Report 26-1

DYNAMIC TEST
OF
P. & S. F. RAILROAD OVERPASS
EL PASO, TEXAS

BY

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Final Report
On
Research Project
Part 1 of 2

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I. Field Test of P & SF Railroad Overpass

Introduction

In March and April of 1962 the Texas Highway Department Bridge Division and the Bureau of Public Roads Physical Research Division joined in a bridge testing program on the P & SF Railroad Overpass in El Paso, Texas. The overpass is on U. S. Highway 80 and carries a heavy volume of interstate truck traffic. This 1388 foot bridge is a combination of three, five, and six span steel I-beam units. (Figure 1.) Undue slab distress is evident in the form of longitudinal and transverse cracking, and heavy spalling of the bridge deck is visible down to the top reinforcing steel. (Figure 2 and 3.)

The object of this test was to determine whether the slab distress mentioned above was caused by excessive stresses, deflections or vibrations.

Description of Bridge

As afore-mentioned, the bridge is made up of a series of three, five, and six span I-beam units. The beams in all units are spaced on 7'-3 3/8" centers, and the slab thickness is 6 1/2". (See Figure 4 for section.) The three span units are continuous over 40'-51'-40' spans, while the five span unit studied (39'-30'-37'-40'-34') is a series of five simply supported spans with the beams framing into a continuous transverse floor beam by riveted beam connectors. The substructure for the three span units is composed of concrete caps with six 14BP73 H-section supporting steel columns, while the steel columns of the five and six span units frame directly into the transverse floor beams of the superstructure. Steel A-frames are spaced at intervals to retard longitudinal movement of the five-span units. All columns and frames of the five and six span units are founded on spread footings with a minimum of three piles per footing. No shear connectors between the steel beams and the concrete deck were used in this structure.

Test Procedure

The structure was test loaded with a moving 3-axle tractor semi-trailer and recordings of dynamic deflection, peak stress, and stress damping were made on one 3-span and one 5-span unit. Instrumentation equipment and assistance was furnished by the Bureau of Public Roads.

Four paths of travel were laid down for the test vehicle to follow. These were positioned to duplicate the average path followed by regular traffic. (Figure 4.) Truck speeds varied from a crawl speed of approximately 2-3 mph to over 40 mph. Approach curvature and grades on the structure prevented higher speeds being attained. Data was taken with the test vehicle making two runs in each direction for each of the four paths of travel. Profile grade lines of each path of travel were taken by leveling to furnish data on the roughness of the bridge deck.

Strain gages were mounted on the test truck axle housings to provide correlation between the sprung load of the truck and the bridge vibration.

Air tubes were stretched across the roadway at the beginning, center, and end of the unit under study with electrical contact switches activating "pips" on the oscilligraph records in the instrument trailer (Figure 5) when the truck wheels passed over the tubes. These "pips" were necessary to calculate longitudinal truck position on the unit and as an aid in calculating truck speed. Transverse position of the truck in regard to the path of travel was indicated by a bracket holding clothespins on one inch intervals. As the truck passed over the bracket positioned on the designated truck centerline path a pointer hanging from the bumper knocked over a pin thus locating the position of the truck with respect to path center. (Figure 6.)

Gage Location

Points of maximum stress and deflections for each of the two units tested were gaged. SR-4 electrical strain measuring gages (Figure 7) were attached to the I-beam flanges at points of maximum bending stress. Deflectometers (Figure 8) were clamped to the bottom flange of the beam and anchored to the ground to record deflection at these same points. The strain gages were located on the bottom of both the top and bottom beam flanges and generally 1-1/2 inches in from the outer edge.

For the three span continuous unit, gages were placed on each of five adjacent beams at the .44 point of the first span measured from the end bearing, at the first interior support, and at midpoint of the interior span.

For the five span unit gages were placed at midpoints of the simple spans and also on the transverse floor beams between column supports in one roadway.

