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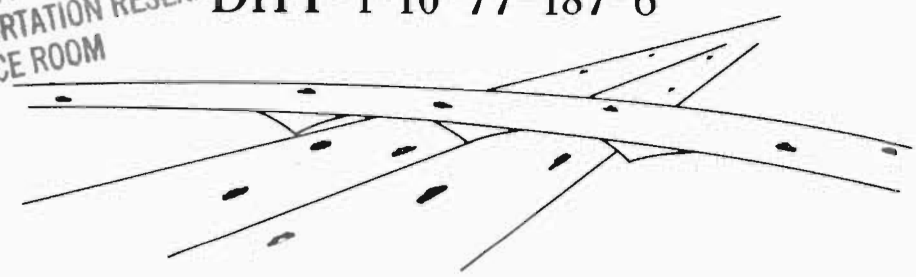

DEPARTMENTAL RESEARCH

Report Number 187-6

A CORRELATION AND CALIBRATION OF FOUR DYNAFLECTS

[redacted]

STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION

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16. Abstract

This report describes the calibration and correlation of the four dynaflect units which obtain data used by the Department of Highways and Public Transportation. It was found that the dynaflects static weight is about 2000 pounds and the dynaflects have a dynamic weight of ± 500 pounds as specified by the fabrication. One unit measured was about 15 years old. The average repeatability of the units was 3.6 percent when expressed in terms of a coefficient of variation. A correlation exercise indicated differences in dynaflects which ranged from 17 percent above the average value of the four units to 10 percent below the average value.

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A Correlation and Calibration of Four Dynaflects

by

Kenneth D. Hankins

Research Report 187-6
Research Study 1-10-77-187

Conducted by

Transportation Planning Division
Research Section

State Department of Highways
and Public Transportation

In Cooperation with the
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Thanks and appreciation are also given to Dr. Clyde E. Lee for the loan of the force plate.

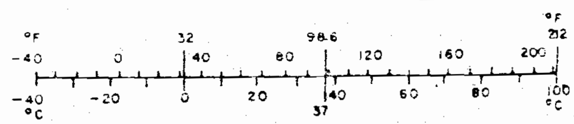
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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IMPLEMENTATION

The information reported herein may be used in the daily operation of the Dynaflect units and in judging the limits and capabilities of the units. Even though routine calibration does not seem warranted, the procedures used herein should serve as a guide for calibration and correlation.

SUMMARY

This report describes the calibration and correlation of the four Dynaflect units which obtain data used by the Department of Highways and Public Transportation. It was found that the Dynaflects static weight is about 2000 pounds and the Dynaflects have a Dynamic weight of $\pm$ 500 pounds as specified by the fabrication. One unit measured was about 15 years old. The average repeatability of the units was 3.6 percent when expressed in terms of a coefficient of variation. A correlation exercise indicated differences in Dynaflects which ranged from 17 percent above the average value of the four units to 10 percent below the average value.

A CORRELATION AND CALIBRATION
OF FOUR DYNAFLECTS

I. Background

There are at present four Dynaflect units operating in Texas which have collected data for Departmental use. The complete history of each unit is not fully known. However, the first unit was purchased by the Department in 1965 and has been maintained and operated by the Research Branch since that time. A second unit was purchased by the Department soon after and was originally operated by District 8 (Abilene) personnel. In about 1970, the second unit was transferred to District 19 (Atlanta). At this time, attempts were made to make the deflection measuring equipment available to all districts in the state on a request basis. The second (District 19) unit began covering the northern part of the state and the first (D-10R, Old) unit was made available to the southern part of the state. A third unit was purchased by Texas Transportation Institute (TTI). (1) This unit was purchased in the 1960's and was originally used by Scrivner and Moore in adapting AASHO Road Test information to Texas conditions. Since that time the unit has been used for research and pavement design purposes not only in Texas but throughout the United States. The fourth unit (D-10R, New) was purchased in 1980 as a replacement for the first unit. This unit contains the latest automated features available from the manufacturer. One of the purposes for this purchase was to improve the speed of data collection. We felt that experience with this equiment could lead to providing inventory data for a Pavement Evaluation System and input to a Pavement Management System. The present plans for the data for this system include skid resistance, roughness and visual evaluation data but not deflection data. Considerable maintenance and upkeep had been performed on the first unit in the recent past (particularly broken tongues and geophone lift assemblies). Since the unit was approaching an age of 15 years, replacement was believed to be necessary. After performing the study reported herein, it would appear the D-10R, Old unit is still capable of obtaining good data. Strengthening, reconditioning, and continued use should be considered.

II. Object

The purpose of the work reported herein was to calibrate the four Dynaflect units working in Texas, to observe deficiencies, and to obtain correlations between the units.

III. The Calibration and Correlation

The four Dynaflects met at the Texas A & M University Research Annex on April 24, 1980 and the following work was performed:

1. A check of the calibrator for each unit.
2. A check of the results of varying the frequency of the calibrator and also the flywheels applying the dynamic load.
3. Linearity check of geophones using a shop-built large calibrator.
4. Check of signal processing and readout instrumentation.
5. Static and dynamic weights.
6. Correlation of units.

IV. The Calibrator Check-Out

Normally, the first action of the Dynaflect crew on reaching the job site will be to calibrate the unit. This is accomplished using a small calibrator furnished with the unit by the manufacturer. The calibrator consists of a cantilever arm pinned at one end and oscillated (raised and lowered) at the free or opposite end by a small eccentric cam. The cam is driven by a 12-VDC motor which receives power from the battery of the tow vehicle. The geophones are plugged into the Dynaflect in the normal manner but placed into a tray attached to the cantilevered arm. The cam oscillates the cantilevered arm at 8 Hertz. The frequency of oscillation can be adjusted from the control cabinet, which is available to the recorder and driver (generally placed on the front seat). The cam forces the geophones to be raised and lowered 5 milli-inches (MI). A given geophone will produce a given voltage (signal) when oscillated at 5 MI. However, it is possible that different geophones will produce different signals when oscillated at 5 MI. Also, a geophone may change output with time. Therefore, the control cabinet allows the operator to calibrate each of the five geophone positions. A check is made to determine if the calibrator is producing 5 MI and this amplitude is adjusted as necessary. Then each of the five geophones are checked and the readout adjusted or calibrated to read 5 MI.

Our check out of the calibrator of each unit was as follows:

1. A strobe light was used to determine if the calibration arm was oscillating at 8 Hertz. Adjustments were made until 8 Hertz was achieved and the readout at the control cabinet was adjusted to indicate 8 Hertz. A small scribed disk which is attached to the cam was used in this process. The disk is available from the manufacturer. Also available as a part of the equipment is a revolution counter which is attached to the motor. The counter is used as a field check of the frequency rate. Each operator was made aware of the count obtained in a given time increment.

2. The amplitude or movement of the geophone was checked and adjusted to 5 MI. This action was accomplished using a dial gauge, the body of which was mounted on a rigid base. The gauge probe was allowed to rest on a notch on the cantilevered are provided for this type of calibration by the manufacturer.

V. Frequency Variation

There will be times during data collection when the frequency will vary and remain unnoticed. As a check on the effect of an undetected change in frequency, the frequency was varied and changes in readout were noted.

Appendix A shows the data collected when the frequency was varied on the "calibrator" by changing the motor speed using the adjustment on the control cabinet. Appendix B offers similar information collected by varying the rotation speed of the "flywheels" on the Dynaflect which produce the dynamic load. Figure 1 shows a plot of both the calibrator and dynamic load (only geophone 1 is shown on the dynamic load). The vertical values on the plot are at the same scale even though the calibrator scale has been shifted with respect to the dynamic load. Note the "calibrator" output changes a large amount and generally decreases as frequency is increased. In contrast a smaller change was found as the "flywheel" frequency was varied. The Operations Manual for Dynamic Deflection Determination System produced by S.I.E., Inc., indicates the unit has a frequency compensating filter and it appears this filter does compensate for minor drift of the flywheel frequency. However, as stated repeatedly in the above mentioned manual, efforts should be made to maintain the frequency at 8 Hertz. The correct frequency is an absolute necessity during calibration.

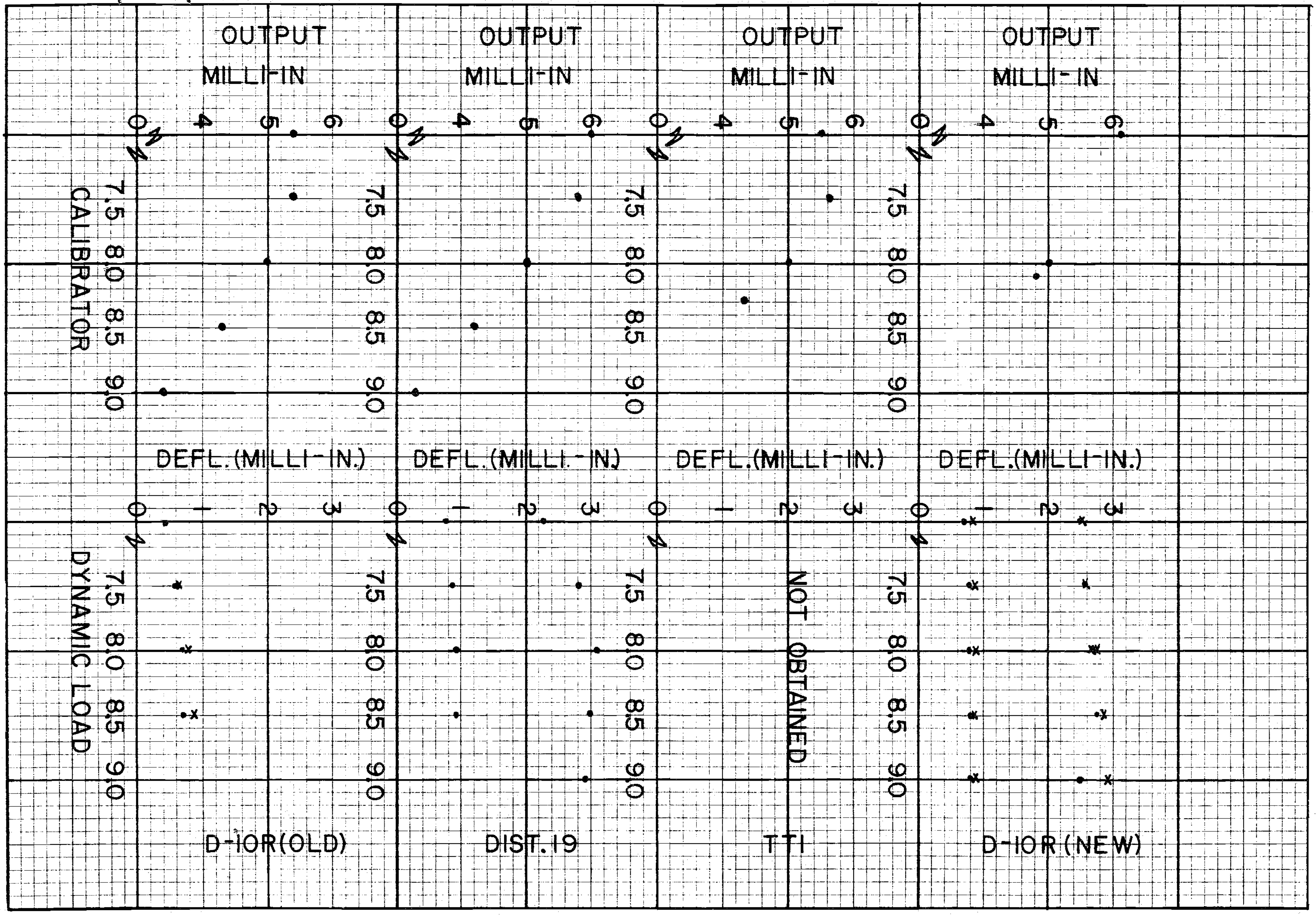


FIGURE 1 - FREQUENCY VARIATION STUDY

VI. Linearity Test of Geophones

In the recent past personnel with the Highway Design Division began to discuss the method used to calibrate the geophones with the Dynaflect. The question concerned the calibration amplitude of 5 MI. This value is very large in comparison to values normally found in data collection on pavement structures. Values found on typical pavements rarely exceed one milli-inch. Design personnel believed it would be preferable to calibrate the geophones at about the value generally found in normal operations. However, if the geophones are calibrated at 5 MI, and are linear, no problems would exist. Therefore, a larger calibrator was fabricated. The larger calibrator is similar to those previously mentioned and uses the same motor and cam. The cantilever arm was lengthened and divided into five locations of equal length. Then, when the oscillation movement of the location at the end is set at 5 MI, a movement of 4, 3, 2 and 1 MI can be expected at the other location points. A geophone placed at each of these five points can be, and was, checked for response.

This type of test was performed using 5 different geophones. The results may be found in the table in Appendix C. The upper part of the table indicates the output as obtained on the Dynaflect at the control cabinet in the front seat. The equiment was set up in the normal manner for calibration except the larger calibrator was substituted for the usual calibrator. The geophone was placed at the end location and calibrated (the potentiometer adjusted) to a 5 MI readout. Then the geophone was placed at each of the other four locations as explained above.

The lower part of the table, in Appendix C, shows the output of each geophone as obtained using an oscilloscope to measure the output. The setup was similar to that described above except the geophone output was monitored with the oscilloscope rather than the readout at the control cabinet. A relatively large scale factor was used on the oscilloscope so that the total wave could be captured. As a consequence, readout sensitivity suffered and the response could not be accurately viewed. Therefore, some variation will be noted. Figure 2 indicates a plot of the results. After testing the five geophones it was obvious the geophone response is linear. The geophones could be calibrated at 1, 2, 3, 4 or 5 MI and the same results achieved.

VII. Instrumentation Tests

The newest Dynaflect is equipped with a digital display with direct readout but the older Dynaflect units were equipped with a meter-type readout and a selectable scale. There were six different scales for selection - a 0.01, 0.03, 0.10, 0.30, 1.00 and 3.00. The meter readout ranged from 0 to 10, but a wide range of values could be obtained by changing scales. The scale factors were used as multipliers. Therefore, to obtain a value, the meter was observed (say a 3.5 was read) and multiplied by the scale factor (say 0.03). The resulting value (3.5 x 0.03 = 0.105) was the deflection in milli-inches.

