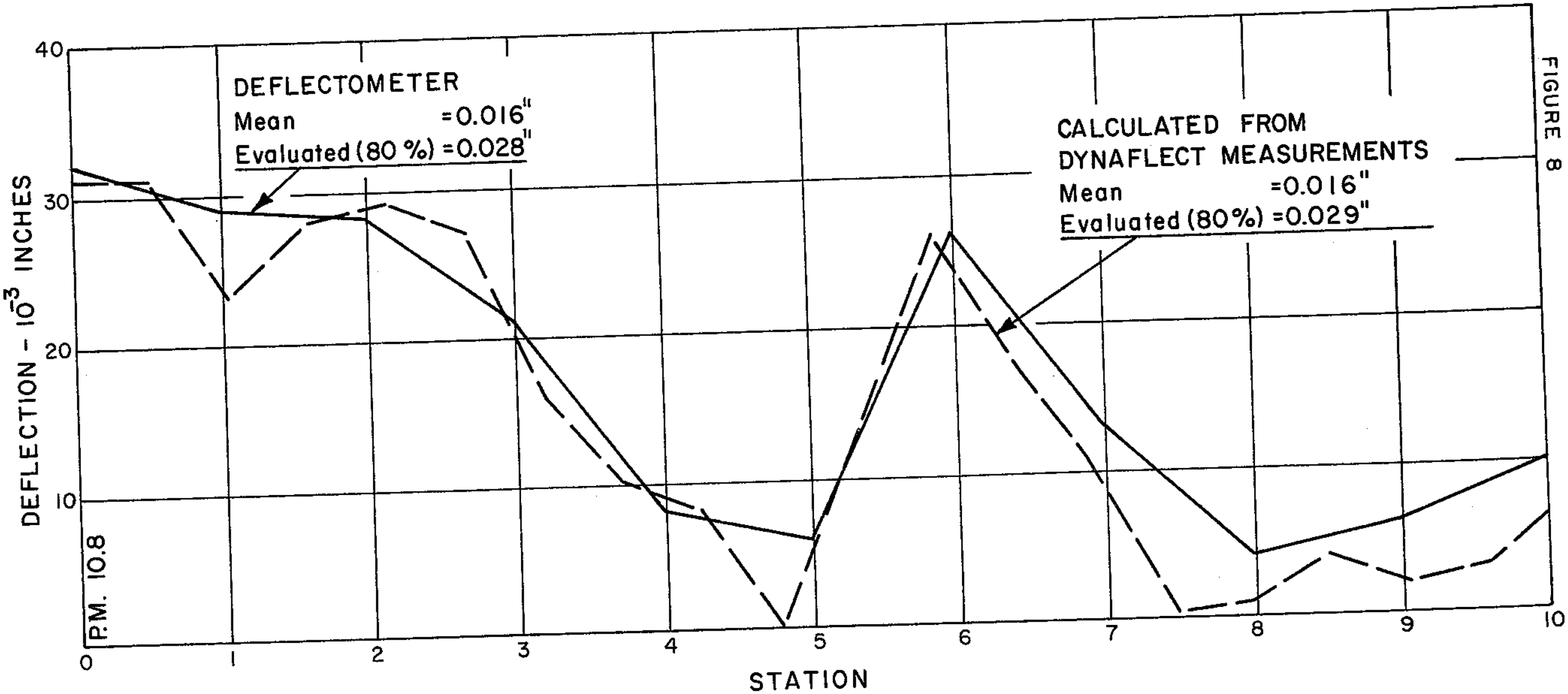