Bridge Instrumentation

Instrumentation for the test program was based on the standard Wheatstone Bridge Theory. Each gage forms one arm of a Wheatstone Bridge. A change in electrical resistance in the active arm of the Wheatstone Bridge unit produces a measurable unbalance in the bridge circuit. This change is directly proportional to the strain produced within the elastic limits of any material. The change is small but may be amplified and fed into a light beam galvanometer for projection onto light sensitive paper for development and use for permanent records. (Figure 9) Forty-eighty individual gage points could be recorded simultaneously and continuously on the equipment available. Generally, this test set-up used 45 gage points with three points in reserve.

Test Vehicle

The test vehicle was loaded with aggregate to approximate H20-S16 axle loadings. Front axle load was 10,000 lbs., drive axle was 30,000 lbs., and trailer axle load was 30,000 lbs. This fell short of the full H20-S16 loading, but was considered to be adequate. Strain measurement of some regular truck traffic, picked at random, showed the resultant stresses under traffic to be below those caused by the test truck. Axle spacing between the front and drive axle was 13.0', while axle spacing between the drive and trailer axle was 20.4'. Spacing between front wheels was 6.6', with 6.25' between drive wheels and 6.03' between trailer wheels. Tire pressure was 80 psi.

II. Analysis of Test Results

Data Processing

Due to anticipated variables between duplicate test runs an attempt was made to choose the run that most nearly fulfilled the test requirements. Irregularities of lateral truck position, variation in speed, and sidesway of the truck due to transverse variation of the vehicle along the planned test path, were weighed collectively in the process of choosing the test run used for analysis.

Tabulated data shows a comparison between the design stresses and deflections, and the measured stresses and deflections of the combined effect of a truck load in each of the four lanes. However, rather than having the truck face the same direction in all lanes, as is done in regular design calculations, the truck faced in the opposite direction in two lanes, the same condition as exists in normal traffic movement. Maximum peak values recorded in the spans for strain and deflection will be used as a basis to compare with the design calculations.

The structure was designed as a non-composite unit but due to the partial composite action caused by the dead load friction between the slab and stringers the recorded deflections are smaller than the calculated deflection. This effect of composite action shows up in that the upper flange stresses are numerically lower than the bottom flange stresses in a typical positive moment area.

III. TEST RESULTS

THREE SPAN CONTINUOUS UNIT: Moments and stresses calculated from measurements of strain and deflections are tabulated for the .44, 1.0, and 1.5 points of the unit. Moments induced during the 30 mph dynamic runs are compared to the H20-44 design moments and the calculated moments based on H20-S16 test loads. Maximum stress includes dead load stress of the unit. Deflections noted are for test truck live load.

(1) Pt.	(2) Design Moments H20-44 (LL+I) KIP.FT.	(3) Measured Moments H20-S16 (LL+I) KIP.FT.	(4) Calculated Moments H20-S16 (LL+I) KIP.FT.	(5) Total Moments Meas(LL+I)+DL KIP.FT.	(6) Max.Stress (based on Col.5) (Incl.DL) psi	(7) Deflection Inches
0.44	274	271	299	348	14,040	0.38"
1.00	264	265	293	415	17,914	-----
1.50	278	279	309	360	15,540	0.70"

FIVE SPAN UNIT: Measurements of stress and deflection are tabulated for midpoints of the simple spans. Measurements made during the 30 mph dynamic runs are compared to the H20-44 design moments and calculated moments based on the actual H20-S16 test truck loading. Maximum beam stress includes DL stress of the structure. Deflections noted are for test truck live load.

*Span Length	Design Moments (LL+I) Kip.Ft. H20-44	Measured Moments (LL+I) Kip.Ft. H20-S16	Calculated Moments (LL+I) Kip.Ft. H20-S16	Total Moments Meas(LL+I)+DL Kip.Ft.	Maximum Stress (Incl.DL) psi	Deflection Inches
40.40'	328	340.8	413.7	483.8	18,800	0.27"
34.54'	271.6	301.8	316.1	405.1	15,600	0.21"
37.17'	309.4	313.1	364.9	442.2	16,400	0.18"

*Measurements made along centerline of roadway.