It is possible that meters are non-linear at each end. For example, with a geophone setting in one spot, an 8.5 has been read on the 0.10 scale and a 2.6 has been obtained when the scale was switched to 0.30. Therefore, the 0.10 scale gave 0.85 milli-inches and the 0.30 scale gave 0.78 milli-inches. Of course, readout or recorder error accounts for a large part of this difference. But it is possible that the Dynaflect instrumentation was becoming old and mechanical parts worn, so a method was devised to check the instrumentation.

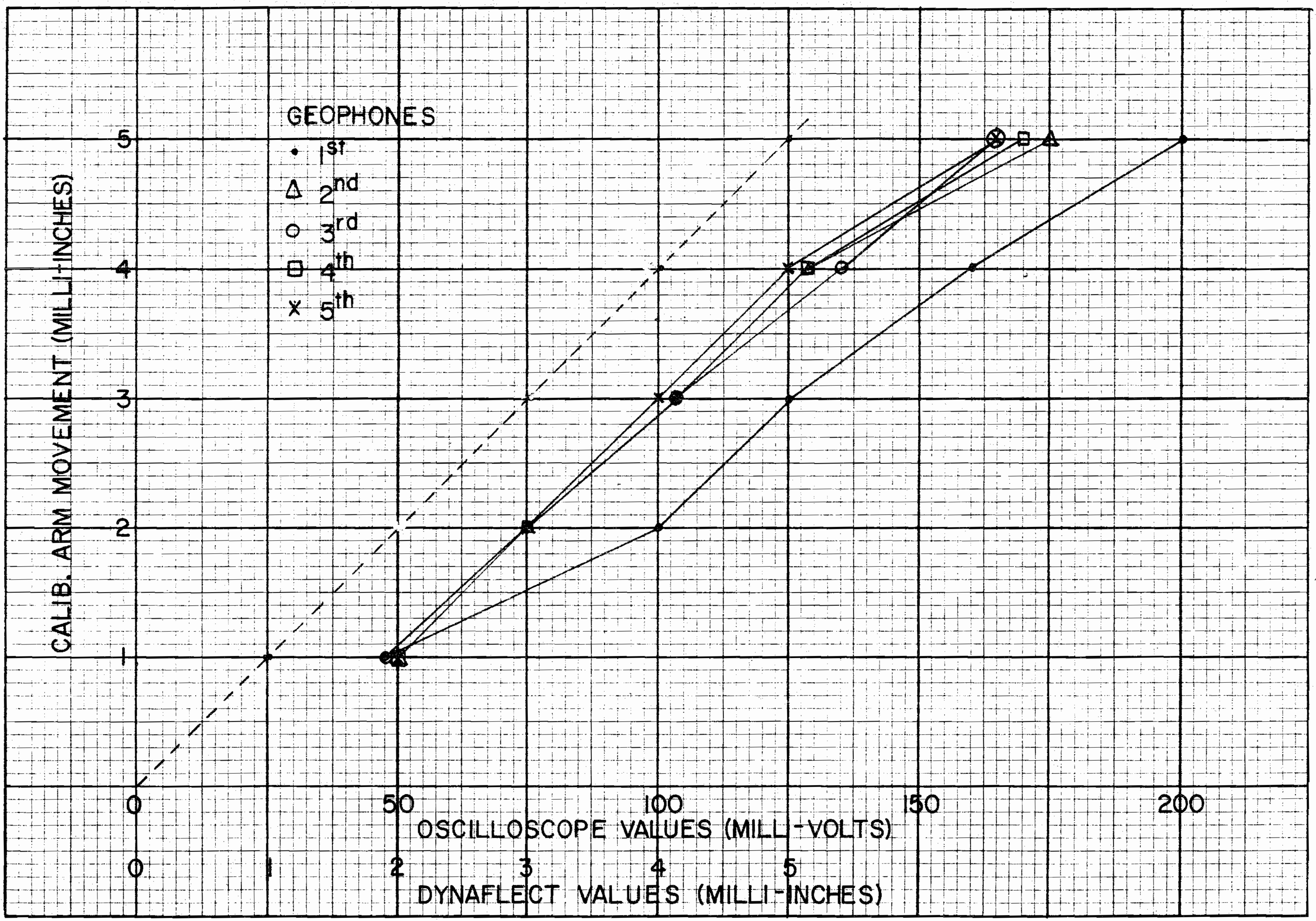


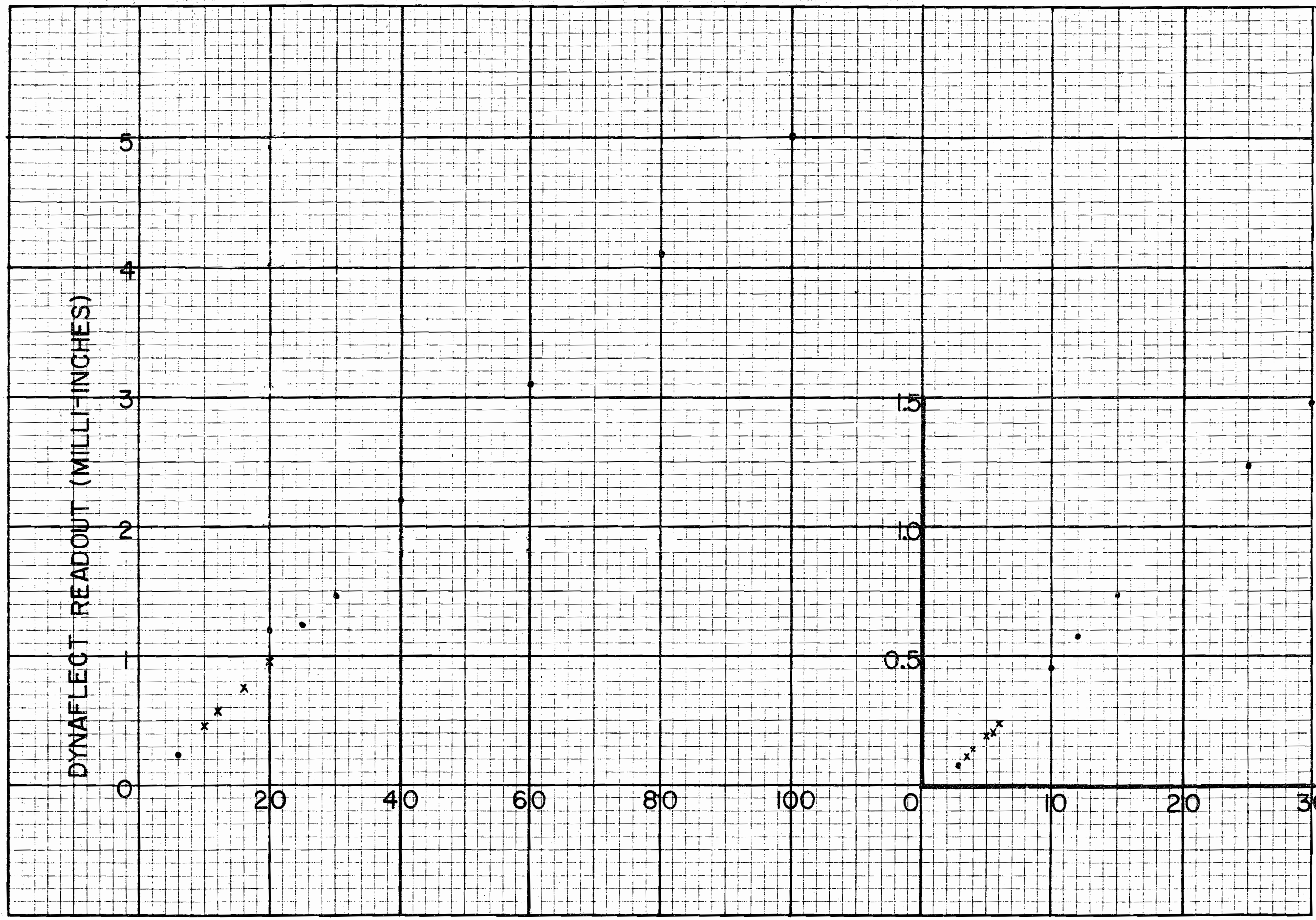
FIGURE 2- LINEARITY TESTS OF GEOPHONES

The method which was devised uses a signal generator to replace the geophone. The signal generator used was capable of generating a large variety of wave types (sine wave, square wave, etc.) at a range of selectable frequencies and amplitudes. Therefore, rather than the geophone producing a signal of varying amplitudes at 8 Hz, the signal generator was used to input to the Dynaflect instrumentation a range of signals (sine waves) of known amplitude at a constant 8 Hz. The readout was obtained from the Dynaflect meter and multiplier for each input signal. The results of the tests are shown in Appendix D and Figures 3 - 6. There was some minor variation noted as scales were changed particularly in the overlap zone. However, the linearity of data and instrumentation output appears to very good. It is still recommended that the scales be changed when meter values are less than 2.5 or greater than 7.5.

VIII. Static and Dynamic Weights

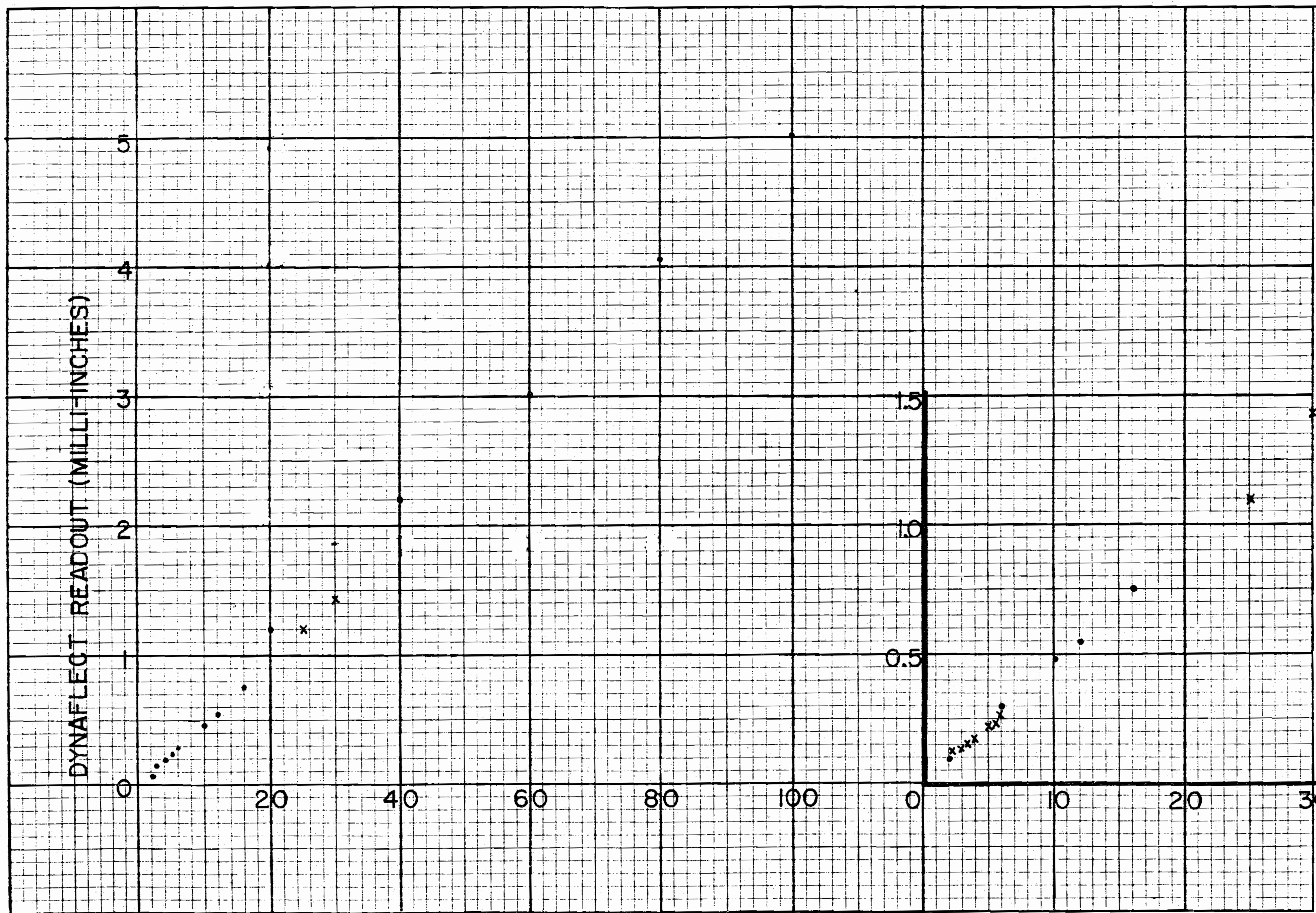
Measurements of static and dynamic weight were obtained with the use of a force plate and strip chart recorder. Pictures of the force plate and recorder are shown in Figures 7 and 8. The force plate was borrowed from Dr. Clyde E. Lee who is with the CFTR at the University of Texas. The load cells and place components are so arranged that the correct magnitude of a load can be recorded regardless of the position of that load on the plate. The force plate was the original plate constructed by Dr. Lee during his studies into measuring dynamic loads of highway-type vehicles. The force plate and recorder were calibrated prior to use by Mr. Richard Zimmer with TTI. Mr. Zimmer used a calibrated load cell with a shop-fabricated sling.