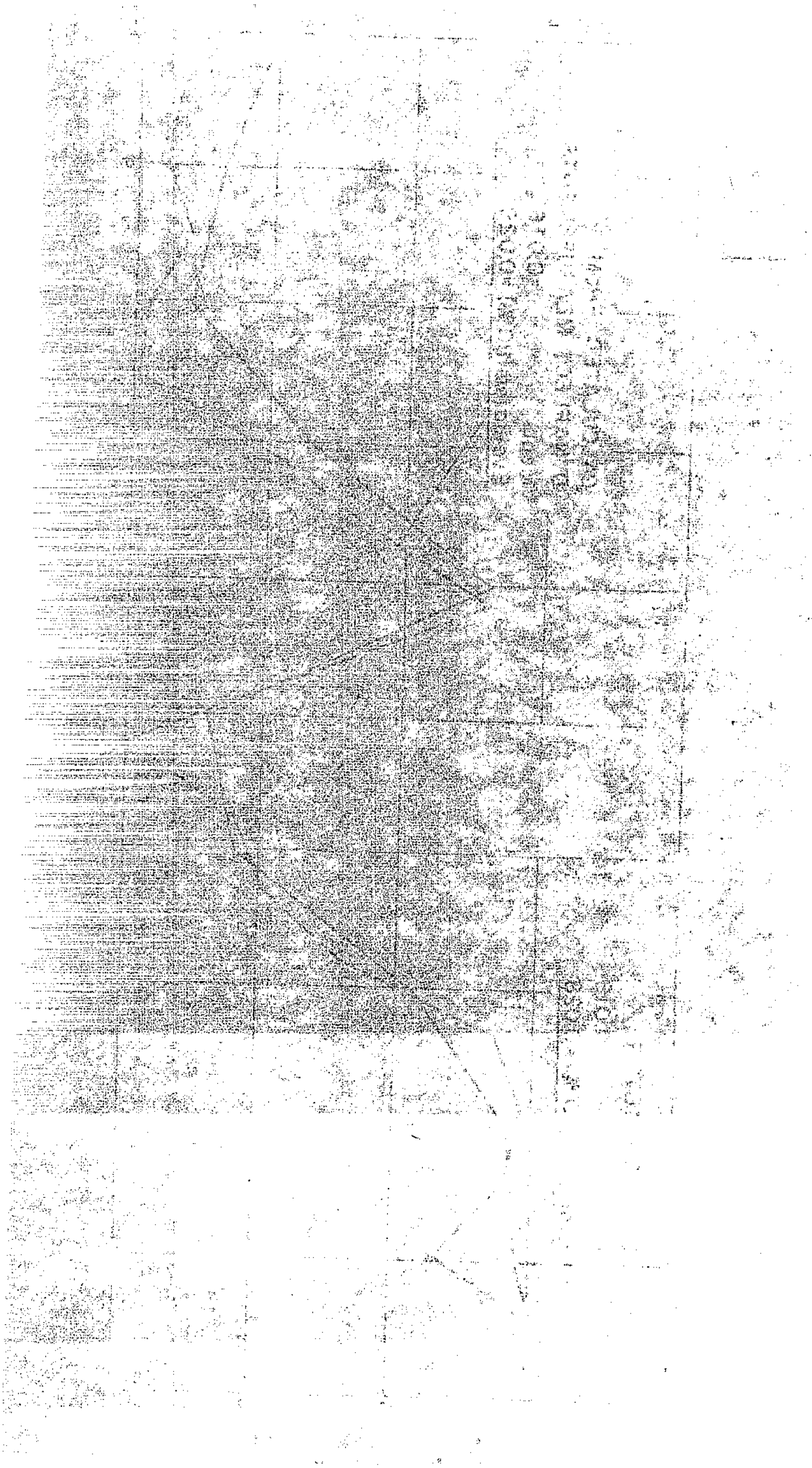