IV. Discussion and Conclusions

A study of the tabulated stresses and deflections indicates that the units are generally being worked within the allowable limits of the design specifications. While these figures give a very general view of the working unit, the recordings of the test runs show a number of other bridge characteristics normally not considered in design work. Of particular interest in this investigation was the possibility of resonant vibration in the structure.

The combination of the natural frequency of the structure and the frequency of the mass-spring system of the test truck acting in the same phase produce the phenomenon of resonance. This resonance could be of such magnitude of high vibration as to be a direct and major factor in the deterioration of the bridge deck, particularly in a structure which has a low rate of energy dissipation. However, a study of the test recordings taken shows no evidence of resonance occuring in this test. As can be seen from the typical test recordings (Figure 9), the structure "settles down" or stops vibrating soon after the test truck leaves the structure. It should be pointed out that the test recordings were mainly confined to the superstructure and only in the testing of the five span unit was the substructure instrumented. In the case of the five span unit the superstructure has a high rate of energy dissipation and therefore, little vibration after the test truck left the unit. However, a low rate of energy dissipation was evident in the substructure allowing the unit superstructure as a whole to move in an orbital pattern for some time after the truck left the span.

Study of the test recordings shows some evidence of isolated instances when the vibrations could have approached resonance. This situation could be attributed to a number of things other than pure resonance. It is possible that peaks of amplitude of vibration of the structure and the mass-spring system for an instant were close to being in phase. This is a problem in probabilities as to the chance that these peaks may happen to coincide in any given length of span. Another possibility of this variance in vibration amplitudes may come from a "beating" action between continuous spans which might influence the maximum displacement of the oscilligram trace on the test recording. This influence could possibly coincide directly at thepoint of maximum displacement thereby, increasing the amount of measured stresses and deflections beyond the allowable of design.

Evidence of movement between the slab and the steel beams was shown in two ways. Vertical separations of .041" maximum were recorded. Other evidence of slab and beam separation and perhaps sliding was noted in that as the truck first came upon the test span the neutral axis of the section was low, indicating non-composite action. Then as the truck approached the point of maximum displacement, the neutral axis began to shift upward until the friction action between the slab and beam was overcome. The neutral axis then shifted downward again only to repeatedly build up and fall off as composite action due to friction was initiated.

As little interaction or continuity between the beams and slab was evident, it was impossible to calculate actual stresses being obtained in the concrete. The slab itself is heavily cracked and attachment of strain gages to the concrete showed strains only where the wheel of the test truck was over the gage point or very near to it. While the slab seemed to distribute the load to some extent, it was evident that no stress reversals were present as would be expected in a composite unit.

The results reported herein do not indicate that excessive stresses, deflections, or vibrations were the major factors in the initial distress of the bridge deck. But it is possible that the small amount of vibration that is present could be a contributing factor to additional slab distress.

ACKNOWLEDGEMENTS

Appreciation is hereby expressed to the Bureau of Public Roads for their excellent technical advice and assistance and for the use of their measuring and recording instruments. Appreciation is also expressed to the administrative, shop, and field personnel of District 24, Texas Highway Department who aided materially in the performance of these tests.