The results of this work are shown in Table I. It should be noted that the strip chart recorder was used to measure both the static and dynamic loads



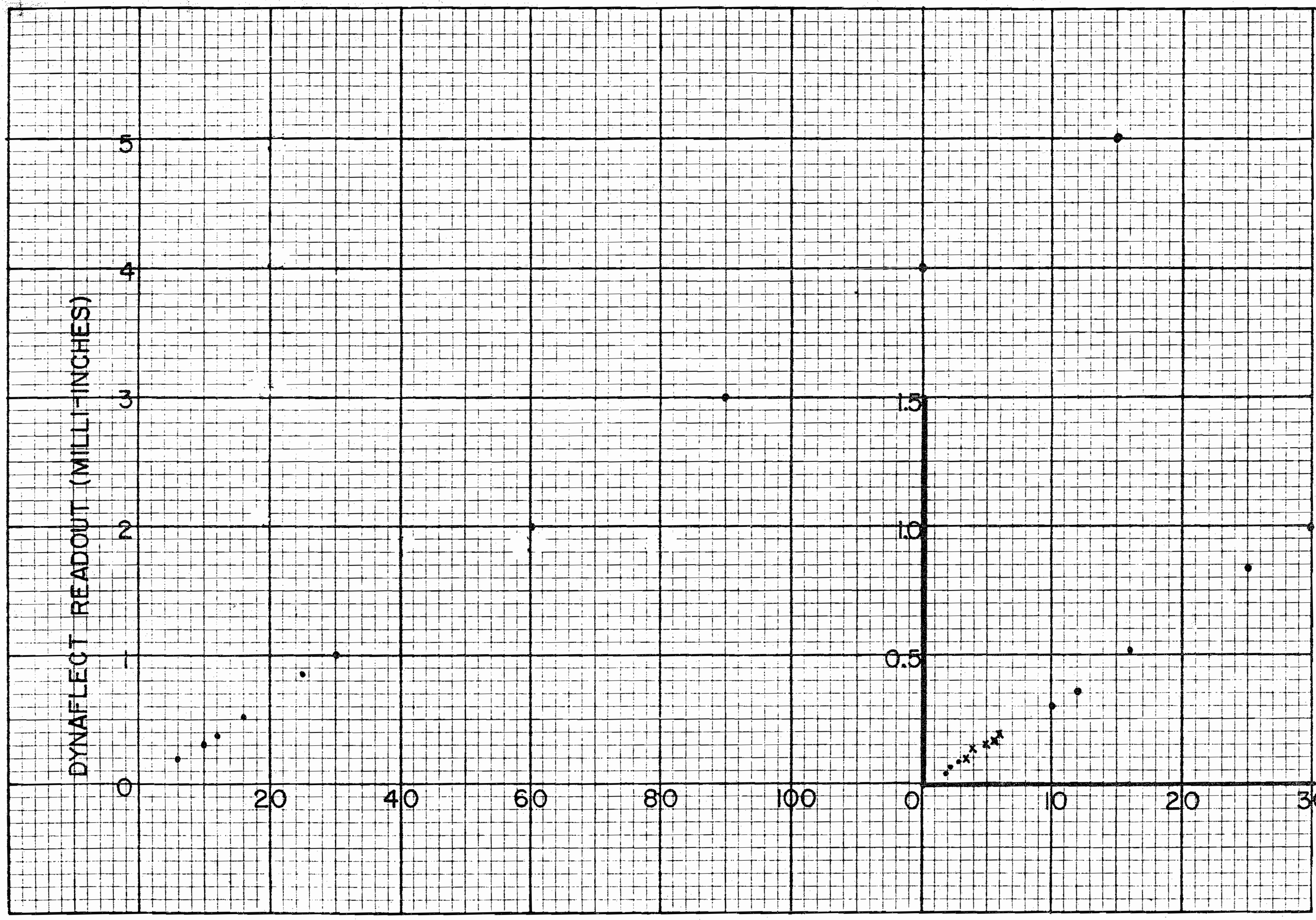
INPUT AMPLITUDE SIGNAL AT 8 HZ. (MILLI-VOLTS)

FIGURE 3 - INSTRUMENTATION TESTS OF D-IOR, OLD UNIT



INPUT AMPLITUDE SIGNAL AT 8 HZ. (MILLI-VOLTS)

FIGURE 4 - INSTRUMENTATION TESTS OF DISTRICT 19 UNIT



INPUT AMPLITUDE SIGNAL AT 8 HZ. (MILLI-VOLTS)

FIGURE 5 - INSTRUMENTATION TESTS OF TTI UNIT

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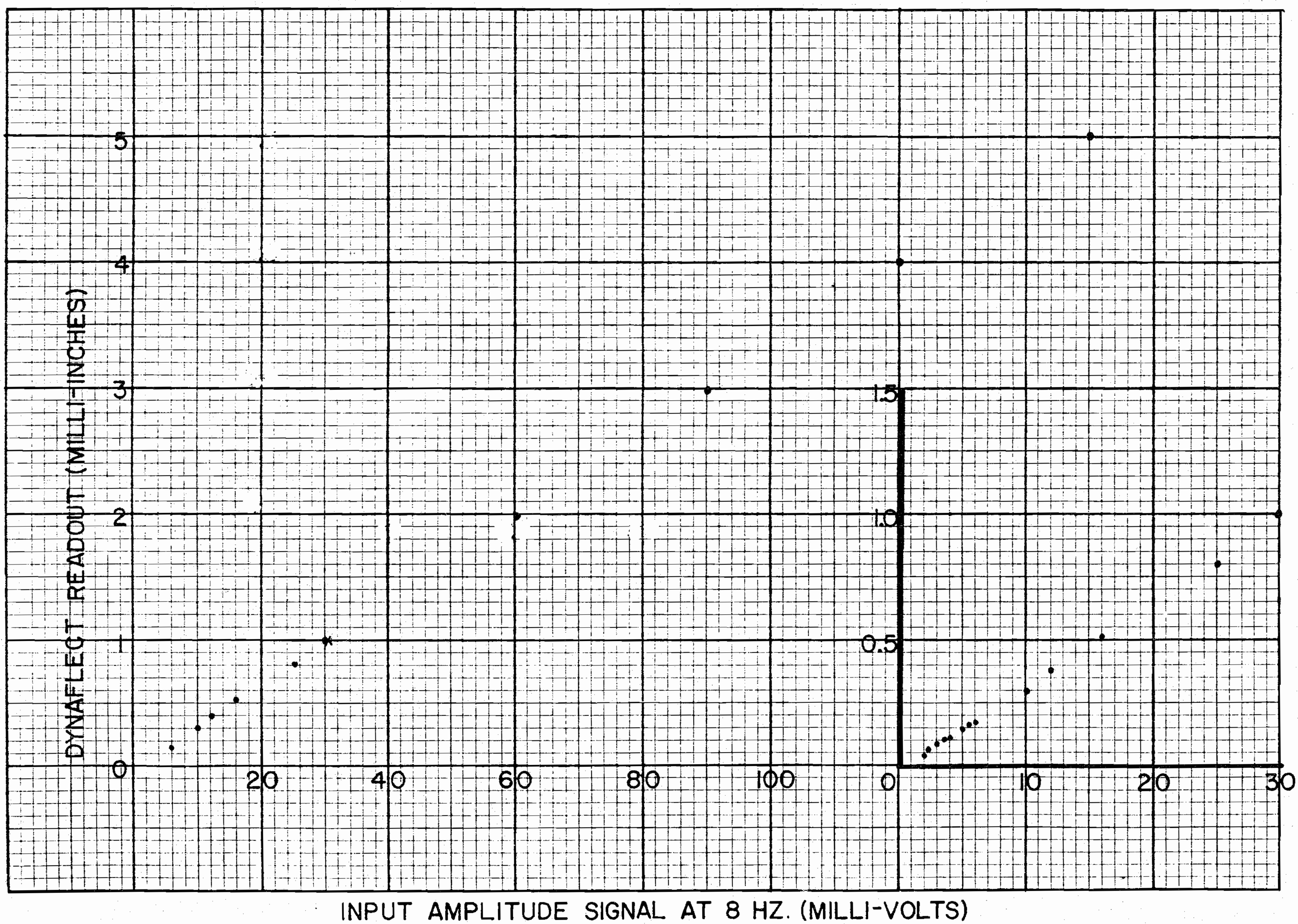


FIGURE 6 - INSTRUMENTATION TESTS OF D-10R (NEW UNIT)

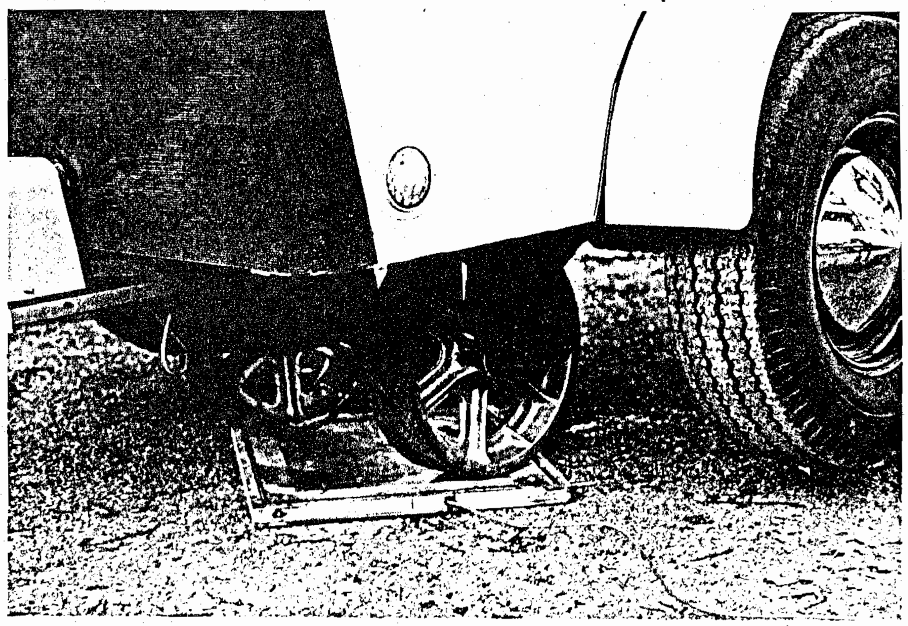


Figure 7 - Dynaflect on the Force Plate

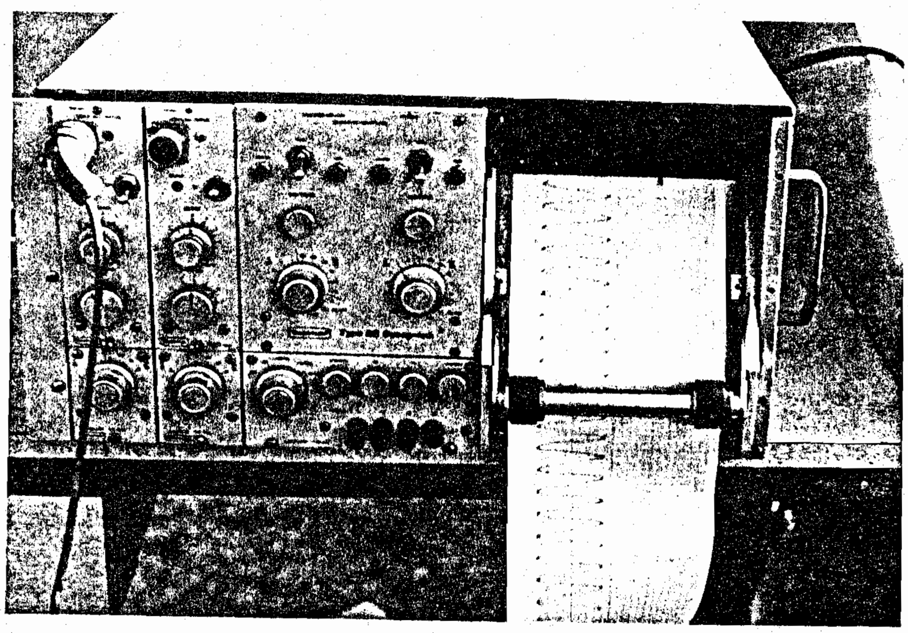


Figure 8 - Recording Static and Dynamic Weight

Table I

Weights of Four Dynaflects

Unit	Static Force	Dynamic Force
District 19	2000	± 505
TTI	2030	± 530
D-10, Old	2080	± 500
D-10, New	2090	± 500

and the load was exerted through the load wheels (load wheels were down). The smallest chart increment was one mm and the scale selected was one mm = 40 pounds. The dynamic load with time appeared as a sine wave on the chart paper and it was possible to check the frequency of 8 Hz. Note also that both load wheels were on the plate. Tests were not made with only one wheel on at a time. The dynamic load shown can be added to the static load. Therefore, the load ranged from about 1500 pounds to 2500 pounds. The Operators Manual for the Dynaflect Dynamic Deflection Determination System produced by S.I.E., Inc. indicates the static trailer weight should be 2000 pounds and the dynamic weight to vary sinusoidally from 2500 to 1500 pounds at 8 Hz. Again, the scale sensitivity is one mm = 40 pounds. Loads varying from the 40-pound increments must be estimated. Therefore, it would appear that despite the years of service, maintenance and repair, the units have maintained reasonably good weights. Both the D-10, Old and D-10, New units have excessive static loads. We were surprised that the new unit was overweight by about 4½ percent since the unit had only been in service a few months. The static and dynamic loads on the TTI unit may be excessive but we cannot be certain because of the inaccuracies and sensitivity of measurement.

IX. Correlation of Units

As a final activity a correlation exercise was developed. Six test sections with two spots in each section were located. The test sections were selected to have subgrades of varying strength and pavement structures of varying strength. One Portland Cement concrete section was included. Each of the sections was established at the Texas A & M University Research Annex where traffic control was not necessary since little or no traffic was expected. Three of the sites were on specially prepared test sections documented by Serivner & Moore in Research Report 32-8. (2) Mr. Jim Stocker and Dr. Bob Lytton assisted in making the test sites available. Their aid is appreciated.

Information concerning the test sections are:

1. Parking lot in front of the Biochemical Engineering Building. Pavement structure unknown but assumed to be a chip seal on 4 to 6 inches of flexible base. Subgrade is a silty clay.

2. 7th Street
   Pavement structure unknown but assumed to be a chip seal on 6 inches of flexible base. Subgrade is a silty clay.

3. Specially prepared test site documented in Research Report 32-8, Site #10.
   Pavement structure is one inch of asphaltic concrete on 12 inches of crushed limestone base on four inches of crushed limestone subbase.

4. Specially prepared test site documented in Research Report 32-8, Site #16.
   Pavement structure is five inches of asphaltic concrete on 12 inches of cement-treated subbase.

5. Specially prepared test site documented in Research Report 32-8, Site #3.

   Pavement structure is one inch of asphaltic concrete on four inches of cement-treated base on 12 inches of crushed limestone subbase.