FIGURE 8





COMPARISON OF MEASURED DEFLECTION BY DEFLECTOMETER AND DYNAFLECT

ROAD 08-Riv-395 PM 8.4/20.3
TRAFFIC INDEX = 10.0

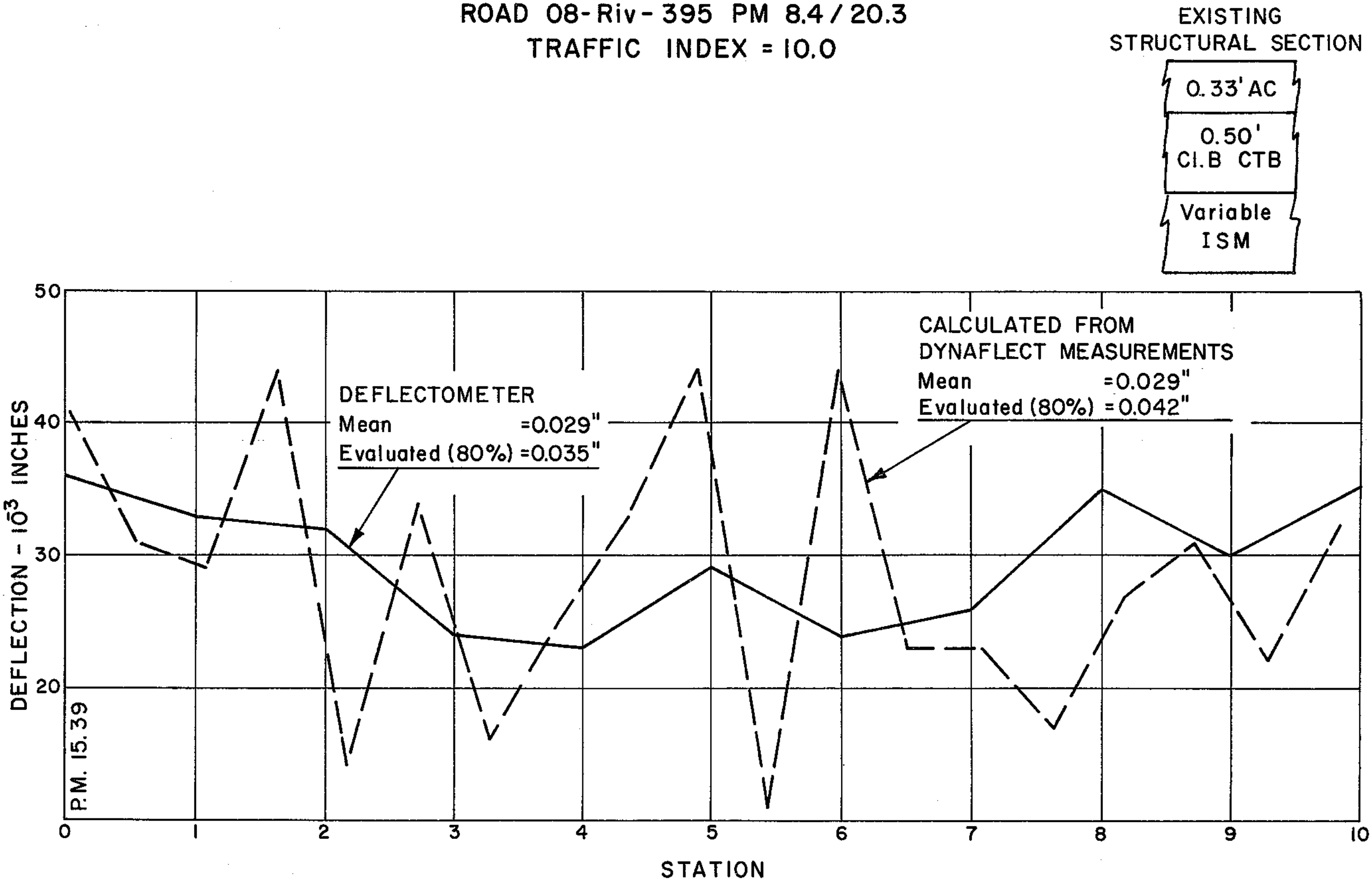


FIGURE 9

COMPARISON OF MEASURED DEFLECTION BY DEFLECTOMETER AND DYNAFLECT

ROAD 10– Mer–MERCY SPRINGS ROAD–O.W.T.