FIGURES

FIGURE 1 P & SF STRUCTURE

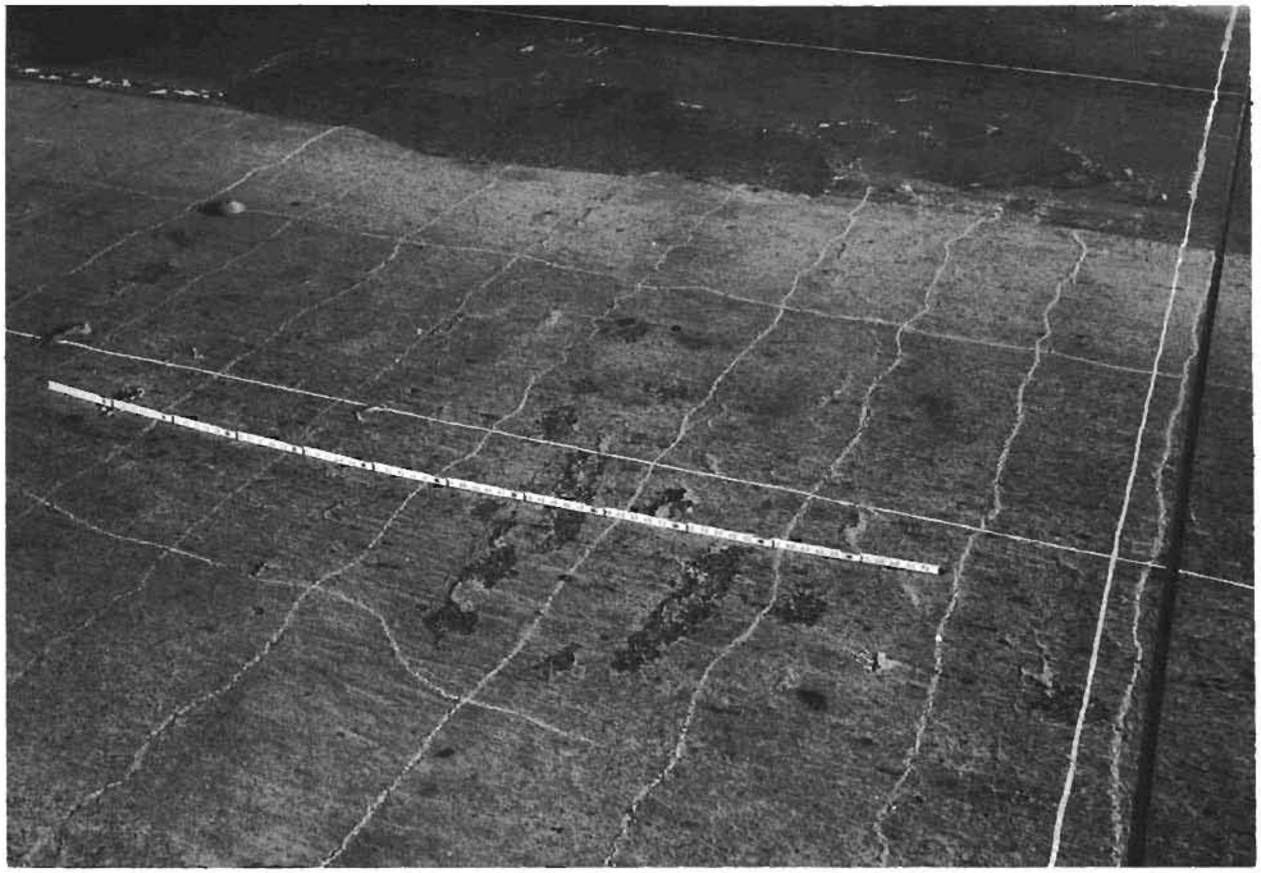

FIGURE 2 LONGITUDINAL AND TRANSVERSE SLAB CRACKING