6. A portion of a Portland Cement concrete slab originally used as a taxiway for aircraft. The airbase was constructed during World War II. The slab was about 20 feet square and uncracked. The two spots were selected on the interior portion of the surface. The pavement structure is eight inches of Portland Cement concrete. Subgrade is silty clay.

The spots were marked with a paint spot about one inch in diameter. Attempts were made to straddle the selected spot with the load wheels and set the #1 geophone (between the load wheels) exactly over the center of the spot. Of course it is not possible, in repeat tests, to position the trailer so that the geophone is exactly centered, especially if time is a factor in testing. The personnel involved then decided that for repeat tests, the #1 geophone should be positioned such that the spot must be within the diameter of the tripod stand of the geophone. This would mean the #1 geophone was positioned within about six inches of the spot on repeat tests. Each Dynaflect had a two-man crew and the recorder helped the driver position the trailer. After several repeat tests we noted the driver and recorder were able to position the #1 geophone very close over the spot. No specific markings were applied for the positioning of the remaining geophones, rather the driver oriented the tow vehicle and trailer at a selected reference point in the distance. Again later observations indicated the remaining four geophones were positioned very close to the same locations of previous tests.

Therfore, the correlation was performed using the following factorial items:

Four Dynaflects.

Six test sections.

Two spots in each test section.

Seven repeat tests at each spot in each section with each Dynaflect.

Some 336 sets of values were obtained. The information desired was:

1. The repeatability of the equipment on a given day.

2. The variation in values on the same section when measurements were obtained only a few feet apart.

3. The relationship between Dynaflects.

4. To determine if Dynaflect values can reveal a significant difference between various pavement structures.

A tabulation of the values obtained may be found in Appendix E. Note the geophones have been arbitrarily numbered consecutively from Number 1 between the load wheels through Number 5 nearest the hitch. The spots have been lettered A & B and the sections numbered in the order given above. Figure 9 indicates the general results which are reflected by Geophone #1. By observing Figure 9 it may be found that generally the variation increases in the following order:

1. Repeat tests of any one Dynaflect (smallest variance)

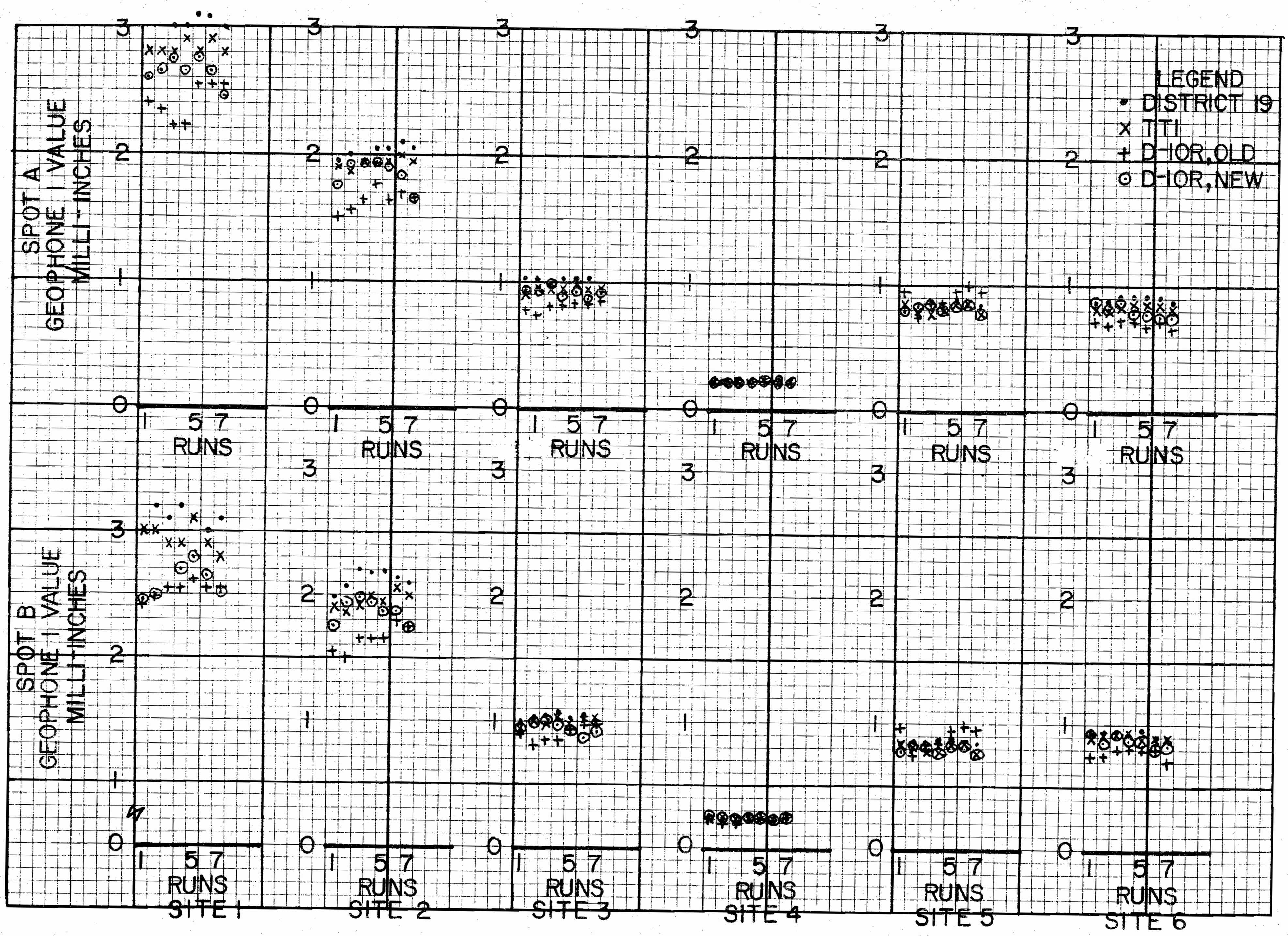


FIGURE 9 - SPOT, SECTION AND DYNAFLECT VARIATION - GEOPHONE 1

2. Different locations on a pavement within a few feet of each other (difference between spot A & B)

3. Difference between Dynaflects.

4. Difference between pavement types.

The variation in repeat tests are smaller when smaller deflections are encountered, so repeatability should be expressed in percent. The variance in repeat tests appears to be slightly larger for the D-10R, Old unit but there is not much difference in variation of the digital (new) unit as compared to the (older) meter-multiplier units. Since the variance in repeat tests is proportionately larger with larger deflection values, postulation would indicate this type of variance to be due to equipment sensitivity, that is, the inability to read the meter scale closer than 0.1. Then when applying the larger multiplier in larger values, larger variance could be expected. However, the digital unit produces values on a three-digit display - one digit to the left of the decimal and two digits to the right. This arrangement should not result in reading error or the proportional type variance, but as stated previously, this type of variance was found on all the equipment. One method of expressing proportional type variance is to use the Coefficient of Variation (COV) which is the standard deviation (a measure of variance) divided by the mean. The COV is a percent. Table II shows the repeatability of the four Dynaflect units expressed in COV terms.

Table II
Variation In Repeated Tests

(Average Coefficient of Variation)

Geophone No.	District 19	TTI	D-10R Old	D-10R New
1	2.6%	3.7%	6.6%	4.6%
2	2.6	2.3	4.8	5.2
3	2.3	2.1	5.8	4.2
4	2.4	2.3	4.0	4.6
5	2.3	2.2	3.6	4.4
Average Per Unit	2.4%	2.5%	5.0%	4.6%
Overall Average		3.6%		

The distance between spots was generally from six to ten feet. Discounting obvious structural differences such as obtaining values at the edge (or corner) versus the interior of a slab we would have believed differences in locations of even six to ten feet would reveal significant difference in deflection values. The information found in this study would indicate the error in missing the location by about ten feet when obtaining repeat tests would not be much larger than the variance in repeat tests over the same spot or position. Table III shows the variation between spots of each Dynaflect expressed in COV terms.

Table III

Variation Between Spots

(Average Coefficient of Variation-Geophone #1)

Site	District 19	TTI	D-10R Old	D-10R New
1	3.0%	3.0%	3.0%	0%
2	4	1	1	1
3	0	2	7	3
4	8	2	3	3
5	4	9	0	11
6	3	8	8	7
Average per Unit	3.7%	4.2%	3.7%	4.2%
Overall Average		4.0%		

The difference in values between sections indicates the Dynaflects are revealing the difference in qualities of pavement structures. However, there is a variance between values obtained with the Dynaflects. This variance seems to be ordered. For example, the D-10R, Old unit seems to produce values which are generally lower than the other units. The District 19 unit appears to be slightly higher. Therefore, a relationship between units is needed.

It was decided to express the relationship of each Dynaflect unit as the average of the four units. These relationships are shown in the plots of Figures 10 through 14. Note each plot concerns a different geophone position. The curves appear to be linear and the equations obtained from the plots are shown in Table IV.

The relationships between units may be found in Appendices F through I. Also, Texas uses a Pavement Stiffness Program which produces a Pavement Stiffness Coefficient. [3] [4] The correlation of the Pavement Stiffness Coefficients as produced by the four units may be found in Appendices J and K.

It would appear that the linear equation for all geophones could be "forced" through a zero intercept (all units read zero at zero deflection) which would still allow the slope to vary as shown in Table IV. In this case the D-10R, Old unit produces Geophone 1 values about 17 percent greater than the average value of the four units. Similarily the District 19 unit produces values about 10 percent less (1.00 - .90) than the average of the four units. This difference is unexplained since close attention was given to calibration as noted earlier in the report.