TRAFFIC INDEX = 8.0

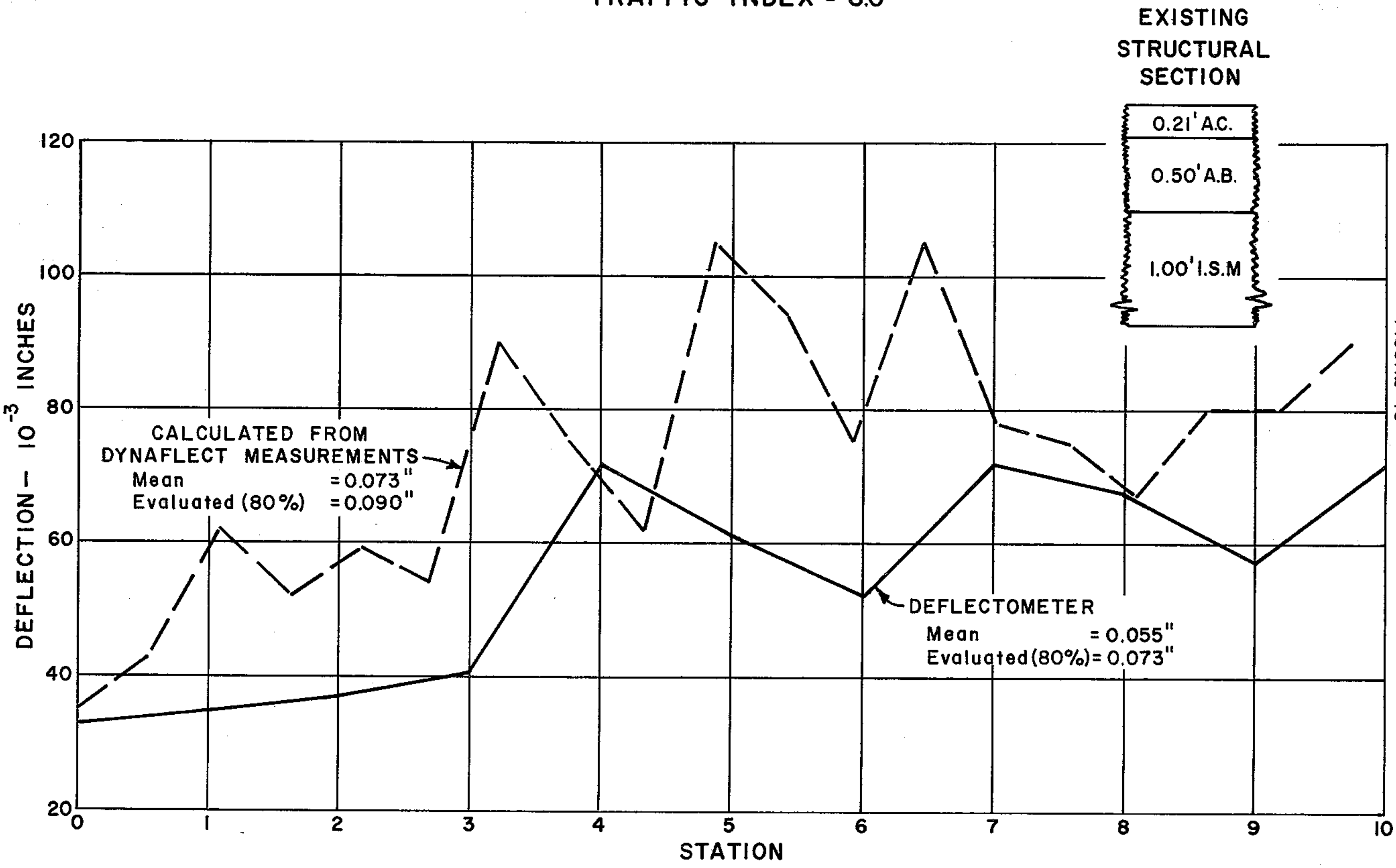