FIGURE 3 CRACKING AND SPALLING OF SLAB

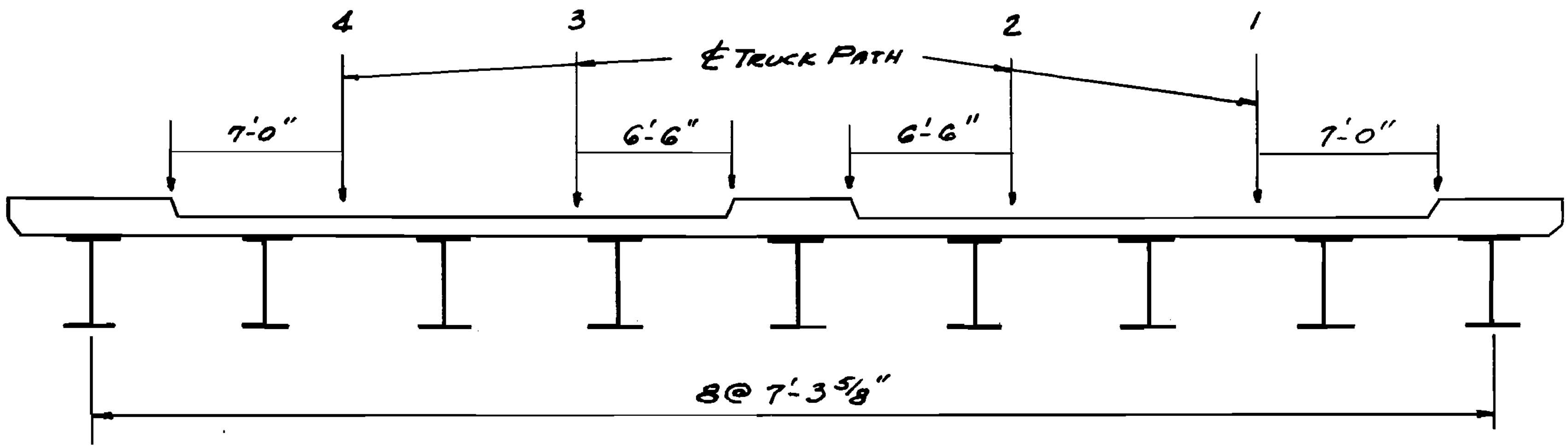

Figure 4 Truck Position During Test Runs