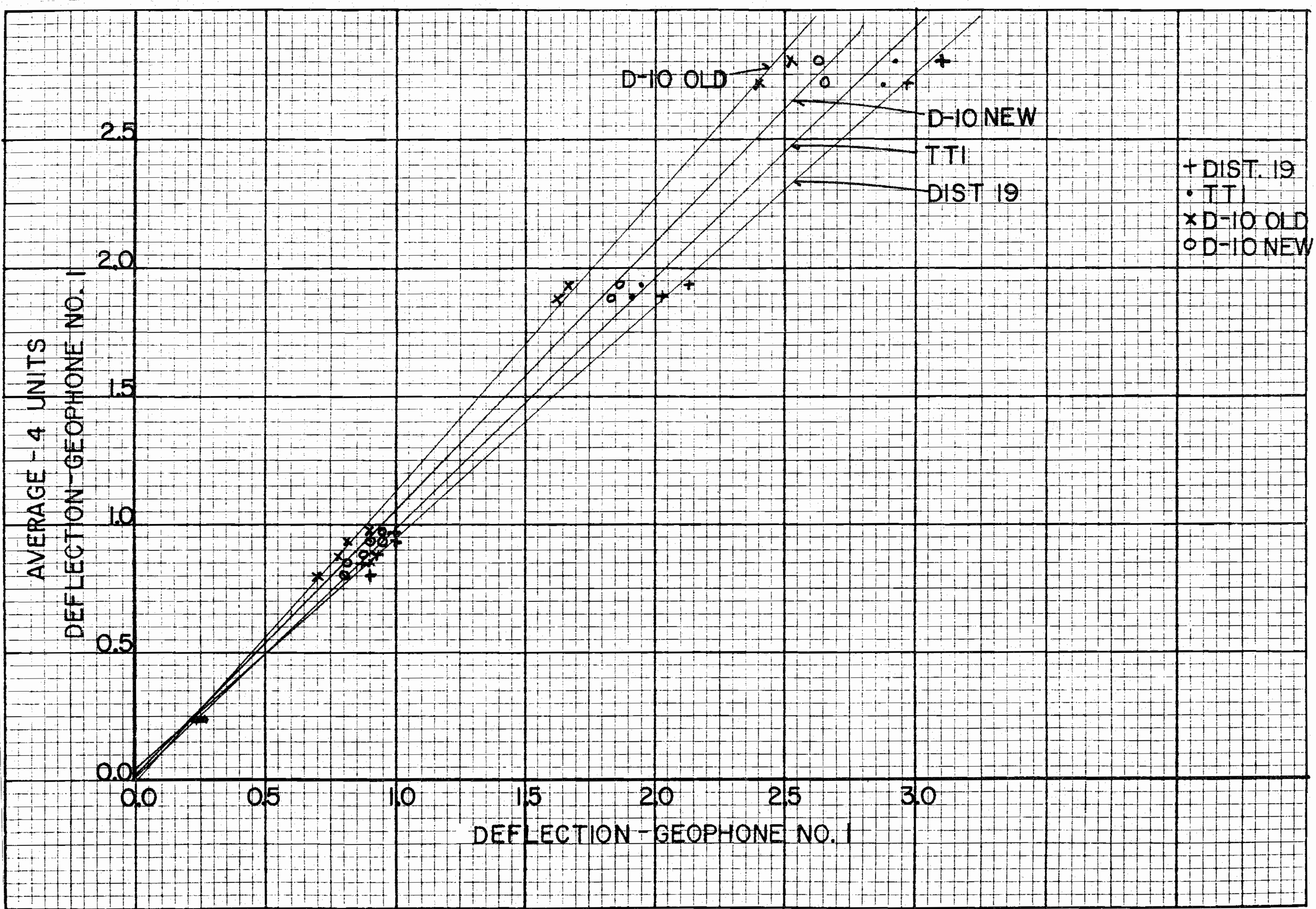


FIGURE 10 - CORRELATION OF FOUR DYNAFLECTS - GEOPHONE 1

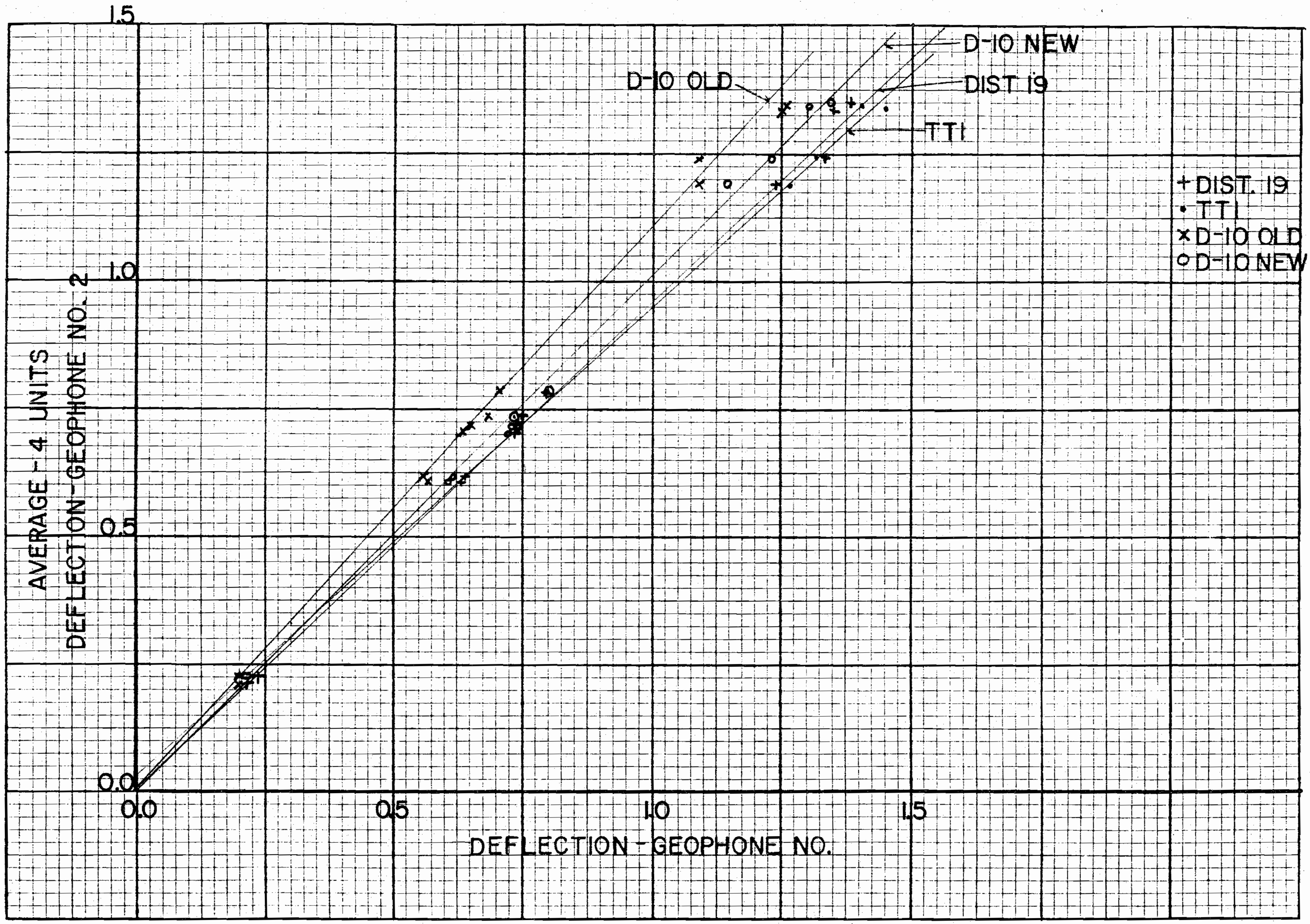


FIGURE II - CORRELATION OF FOUR DYNAFLECTS - GEOPHONE 2

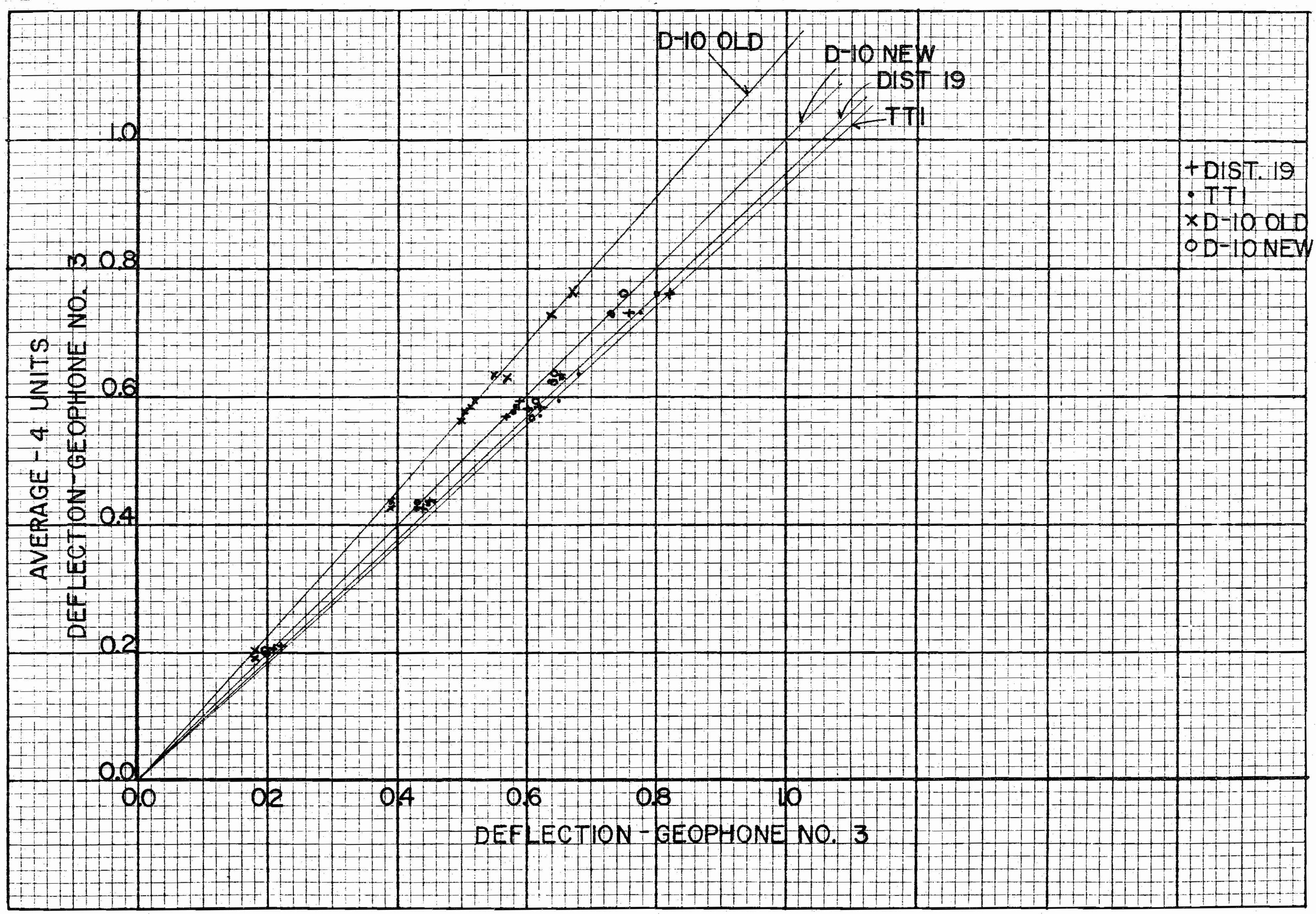


FIGURE 12 - CORRELATION OF FOUR DYNAFLECTS - GEOPHONE 3

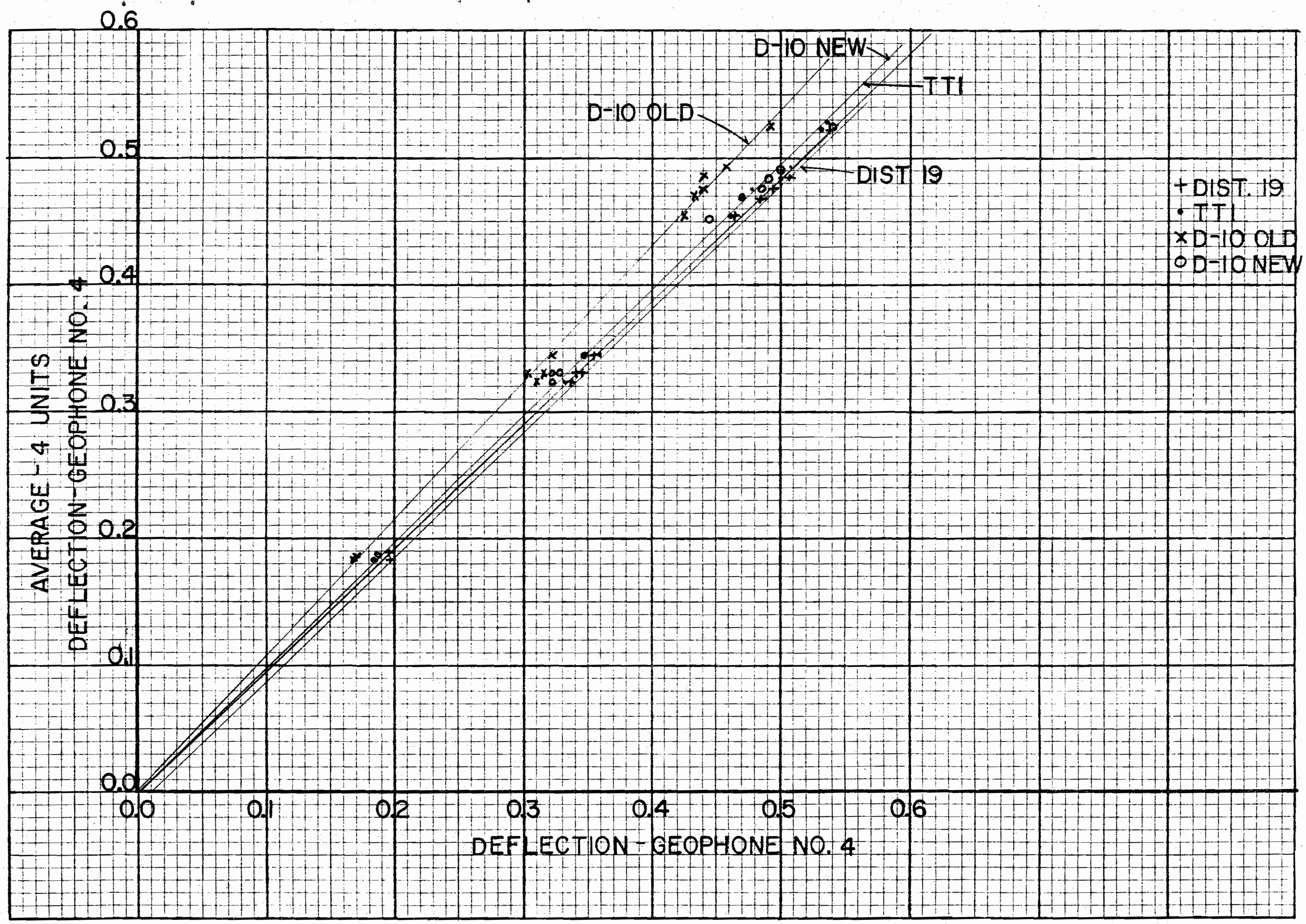


FIGURE 13 - CORRELATION OF FOUR DYNAFLECTS - GEOPHONE 4

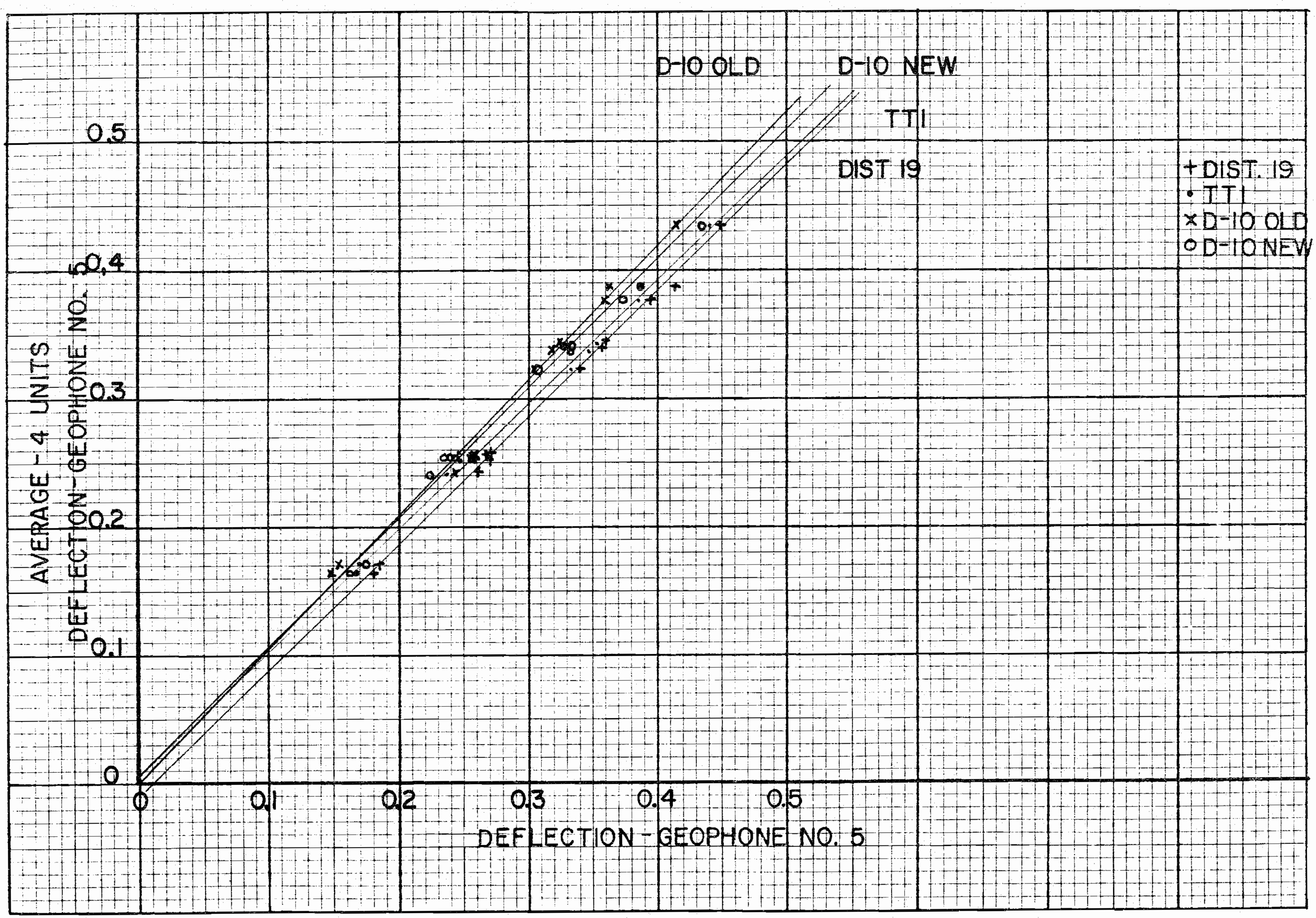


FIGURE 14 - CORRELATION OF FOUR DYNAFLECTS - GEOPHONE 5

Table IV

Results of the Four Dynaflect Correlations

Unit	Intercept	Slope
Geophone 1		
D-10R, Old	-.05	1.17
D-10R, New	0	1.04
TTI	+0.03	0.97
District 19	+0.03	0.90
Geophone 2		
D-10R, Old	0	1.11
D-10R, New	0	1.02
TTI	0.04	0.92
District 19	0.01	0.96
Geophone 3		
D-10R, Old	0	1.14
D-10R, New	0	1.00
TTI	0	0.93
District 19	0	0.96
Geophone 4		
D-10R, Old	0.003	1.07
D-10R, New	0	1.00
TTI	0	0.98
District 19	-.007	0.98
Geophone 5		
D-10R, Old	0	1.06
D-10R, New	0.008	1.02
TTI	0.008	0.99
District 19	-.010	0.98

Equation Format
Y = intercept + slope (x)

Where:
Y = average value of the four Dynaflect units

X = the Dynaflect unit in question

X. Conclusions

It would appear Dynaflect units provide reproducable deflection information over long periods. This statement is based on the fact that calibration devices, static weight, instrumentation, and dynamic weights appear to be specificed by the fabricator and relatively unchanged in units as old as 15 years.