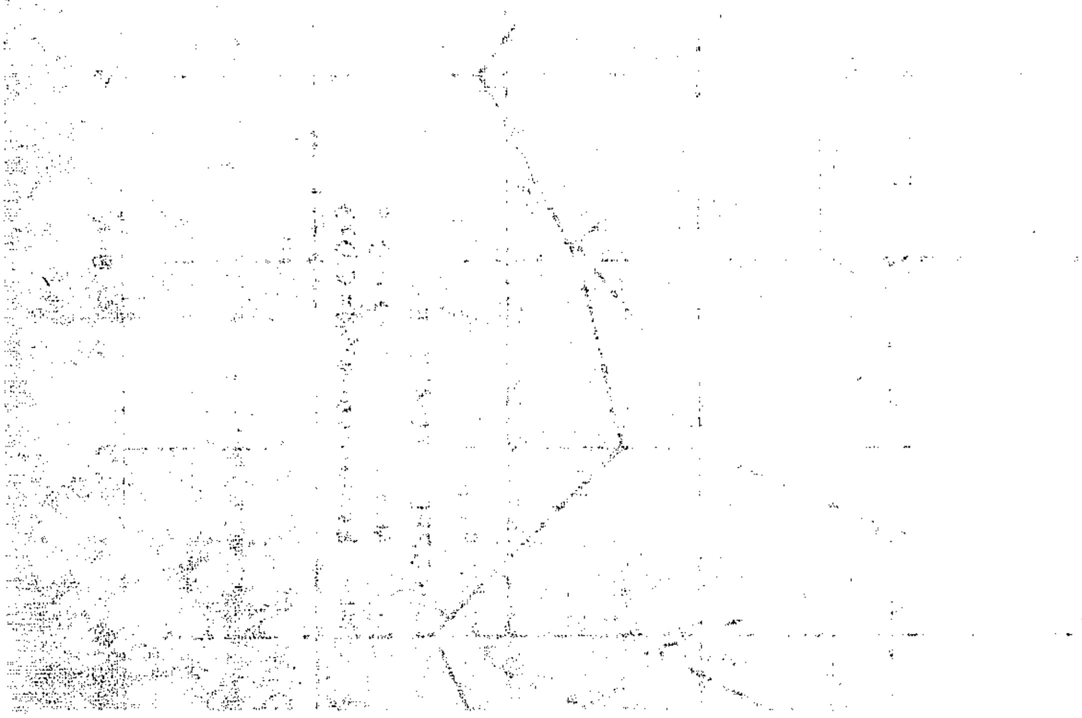