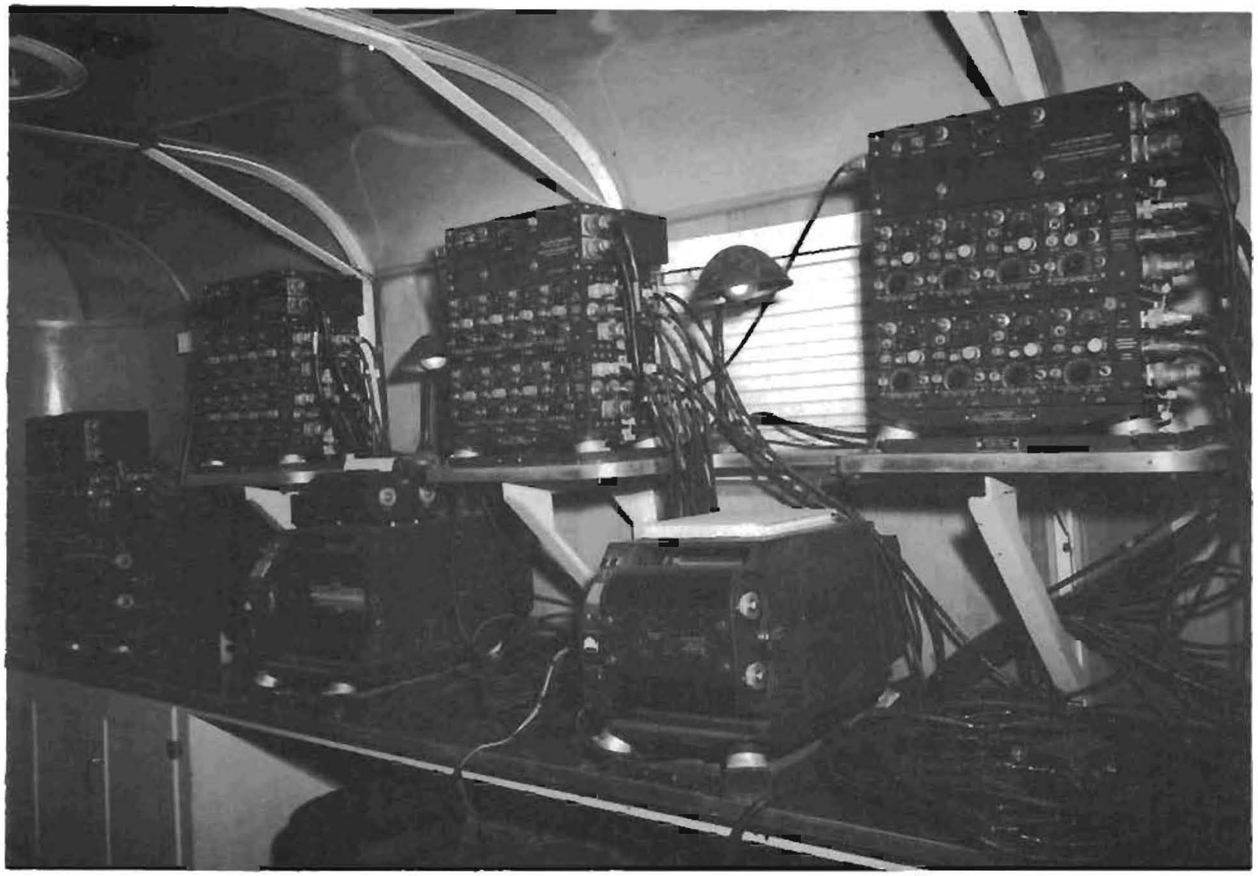

FIGURE 5 INTERIOR OF INSTRUMENT TRAILER

FIGURE 6 DYNAMIC TEST RUN