The calibration method, which uses a calibrator with an amplitude of 5 milli-inches at 8 Hertz, produces a linear output if geophones as specified by the manufacturer are also used. There is no need to calibrate at smaller amplitudes.

The average repeatability of the four dynaflects tested was 3.6 percent of the value being obtained, regardless of geophone position. The average repeatability ranged from 2.4 percent to 5.0 percent among the four units.

The average variations in Geophone 1 found between spots 6 to 10 feet apart was 4.0 percent of average value obtained. The variation between spots ranged from 3.7 percent to 4.2 percent in the four units tested.

An unexplained difference between Dynaflect units was found. Based on the average value of the four units, this difference ranged from 17 percent greater than the average to 10 percent lower than the average.

It is not suggested that Dynaflects be calibrated periodically. However, it would be interesting to perform the work reported herein at another time in order to study the day-to-day variation.

References

1. Scrivner, F. H. and Moore W. M.; An Electro-Mechanical System for Measuring the Dynamic Deflection of a Road Surface Caused by an Oscillating Load; Report 32-4; Texas Transportation Institute; Texas Highway Department and Bureau of Public Roads - Sponsors; December, 1964.

2. Scrivner, F. H. and Moore, W. M.; Evaluation of the Stiffness of Individual Layers in a Specially Designed Pavement Facility from Surface Deflections; Report 32-8; Texas Transportation Institute; Texas Highway Department and Bureau of Public Roads - Sponsors; June, 1966.

3. Scrivner, F. H. and Moore, W. M., and Carey, G. R.; A Systems Approach to the Flexible Pavement Design Problem; Report 32-11; Texas Transportation Institute; Texas Highway Department and Federal Highway Administration - Sponsors; October, 1968.

4. Brown, J. L., Butler, L. J., Orellana, H. E.; A Recommended Texas Highway Department Pavement Design System Users Manual; Reprot 123-2; Texas Highway Department, Center for Highway Research and Texas Transportation Institute; Federal Highway Administration - Sponsors; March, 1970.

Appendix A

Frequency Variation Performed With the Calibrator

Frequency Variation
Performed with the Calibrator

Unit	Frequency	Output
D-10R, New	8 Hz	5.0
	7 Hz	6.1
	8.1 Hz	4.8
TTI	8 Hz	5.0
	7 Hz	5.5
	7.5 Hz	5.6
	8.3 Hz	4.35
District 19	8 Hz	5.0
	7 Hz	6.0
	7.5 Hz	5.8
	8.5 Hz	4.2
	9 Hz	3.3
D-10R, Old	8 Hz	5.0
	7 Hz	5.4
	7.5 Hz	5.4
	8.5 Hz	4.3
	9 Hz	3.4

Appendix B

Frequency Variation Performed With the Dynamic Load

Frequency Variation
Performed with the Dynamic Load

Unit	Section	Geo. 1	Geo. 2	Geo. 3	Geo. 4	Geo. 5	Frequency Variat.(Hz)
D-10R New	6A	.79	.71	.59	.45	.34	8.0
		.75	.67	.56	.43	.32	7.0
		.76	.68	.57	.44	.32	7.5
		.76	.68	.57	.44	.32	8.0
		.80	.72	.59	.46	.34	8.5
		.80	.72	.59	.46	.34	9.0
	6B	.87	.78	.64	.50	.37	8.0
		.82	.73	.61	.47	.34	7.0
		.84	.75	.62	.48	.36	7.5
		.86	.76	.63	.49	.36	8.0
		.83	.74	.61	.47	.35	8.5
		.83	.74	.60	.47	.35	9.0
	1A	2.75	1.35	.63	.34	.23	8.0
		2.51	1.25	.61	.32	.22	7.0
		2.57	1.28	.62	.33	.23	7.5
		2.63	1.31	.63	.34	.24	8.0
		2.73	1.36	.64	.36	.25	8.5
		2.49	1.22	.57	.32	.22	9.0
	1B	2.80	1.39	.63	.35	.24	8.0
		2.49	1.30	.60	.33	.22	7.0
		2.58	1.33	.62	.34	.23	7.5
		2.73	1.38	.63	.35	.25	8.0
		2.84	1.34	.63	.35	.25	8.5
		2.94	1.34	.63	.36	.26	9.0
Dist 19	6A	.93					8.0
		.87					7.5
		.78					7.0
		.93					8.5
	1A	2.80	1.26	.57	.34	.234	7.5
		2.22	1.08	.49	.29	.213	7.0
		2.90	1.20	.55	.34	.270	9.0
		3.00	1.32	.59	.36	.280	8.5
		3.10	1.35	.61	.36	.270	8.0
D-10R Old	6A	.71	.63	.52	.42	.32	8.0
		.48	.42	.35	.29	.23	7.0
		.74	.67	.54	.43	.33	8.5
		.60	.53	.43	.34	.27	7.5
	6B	.67	.60	.49	.40	.31	7.5
		.85	.76	.60	.49	.37	8.5
		.77	.69	.56	.44	.35	8.0

Appendix C

Geophone Tests Using the Large Calibrator

Obtained
April 15, 1980

Geophone Tests Using the
Large Calibrator
(Dynaflect Readout in Milli-Inches)

Geophone No.	Position or Movement of Calibration Arm				
	1 MI	2 MI	3 MI	4 MI	5 MI
#1	0.96	1.97	2.92	3.90	5.00
#2	0.97	1.97	3.00	4.03	5.00
#3	0.98	1.98	3.01	4.03	5.00
#4	0.97	1.97	2.98	4.02	5.00
#5	0.97	1.97	3.02	4.01	5.00

(Values Obtained with an Oscilliscope in Milli-Volts)

Geophone No.	Position or Movement of Calibration Arm				
	1 MI	2 MI	3 MI	4 MI	5 MI
#1	50	100	125	160	200
#2	50	75	105	130	175
#3	48	75	105	135	165
#4	50	75	105	130	170
#5	50	75	100	125	165

Appendix D

Instrumentation Tests

D-10R, Old 4/23/80

Voltage on Scope @8 Hz (milli-volts)	Dynaflect Readout				
	Position #1	Position #2	Position #3	Position #4	Position #5
100	5.0 - 1.0	5.0 - 1.0	5.0 - 1.0	5.0 - 1.0	5.0 - 1.0
80	4.1 - 1.0	4.1 - 1.0	4.1 - 1.0	4.1 - 1.0	4.0 - 1.0
60	3.1 - 1.0	3.1 - 1.0	3.1 - 1.0	3.1 - 1.0	3.1 - 1.0
40	2.2 - 1.0	2.2 - 1.0	2.2 - 1.0	2.2 - 1.0	2.2 - 1.0
20	3.2 - 0.3	3.2 - 0.3	3.2 - 0.3	3.2 - 0.3	3.1 - 0.3
	1.2 - 1.0	1.2 - 1.0	1.2 - 1.0	1.2 - 1.0	1.2 - 1.0
2.7	7.1 - 0.01	7.1 - 0.01	7.1 - 0.01	7.1 - 0.01	7.0 - 0.01
3	7.4 - 0.01	7.4 - 0.01	7.4 - 0.01	7.4 - 0.01	7.3 - 0.01
3.5	3.8 - 0.03	3.9 - 0.03	3.9 - 0.03	3.9 - 0.03	3.9 - 0.03
4	4.3 - 0.03	4.3 - 0.03	4.3 - 0.03	4.4 - 0.03	4.3 - 0.03
5	6.2 - 0.03	6.3 - 0.03	6.2 - 0.03	6.3 - 0.03	6.2 - 0.03
5.5	7.0 - 0.03	7.0 - 0.03	7.0 - 0.03	7.0 - 0.03	6.9 - 0.03
5.9	7.4 - 0.03	7.4 - 0.03	7.4 - 0.03	7.4 - 0.03	7.4 - 0.03
6	7.6 - 0.03	7.6 - 0.03	7.6 - 0.03	7.6 - 0.03	7.5 - 0.03
10	4.7 - 0.10	4.7 - 0.10	4.7 - 0.10	4.7 - 0.10	4.6 - 0.10
12	5.8 - 0.10	5.8 - 0.10	5.8 - 0.10	5.8 - 0.10	5.7 - 0.10
16	7.3 - 0.10	7.4 - 0.10	7.3 - 0.10	7.4 - 0.10	7.2 - 0.10
25	4.1 - 0.30	4.1 - 0.30	4.1 - 0.30	4.1 - 0.30	4.1 - 0.30
30	4.9 - 0.30	5.0 - 0.30	4.95- 0.30	5.0 - 0.30	5.0 - 0.30

TTI Unit 4/23/80

Voltage on Scope @8 Hz (milli-volts)	Dynaflect Readout				
	Position #1 R - M	Position #2 R - M	Position #3 R - M	Position #4 R - M	Position #5 R - M
150	5.0 - 1.0	5.0 - 1.0	5.0 - 1.0	5.0 - 1.0	5.0 - 1.0
120	4.0 - 1.0	4.0 - 1.0	4.0 - 1.0	4.05 - 1.0	4.05 - 1.0
90	3.0 - 1.0	3.0 - 1.0	3.0 - 1.0	3.02 - 1.0	3.05 - 1.0
60	6.6 - 0.3	6.7 - 0.3	6.7 - 0.3	6.8 - 0.3	6.8 - 0.3
30	3.3 - 0.3	3.3 - 0.3	3.3 - 0.3	3.3 - 0.3	3.4 - 0.3
2	4.7 - 0.01	4.7 - 0.01	4.7 - 0.01	4.7 - 0.01	4.7 - 0.01
2.3	5.4 - 0.01	5.5 - 0.01	5.6 - 0.01	5.6 - 0.01	5.6 - 0.01
		2.9 - 0.03			
3	8.0 - 0.01	8.1 - 0.01	8.1 - 0.01	8.2 - 0.01	8.2 - 0.01
3.5	3.3 - 0.03	3.3 - 0.03	3.4 - 0.03	3.4 - 0.03	3.4 - 0.03
4	3.8 - 0.03	3.8 - 0.03	3.8 - 0.03	3.8 - 0.03	3.8 - 0.03
5	5.0 - 0.03	5.1 - 0.03	5.1 - 0.03	5.2 - 0.03	5.2 - 0.03
5.5	5.5 - 0.03	5.5 - 0.03	5.5 - 0.03	5.6 - 0.03	5.6 - 0.03
5.9	5.9 - 0.03	5.9 - 0.03	5.9 - 0.03	6.0 - 0.03	6.0 - 0.03
6	6.1 - 0.03	6.1 - 0.03	6.2 - 0.03	6.2 - 0.03	6.2 - 0.03
10	3.0 - 0.10	3.1 - 0.10	3.1 - 0.10	3.2 - 0.10	3.2 - 0.10
12	3.7 - 0.10	3.8 - 0.10	3.8 - 0.10	3.8 - 0.10	3.8 - 0.10
16	5.2 - 0.10	5.2 - 0.10	5.2 - 0.10	5.3 - 0.10	5.3 - 0.10
25	8.4 - 0.10	8.4 - 0.10	8.4 - 0.10	8.6 - 0.10	8.6 - 0.10
30	3.3 - 0.10	3.4 - 0.10	3.4 - 0.10	3.4 - 0.10	3.4 - 0.30