FIGURE 10



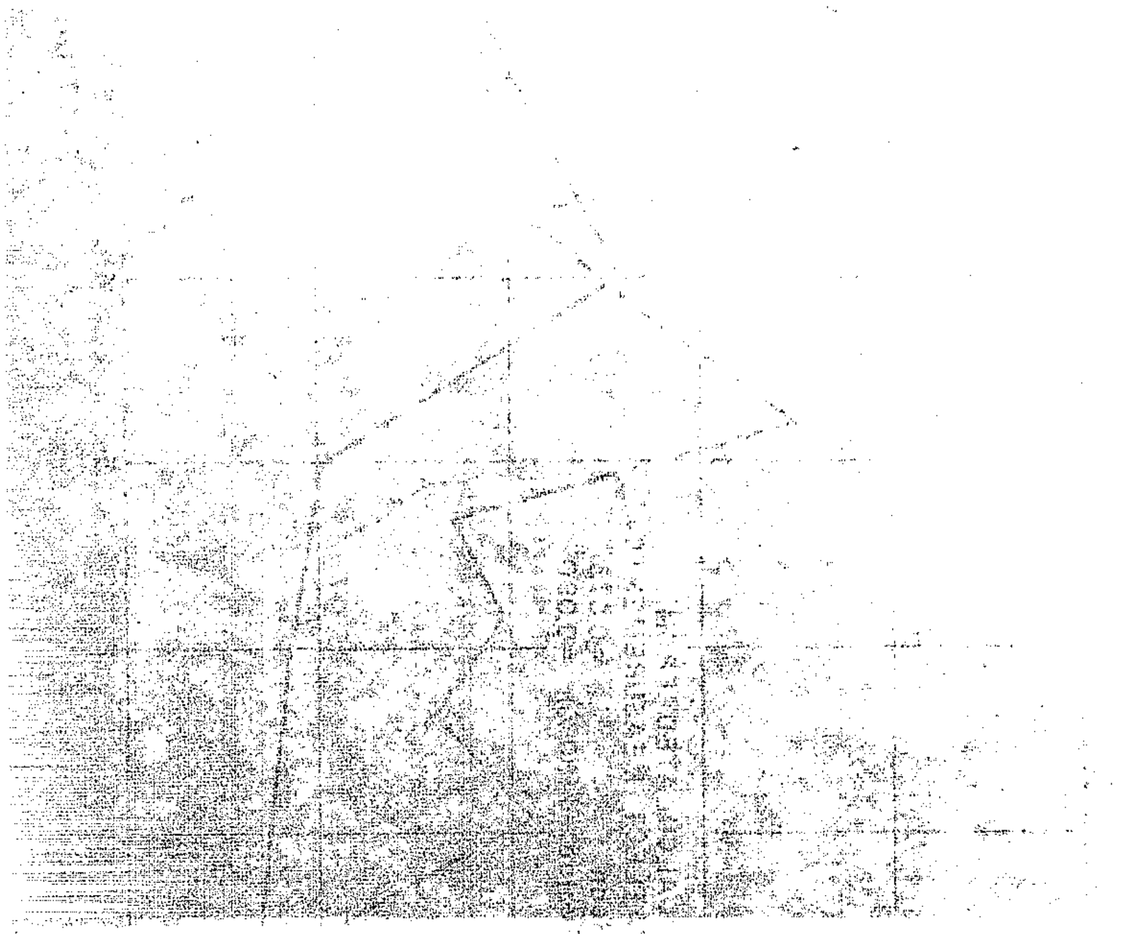