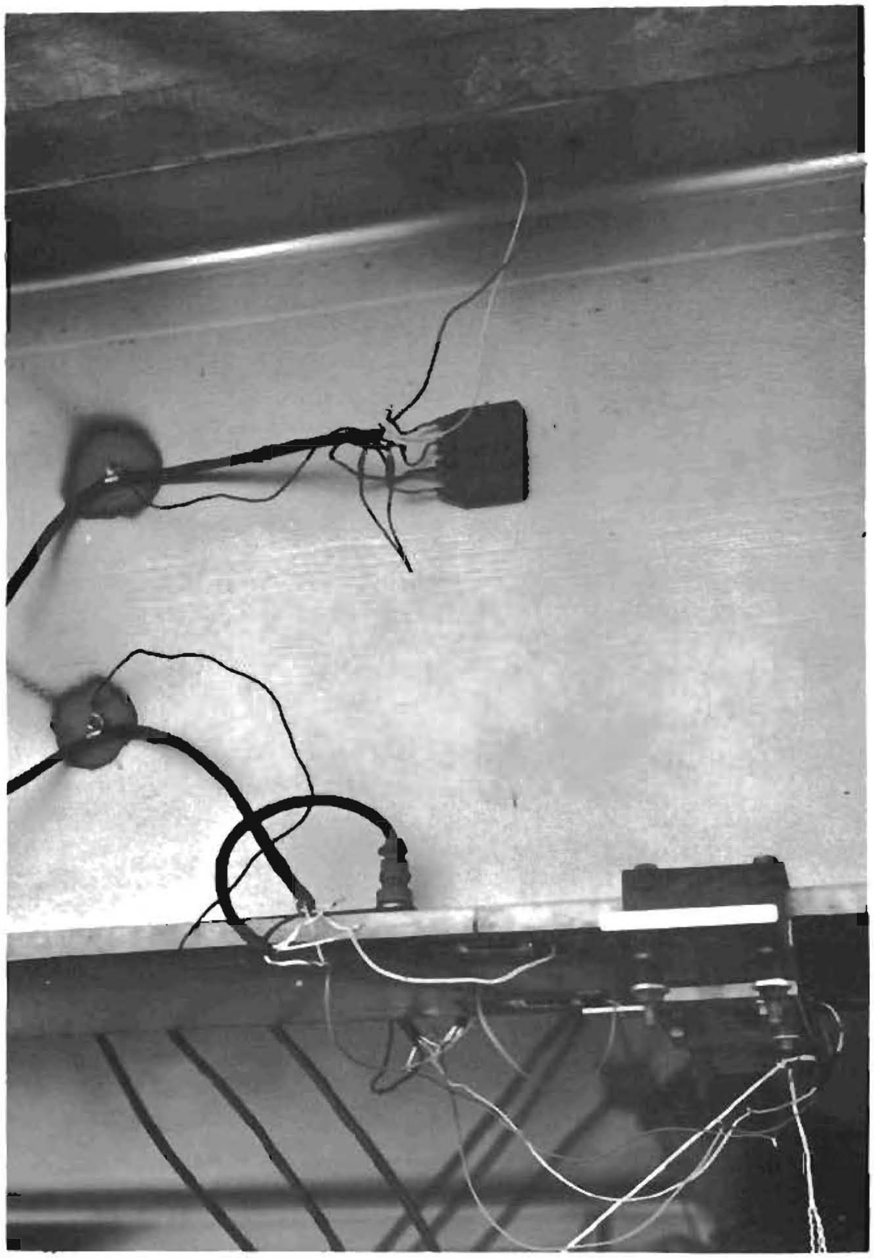

FIGURE 7 SR-4 STRAIN GAGES ATTACHED TO BEAM

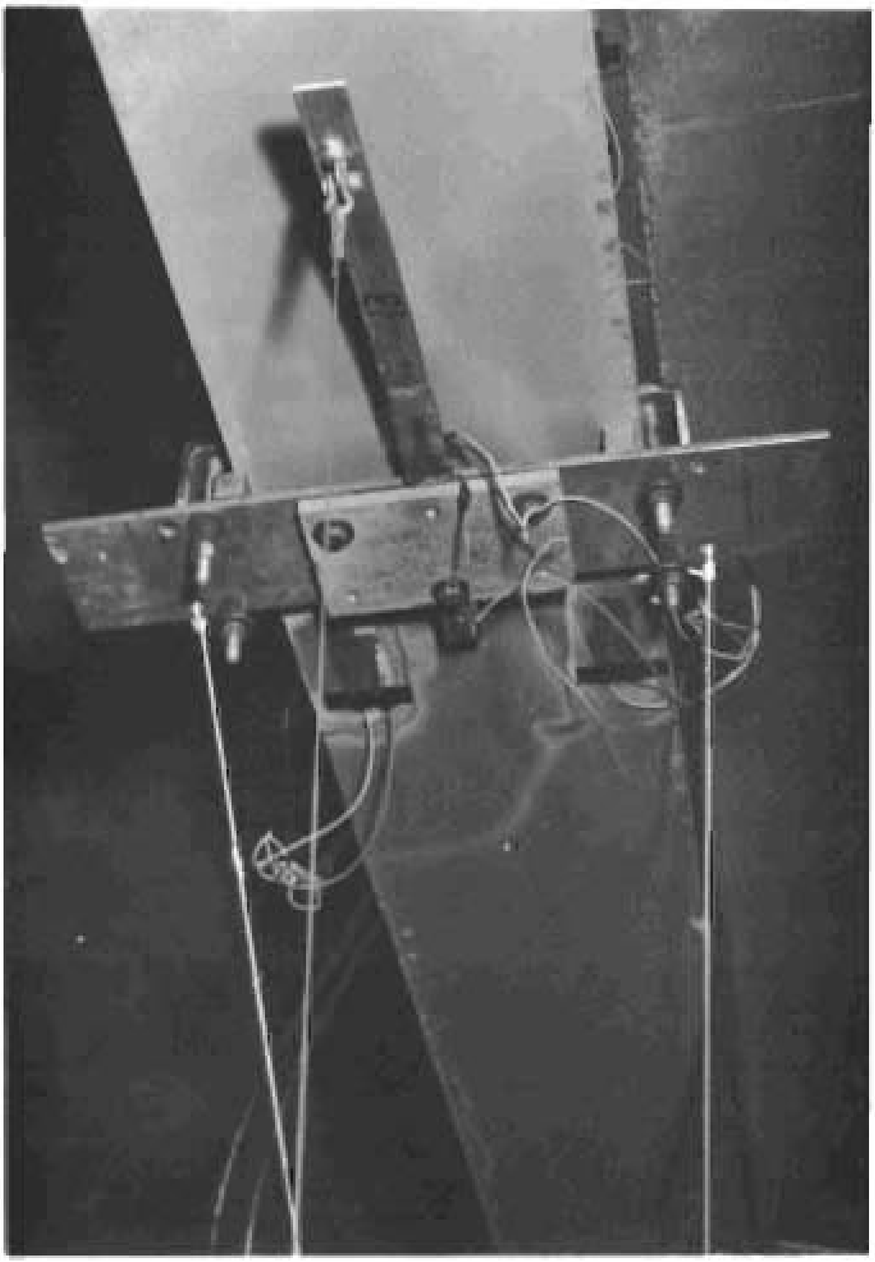