District 19 Unit 4/23/80

Voltage on Scope @8 Hz (milli-volts)	Dynaflect Readout				
	Position #1	Position #2	Position #3	Position #4	Position #5
100	5.0 - 1.0	5.0 - 1.0	5.0 - 1.0	5.0 - 1.0	5.0 - 1.0
80	4.05- 1.0	4.0 - 1.0	4.0 - 1.0	4.2 - 1.0	4.0 - 1.0
60	3.0 - 1.0	3.0 - 1.0	3.0 - 1.0	3.0 - 1.0	3.0 - 1.0
40	2.2 - 1.0	2.2 - 1.0	2.2 - 1.0	2.2 - 1.0	2.2 - 1.0
20	1.2 - 1.0	1.2 - 1.0	1.2 - 1.0	1.2 - 1.0	1.2 - 1.0
2	8.0 - 0.01	7.8 - 0.01	7.9 - 0.01	8.2 - 0.01	7.8 - 0.01
2.3	3.4 - 0.03	3.2 - 0.03	3.2 - 0.03	3.2 - 0.03	3.2 - 0.03
	9.2 - 0.01				
3	4.6 - 0.03	4.3 - 0.03	4.3 - 0.03	4.4 - 0.03	4.6 - 0.03
3.5	5.0 - 0.03	5.0 - 0.03	5.0 - 0.03	5.0 - 0.03	5.0 - 0.03
4	5.9 - 0.03	5.8 - 0.03	5.8 - 0.03	5.9 - 0.03	5.8 - 0.03
5	7.3 - 0.03	7.2 - 0.03	7.2 - 0.03	7.4 - 0.03	7.2 - 0.03
5.5	7.8 - 0.03	7.8 - 0.03	7.8 - 0.03	8.0 - 0.03	7.8 - 0.03
5.9	2.8 - 0.10	2.8 - 0.10	2.8 - 0.10	2.9 - 0.10	2.7 - 0.10
	8.6 - 0.03	8.6 - 0.03	8.6 - 0.03	8.8 - 0.03	8.6 - 0.03
6	2.8 - 0.10	2.7 - 0.10	2.7 - 0.10	2.7 - 0.10	2.7 - 0.10
10	4.6 - 0.10	4.6 - 0.10	4.6 - 0.10	4.7 - 0.10	4.6 - 0.10
12	5.5 - 0.10	5.5 - 0.10	5.5 - 0.10	5.6 - 0.10	5.5 - 0.10
16	7.5 - 0.10	7.4 - 0.10	7.4 - 0.10	7.6 - 0.10	7.4 - 0.10
25	4.0 - 0.30	3.9 - 0.30	3.9 - 0.30	4.0 - 0.30	3.9 - 0.30
30	4.8 - 0.30	4.8 - 0.30	4.8 - 0.30	4.9 - 0.30	4.8 - 0.30

D-10R, New 4/23/80

Voltage on Scope @8 Hz (milli-volts)	Dynaflect Readout				
	Position #1	Position #2	Position #3	Position #4	Position #5
1					
1.5					
1.75					
2	0.04	0.03	0.03	0.04	0.04
2.3	0.06	0.05	0.05	0.06	0.05
2.8					
3	0.08	0.07	0.07	0.07	0.07
3.2					
3.5	0.09	0.08	0.08	0.09	0.09
3.7					
4	0.11	0.10	0.10	0.11	0.11
4.4					
5	0.14	0.13	0.13	0.14	0.13
5.5	0.16	0.15	0.15	0.16	0.15
5.9	0.17	0.16	0.16	0.16	0.16
6	0.17	0.16	0.16	0.17	0.17
6.1					
6.2					
6.4					
10	0.31	0.30	0.30	0.31	0.31
12	0.38	0.37	0.37	0.38	0.38
16	0.52	0.51	0.51	0.51	0.51
18					
21					
25	0.81	0.80	0.80	0.81	0.81
28					
30	0.99	0.98	0.98	0.98	0.99

D-10R, New 4/23/80

Voltage on Scope @8 Hz (milli-volts)	Dynaflect Readout				
	Position #1	Position #2	Position #3	Position #4	Position #5
30	0.98	0.97	0.96	0.97	0.97
60	1.96	1.96	1.96	1.96	1.97
90	2.95	2.95	2.94	2.95	2.96
120	3.98	4.00	3.99	4.00	4.00
150	5.00	5.00	5.00	5.00	5.00

Appendix E

Correlation Data

4-Dynaflect
Correlation
Geophone 1

	Dist 19	TTI	D-10 Old	D-10 New	Mean	S.D.	C.O.V.
Site 1							
A 1	2.80	2.8	2.40	2.61	2.65	0.19	7 %
2	2.80	2.8	2.34	2.63	2.64	0.22	8 %
3	3.00	2.8	2.22	2.75	2.69	0.33	12 %
4	3.00	2.9	2.22	2.67	2.70	0.35	13 %
5	3.10	2.8	2.52	2.79	2.80	0.24	8 %
6	3.10	2.9	2.52	2.65	2.79	0.26	9 %
7	3.00	2.8	2.55	2.46	2.70	0.25	9 %
Mean	2.97	2.83	2.40	2.65	2.713		9.4%
S.D.	0.13	0.05	0.14	0.11			
C.O.V.	4%	2%	6%	4%			
B 1	3.0	3.0	2.4	2.42	2.71	0.34	13 %
2	3.2	3.0	2.46	2.48	2.79	0.37	13 %
3	3.1	2.9	2.52	2.71	2.81	0.25	9 %
4	3.2	2.9	2.52	2.80	2.86	0.28	10 %
5	3.1	3.1	2.61	2.90	2.93	0.23	8 %
6	3.0	2.9	2.55	2.64	2.77	0.21	8 %
7	3.1	2.8	2.55	2.51	2.74	0.27	10 %
Mean	3.10	2.94	2.52	2.64	2.800		10.1%
S.D.	0.08	0.10	0.07	0.18			
C.O.V.	3%	3%	3%	6.7%			
Site 2							
A 1	1.95	1.89	1.50	1.75	1.77	0.20	11 %
2	2.01	1.86	1.56	1.91	1.84	0.19	11 %
3	1.95	1.92	1.62	1.91	1.85	0.15	8 %
4	2.04	1.89	1.77	1.91	1.90	0.11	6 %
5	2.07	1.92	1.65	1.88	1.88	0.17	9 %
6	2.10	1.98	1.68	1.83	1.90	0.18	10 %
7	2.04	1.92	1.68	1.66	1.83	0.19	10 %
Mean	2.02	1.91	1.64	1.84	1.853		9.3%
S.D.	0.06	0.04	0.09	0.10			
C.O.V.	3%	2%	5%	5%			
B 1	1.98	1.89	1.56	1.76	1.80	0.18	10 %
2	2.07	1.83	1.50	1.92	1.83	0.24	13 %
3	2.22	1.92	1.68	1.98	1.95	0.22	11 %
4	2.19	1.98	1.68	1.97	1.96	0.21	11 %
5	2.19	1.95	1.65	1.88	1.92	0.22	12 %
6	2.16	2.07	1.80	1.87	1.98	0.17	8 %
7	2.10	1.98	1.74	1.74	1.89	0.18	10 %
Mean	2.13	1.95	1.66	1.87	1.903		10.7%
S.D.	0.08	0.08	0.10	0.09			
C.O.V.	4%	4%	6%	5%			

Geophone 1

	Dist 19	TTI	D-10 Old	D-10 New	Mean	S.D.	C.O.V.
Site 3							
A 1	1.02	0.90	0.73	0.92	0.91	0.10	11 %
2	1.02	0.96	0.74	0.93	0.91	0.12	13 %
3	0.99	0.96	0.82	1.00	0.94	0.08	9 %
4	1.02	0.96	0.82	0.89	0.92	0.09	9 %
5	1.02	0.99	0.85	0.92	0.95	0.08	8 %
6	1.02	0.96	0.84	0.87	0.92	0.08	9 %
7	0.99	0.96	0.86	0.92	0.93	0.06	6 %
Mean	1.01	0.96	0.82	0.92	0.928		7.7%
S.D.	0.01	0.03	0.04	0.04			
C.O.V.	1%	3%	5%	4%			
B 1	0.99	0.96	0.90	0.94	0.95	0.04	4 %
2	1.02	0.99	0.80	1.00	0.95	0.10	11 %
3	1.02	0.96	0.86	1.00	0.96	0.07	7 %
4	1.05	1.02	0.87	0.97	0.98	0.08	8 %
5	1.02	0.99	0.96	0.96	0.98	0.03	3 %
6	1.05	1.02	0.99	0.88	0.99	0.07	7 %
7	1.02	1.02	0.99	0.94	0.99	0.04	4 %
Mean	1.02	0.99	0.91	0.96	0.970		
S.D.	0.02	0.03	0.07	0.04			
C.O.V.	2%	3%	8%	4%			
Site 4							
Spot A1	0.249	0.237	0.210	0.25	0.237	0.019	7.9%
2	0.255	0.243	0.207	0.24	0.236	0.021	8.7%
3	0.258	0.240	0.250	0.26	0.245	0.023	9.6%
4	0.258	0.243	0.250	0.25	0.250	0.006	2.5%
5	0.255	0.246	0.250	0.24	0.248	0.006	2.6%
6	0.258	0.249	0.240	0.23	0.244	0.012	4.9%
7	0.255	0.252	0.240	0.23	0.244	0.012	4.7%
Mean	0.255	0.236	0.235	0.243	0.242		
S.D.	0.003	0.016	0.019	0.011			
C.O.V.	1.3%	6.9%	8.0%	4.6%			
Spot B1	0.234	0.228	0.220	0.25	0.233	0.013	5.5%
2	0.234	0.228	0.195	0.23	0.222	0.018	8.1%
3	0.228	0.228	0.204	0.22	0.220	0.011	5.1%
4	0.228	0.234	0.240	0.23	0.233	0.005	2.3%
5	0.228	0.234	0.240	0.23			
6	0.228	0.225	0.231	0.22	0.226	0.005	2.1%
7	0.231	0.219	0.250	0.23	0.233	0.013	5.5%
Mean	0.230	0.228	0.226	0.230	0.234		
S.D.	0.003	0.005	0.020	0.010			
C.O.V.	1.2%	2.3%	9.0%	4.3%			

Geophone 1

		Dist 19	TTI	D-10 Old	D-10 New	Mean	S.D.	C.O.V.
Site 5								
A	1	0.84	0.84	0.96	0.79	0.86	0.07	8 %
	2	0.87	0.80	0.74	0.82	0.81	0.05	7 %
	3	0.87	0.79	0.85	0.83	0.84	0.03	4 %
	4	0.87	0.81	0.85	0.79	0.83	0.04	4 %
	5	0.90	0.82	0.96	0.82	0.875	0.068	7.8%
	6	0.87	0.84	0.99	0.87	0.89	0.07	7 %
	7	0.87	0.78	0.96	0.79	0.85	0.08	10 %
	Mean	0.87	0.81	0.90	0.82	0.850		
	S.D.	0.02	0.02	0.09	0.03			
	C.O.V.	2%	3%	10%	3.6%			
B	1	1.02	0.96	0.96	0.96	0.98	0.03	3 %
	2	0.90	0.87	0.74	0.97	0.87	0.10	11 %
	3	0.93	0.96	0.85	1.02	0.94	0.07	8 %
	4	0.87	0.96	0.85	0.93	0.90	0.05	6 %
	5	0.90	0.96	0.96	0.96	0.945	0.03	3.2%
	6	0.93	0.90	0.99	0.95	0.94	0.04	4 %
	7	0.90	0.87	0.96	0.93	0.92	0.04	4 %
	Mean	0.92	0.93	0.90	0.96	0.928		
	S.D.	0.05	0.04	0.09	0.03			
	C.O.V.	5%	5%	10%	3.2%			
Site 6								
	1	0.87	0.80	0.71	0.84	0.81	0.07	9 %
	2	0.87	0.81	0.69	0.79	0.79	0.07	9 %
	3	0.90	0.81	0.73	0.86	0.83	0.07	9 %
	4	0.90	0.83	0.73	0.80	0.82	0.07	9 %
	5	0.90	0.82	0.69	0.79	0.80	0.087	10.8%
	6	0.90	0.82	0.72	0.73	0.79	0.08	11 %
	7	0.87	0.80	0.66	0.73	0.77	0.09	12 %
	Mean	0.89	0.81	0.70	0.79	0.798		
	S.D.	0.02	0.01	0.03	0.049			
	C.O.V.	2%	1%	4%	6.3%			
Spot B1		0.96	0.90	0.77	0.93	0.89	0.08	9 %
	2	0.93	0.91	0.76	0.87	0.87	0.08	9 %
	3	0.96	0.93	0.80	0.92	0.90	0.07	8 %
	4	0.93	0.93	0.80	0.88	0.89	0.06	7 %
	5	0.93	0.88	0.81	0.87	0.87	0.049	5.7
	6	0.90	0.90	0.81	0.81	0.86	0.05	6 %
	7	0.90	0.90	0.71	0.83	0.84	0.09	11 %
	Mean	0.93	0.91	0.78	0.87	0.873		
	S.D.	0.02	0.02	0.04	0.043			
	C.O.V.	3%	2%	5%	5%			

4 Dynaflect
Correlation
Geophone 2

	Dist 19	TTI	D-10 Old	D-10 New	Mean	S.D.	C.O.V.
Site 1							
A 1	1.32	1.44	1.29	1.36	1.35	0.07	5 %
2	1.41	1.38	1.23	1.28	1.33	0.08	6 %
3	1.38	1.38	1.20	1.35	1.33	0.09	6 %
4	1.35	1.41	1.17	1.34	1.32	0.10	8 %
5	1.44	1.41	1.32	1.44	1.40	0.06	4 %
6	1.41	1.38	1.26	1.34	1.35	0.065	4.8%
7	1.32	1.44	1.35	1.25	1.34	0.08	6 %
Mean	1.38	1.41	1.26	1.34	1.348		
S.D.	0.05	0.03	0.06	0.06			
C.O.V.	3%	2%	5%	4.5%			
B 1	1.29	1.38	1.17	1.18	1.26	0.10	8 %
2	1.32	1.47	1.14	1.27	1.30	0.14	10 %
3	1.35	1.44	1.20	1.39	1.35	0.10	8 %
4	1.38	1.44	1.32	1.39	1.38	0.05	4 %
5	1.38	1.59	1.38	1.40	1.44	0.10	7 %
6	1.32	1.44	1.29	1.31	1.34	0.068	5.1%
7	1.38	1.38	1.23	1.24	1.31	0.08	6 %
Mean	1.35	1.45	1.25	1.31	1.340		
S.D.	0.04	0.07	0.09	0.086			
C.O.V.	3%	5%	7%	6.6%			
Site 2							
A 1	1.17	1.26	1.02	1.13	1.15	0.10	9 %
2	1.20	1.26	1.08	1.19	1.18	0.08	6 %
3	1.20	1.26	1.05	1.19	1.18	0.09	8 %
4	1.26	1.26	1.20	1.23	1.24	0.03	2 %
5	1.29	1.29	1.11	1.16	1.21	0.09	8 %
6	1.29	1.29	1.08	1.20	1.22	0.10	8 %
7	1.26	1.29	1.11	1.09	1.19	0.10	9 %
Mean	1.24	1.27	1.09	1.17	1.193		
S.D.	0.05	0.02	0.06	0.05			
C.O.V.	4%	1%	5%	4%			
B 1	1.20	1.44	1.05	1.13	1.21	0.17	14 %
2	1.32	1.26	1.02	1.24	1.21	0.13	11 %
3	1.38	1.26	1.11	1.25	1.25	0.11	9 %
4	1.32	1.32	1.11	1.36	1.28	0.11	9 %
5	1.38	1.29	1.11	1.25	1.26	0.11	9 %
6	1.35	1.35	1.14	1.24	1.27	0.10	8 %
7	1.35	1.32	1.11	1.11	1.22	0.13	11 %
Mean	1.33	1.32	1.09	1.23	1.243		
S.D.	0.06	0.06	0.04	0.08			
C.O.V.	5%	5%	4%	7%			