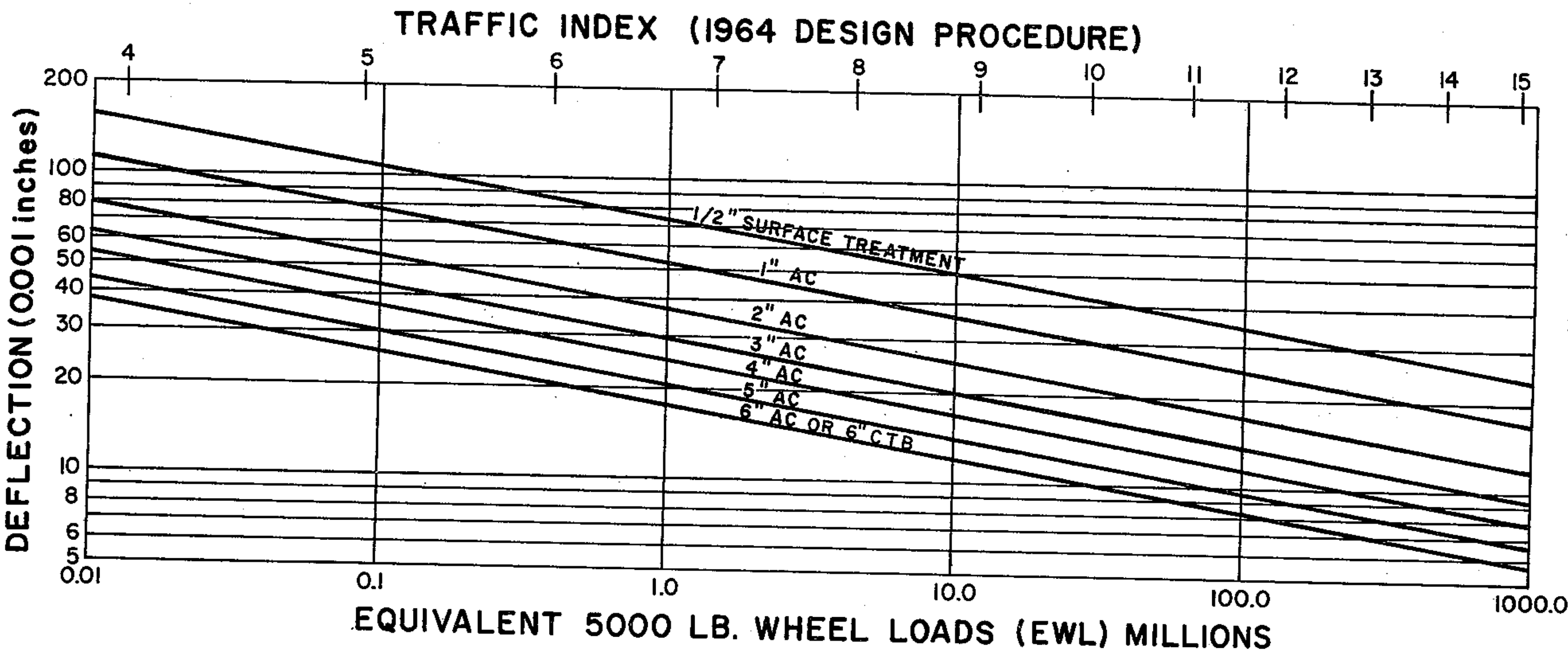
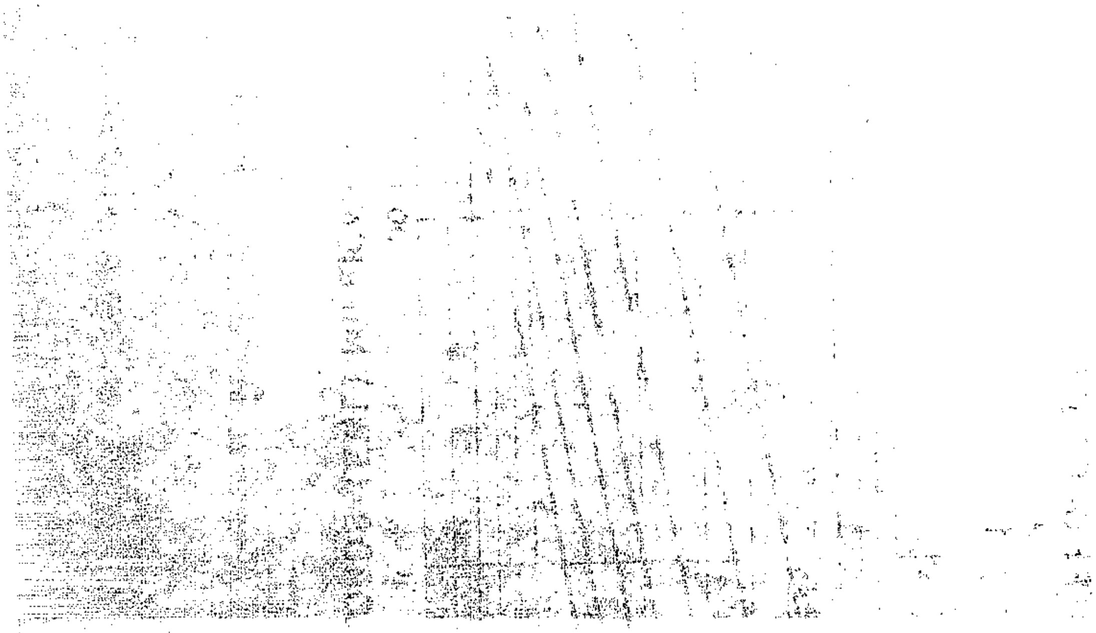