FIGURE 8 DEFLECTOMETER

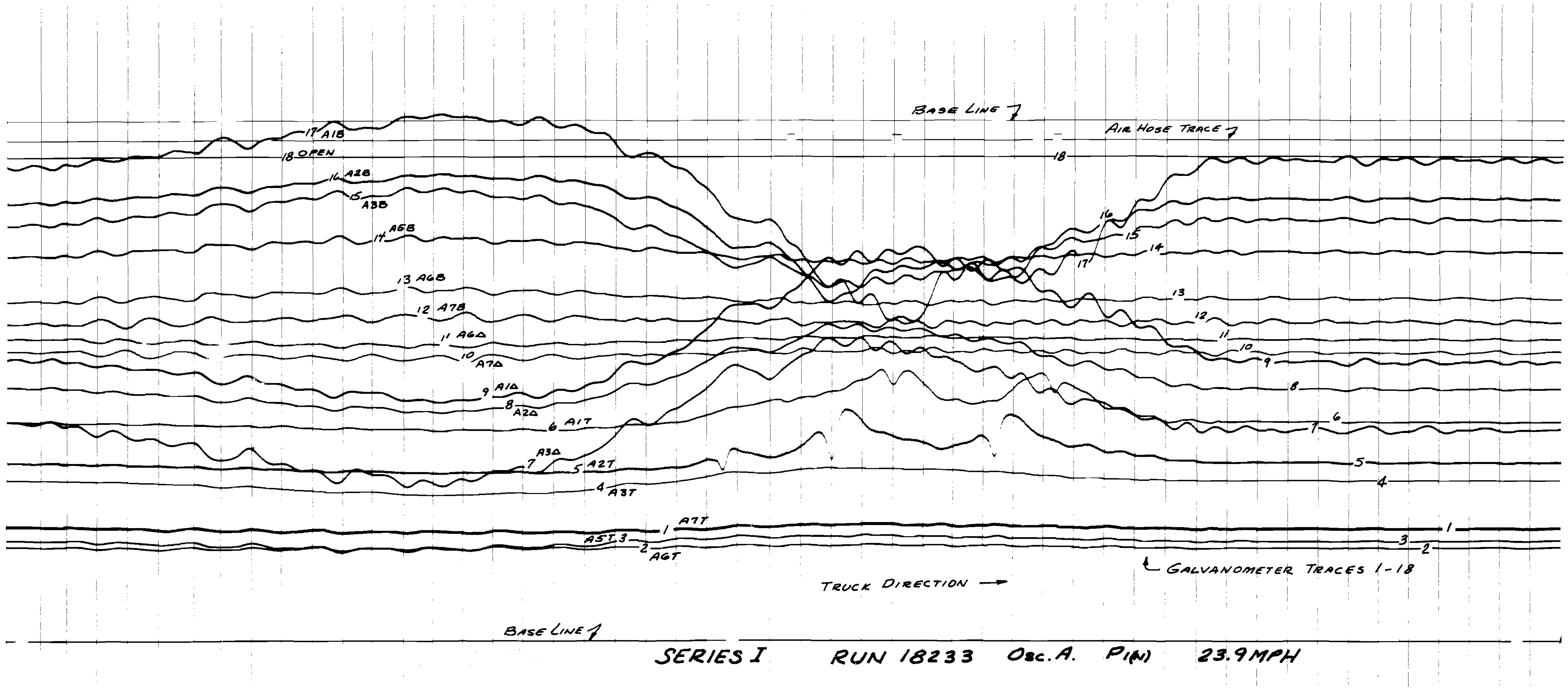

FIGURE 9 TYPICAL TRACE RECORDING OF TEST RUN