FIGURE 11

VARIATION IN TOLERABLE DEFLECTION BASED ON A.C. FATIGUE TESTS





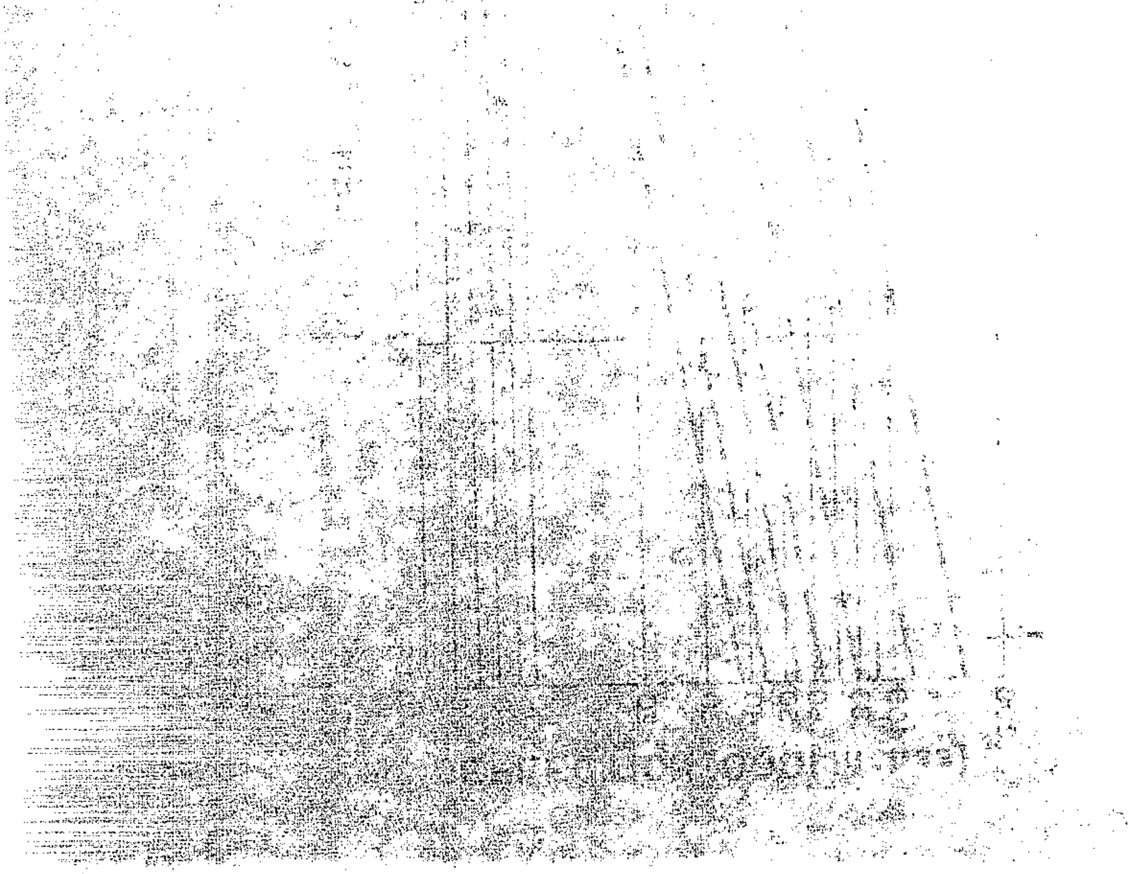


Figure 12

REDUCTION IN DEFLECTION RESULTING FROM PAVEMENT RECONSTRUCTION