Geophone 2

	Dist 19	TTI	D-10 Old	D-10 New	Mean	S.D.	C.O.V.
Site 3							
A 1	0.62	0.61	0.53	0.60	0.59	0.04	7 %
2	0.63	0.63	0.54	0.60	0.60	0.04	7 %
3	0.64	0.65	0.56	0.65	0.63	0.04	7 %
4	0.64	0.64	0.55	0.67	0.63	0.05	8 %
5	0.65	0.64	0.60	0.62	0.63	0.02	3.5%
6	0.65	0.65	0.58	0.57	0.61	0.04	7 %
7	0.64	0.64	0.58	0.60	0.62	0.03	5 %
Mean	0.64	0.64	0.56	0.62	0.615		
S.D.	0.01	0.01	0.02	0.034			
C.O.V.	2%	2%	4%	5.5%			
B 1	0.61	0.62	0.53	0.60	0.59	0.04	7 %
2	0.63	0.62	0.55	0.64	0.61	0.04	7 %
3	0.63	0.62	0.58	0.62	0.61	0.02	4 %
4	0.64	0.64	0.57	0.64	0.62	0.04	6 %
5	0.65	0.64	0.56	0.61	0.62	0.04	6.5%
6	0.64	0.64	0.60	0.56	0.61	0.04	6 %
7	0.63	0.66	0.59	0.61	0.62	0.03	5 %
Mean	0.63	0.63	0.57	0.61	0.610		
S.D.	0.01	0.02	0.02	0.027			
C.O.V.	2%	2%	4%	4.5%			
Site 4							
Spot A1	0.234	0.222	0.198	0.22	0.219	0.015	6.8%
2	0.234	0.222	0.198	0.21	0.216	0.015	7.2%
3	0.237	0.228	0.201	0.23	0.224	0.016	7.1%
4	0.237	0.228	0.210	0.24	0.229	0.014	5.9%
5	0.240	0.231	0.204	0.22	0.224	0.016	6.9%
6	0.237	0.228	0.207	0.21	0.221	0.014	6.5%
7	0.237	0.234	0.204	0.20	0.219	0.019	8.9%
Mean	0.237	0.228	0.203	0.218	0.222		
S.D.	0.002	0.004	0.004	0.013			
C.O.V.	0.9%	1.9%	2.2%	6.2%			
Spot B1	0.219	0.216	0.186	0.23	0.213	0.019	8.8%
2	0.225	0.210	0.186	0.21	0.208	0.016	7.8%
3	0.225	0.219	0.195	0.20	0.210	0.015	6.9%
4	0.225	0.225	0.228	0.22	0.225	0.003	1.5%
5	0.225	0.219	0.189	0.22	0.213	0.016	7.7%
6	0.225	0.216	0.216	0.20	0.214	0.010	4.9%
7	0.219	0.213	0.219	0.21	0.215	0.005	2.1%
Mean	0.223	0.217	0.203	0.213	0.214		
S.D.	0.003	0.005	0.018	0.011			
C.O.V.	1.3%	2.2%	8.7%	5.2%			

Geophone 2

	Dist 19	TTI	D-10 Old	D-10 New	Mean	S.D.	C.O.V.
Site 5							
A 1	0.72	0.79	0.65	0.72	0.72	0.06	8 %
2	0.74	0.74	0.63	0.74	0.71	0.06	8 %
3	0.75	0.73	0.66	0.76	0.73	0.05	6 %
4	0.75	0.74	0.63	0.73	0.71	0.06	8 %
5	0.75	0.76	0.69	0.73	0.73	0.03	4 %
6	0.73	0.78	0.70	0.73	0.74	0.03	4 %
7	0.73	0.72	0.69	0.72	0.72	0.02	2 %
Mean	0.74	0.75	0.66	0.73	0.720		
S.D.	0.01	0.03	0.03	0.01			
C.O.V.	2%	3%	4%	2%			
B 1	0.76	0.76	0.81	0.74	0.77	0.03	4 %
2	0.76	0.75	0.63	0.78	0.73	0.06	9 %
3	0.76	0.74	0.67	0.78	0.74	0.05	6 %
4	0.75	0.74	0.69	0.73	0.73	0.03	4 %
5	0.75	0.74	0.67	0.74	0.73	0.04	5 %
6	0.73	0.73	0.68	0.73	0.72	0.03	3 %
7	0.73	0.72	0.68	0.69	0.71	0.02	3 %
Mean	0.75	0.74	0.69	0.74	0.730		
S.D.	0.01	0.01	0.06	0.03			
C.O.V.	2%	2%	8%	4%			
Site 6A							
1	0.72	0.73	0.63	0.74	0.71	0.05	7 %
2	0.74	0.74	0.62	0.71	0.70	0.06	8 %
3	0.76	0.74	0.66	0.76	0.73	0.05	7 %
4	0.75	0.75	0.66	0.77	0.73	0.05	7 %
5	0.73	0.74	0.62	0.72	0.70	0.06	8 %
6	0.72	0.75	0.64	0.66	0.69	0.05	7 %
7	0.71	0.73	0.63	0.65	0.68	0.05	7 %
Mean	0.73	0.74	0.64	0.72	0.708		
S.D.	0.02	0.01	0.02	0.05			
C.O.V.	2%	1%	3%	6%			
B1	0.81	0.81	0.69	0.83	0.79	0.06	8 %
2	0.81	0.82	0.70	0.78	0.78	0.05	7 %
3	0.84	0.80	0.73	0.89	0.82	0.07	8 %
4	0.84	0.81	0.71	0.81	0.79	0.06	7 %
5	0.77	0.79	0.73	0.80	0.77	0.03	4 %
6	0.77	0.82	0.73	0.73	0.76	0.04	6 %
7	0.77	0.81	0.69	0.74	0.75	0.05	7 %
Mean	0.80	0.81	0.71	0.80	0.780		
S.D.	0.03	0.01	0.02	0.05			
C.O.V.	4%	1%	3%	7%			

4 Dynaflect
Correlation
Geophone 3

		Dist 19	TTI	D-10 Old	D-10 New	Mean	S.D.	C.O.V.
Site 1								
A	1	0.57	0.62	0.51	0.62	0.58	0.05	9 %
	2	0.59	0.61	0.49	0.59	0.57	0.05	10 %
	3	0.57	0.62	0.42	0.63	0.56	0.10	17 %
	4	0.57	0.62	0.45	0.62	0.57	0.08	14 %
	5	0.60	0.62	0.55	0.63	0.60	0.04	6 %
	6	0.53	0.62	0.51	0.61	0.57	0.06	10 %
	7	0.54	0.64	0.55	0.56	0.57	0.05	8 %
	Mean	0.57	0.62	0.50	0.61	0.575		
	S.D.	0.02	0.01	0.05	0.03			
	C.O.V.	4%	1%	10%	4%			
B	1	0.60	0.64	0.49	0.56	0.57	0.06	11 %
	2	0.59	0.65	0.48	0.58	0.58	0.07	12 %
	3	0.59	0.66	0.51	0.64	0.60	0.07	11 %
	4	0.59	0.64	0.51	0.63	0.59	0.06	10 %
	5	0.60	0.68	0.55	0.65	0.62	0.06	9 %
	6	0.59	0.63	0.54	0.61	0.59	0.04	7 %
	7	0.59	0.62	0.53	0.57	0.58	0.04	7 %
	Mean	0.59	0.65	0.52	0.61	0.593		
	S.D.	0.005	0.02	0.03	0.04			
	C.O.V.	0.8%	3%	5%	6%			
Site 2								
A	1	0.71	0.78	0.58	0.72	0.70	0.08	12 %
	2	0.73	0.77	0.61	0.75	0.72	0.07	10 %
	3	0.81	0.78	0.62	0.74	0.74	0.08	11 %
	4	0.81	0.78	0.75	0.77	0.78	0.03	3 %
	5	0.81	0.78	0.64	0.73	0.74	0.07	10 %
	6	0.81	0.81	0.64	0.73	0.75	0.08	11 %
	7	0.81	0.80	0.61	0.68	0.73	0.10	13 %
	Mean	0.78	0.79	0.64	0.73	0.735		
	S.D.	0.04	0.01	0.05	0.03			
	C.O.V.	6%	2%	9%	4%			
B	1	0.81	0.81	0.72	0.72	0.77	0.05	7 %
	2	0.81	0.76	0.61	0.78	0.74	0.09	12 %
	3	0.87	0.80	0.64	0.79	0.78	0.10	12 %
	4	0.81	0.81	0.75	0.80	0.79	0.03	4 %
	5	0.84	0.79	0.65	0.76	0.76	0.08	11 %
	6	0.81	0.82	0.66	0.73	0.76	0.08	10 %
	7	0.81	0.81	0.64	0.70	0.74	0.08	11 %
	Mean	0.82	0.80	0.67	0.75	0.760		
	S.D.	0.02	0.02	0.05	0.04			
	C.O.V.	3%	3%	7%	5%			

Geophone 3

	Dist 19	TTI	D-10 Old	D-10 New	Mean	S.D.	C.O.V.
Site 3							
A 1	0.45	0.44	0.37	0.43	0.42	0.04	9 %
2	0.44	0.45	0.37	0.43	0.42	0.04	9 %
3	0.45	0.46	0.37	0.46	0.44	0.04	10 %
4	0.45	0.46	0.39	0.42	0.43	0.03	7 %
5	0.45	0.46	0.41	0.43	0.44	0.02	5 %
6	0.45	0.46	0.40	0.41	0.43	0.03	7 %
7	0.44	0.46	0.41	0.43	0.44	0.02	5 %
Mean	0.45	0.46	0.39	0.43	0.433		
S.D.	0.005	0.008	0.19	0.02			
C.O.V.	1%	1.7%	4.8%	4%			
B 1	0.42	0.44	0.35	0.42	0.41	0.04	9.6%
2	0.44	0.45	0.38	0.45	0.43	0.03	7.8%
3	0.44	0.45	0.39	0.44	0.43	0.03	6.3%
4	0.44	0.46	0.40	0.43	0.43	0.03	5.8%
5	0.45	0.46	0.40	0.43	0.44	0.03	6.2%
6	0.44	0.45	0.42	0.40	0.43	0.02	5.2%
7	0.44	0.47	0.41	0.42	0.44	0.03	6 %
Mean	0.44	0.45	0.39	0.43	0.428		
S.D.	0.009	0.01	0.02	0.02			
C.O.V.	2%	2.2%	5.9%	4%			
Site 4							
Spot A1	0.216	0.210	0.180	0.20	0.202	0.016	7.8%
2	0.213	0.213	0.180	0.20	0.202	0.016	7.7%
3	0.216	0.213	0.180	0.21	0.205	0.017	8.1%
4	0.219	0.213	0.192	0.20	0.206	0.012	5.9%
5	0.219	0.216	0.186	0.198	0.205	0.016	7.6%
6	0.213	0.216	0.183	0.19	0.201	0.016	8.2%
7	0.213	0.219	0.189	0.19	0.203	0.016	7.6%
Mean	0.216	0.214	0.184	0.198	0.203		
S.D.	0.003	0.003	0.005	0.007			
C.O.V.	1.2%	1.4%	2.6%	3.5%			
Spot B1	0.210	0.204	0.162	0.22	0.199	0.026	12.8%
2	0.216	0.201	0.174	0.20	0.198	0.017	8.8%
3	0.213	0.210	0.177	0.19	0.198	0.017	8.6%
4	0.213	0.216	0.192	0.20	0.205	0.011	5.5%
5	0.213	0.210	0.174	0.20	0.199	0.018	8.9%
6	0.216	0.210	0.198	0.19	0.204	0.012	5.7%
7	0.204	0.198	0.195	0.20	0.199	0.004	1.9%
Mean	0.212	0.207	0.182	0.200	0.200		
S.D.	0.004	0.006	0.013	0.100			
C.O.V.	2%	3%	7.4%	5%			

Geophone 3

	Dist 19	TTI	D-10 Old	D-10 New	Mean	S.D.	C.O.V.
Site 5							
A 1	0.62	0.70	0.56	0.63	0.628	0.057	9.1%
2	0.65	0.65	0.55	0.65	0.625	0.050	8 %
3	0.65	0.64	0.56	0.66	0.628	0.046	7.3%
4	0.65	0.65	0.58	0.64	0.630	0.034	5.3%
5	0.65	0.66	0.60	0.64	0.638	0.026	4.1%
6	0.63	0.69	0.60	0.64	0.640	0.037	5.8%
7	0.63	0.63	0.56	0.64	0.615	0.037	6 %
Mean	0.64	0.66	0.573	0.643	0.629		
S.D.	0.013	0.026	0.021	0.010			
C.O.V.	2%	3.9%	3.6%	1.5%			
B 1	0.61	0.60	0.53	0.59	0.583	0.036	6.2%
2	0.63	0.62	0.50	0.61	0.590	0.061	10.3%
3	0.62	0.62	0.50	0.62	0.590	0.060	10.2%
4	0.62	0.62	0.52	0.58	0.585	0.047	8.1%
5	0.62	0.61	0.52	0.59	0.585	0.045	7.7%
6	0.60	0.61	0.53	0.58	0.580	0.036	6.1%
7	0.61	0.61	0.52	0.55	0.573	0.045	7.9%
Mean	0.616	0.613	0.517	0.588	0.584		
S.D.	0.01	0.008	0.013	0.023			
C.O.V.	1.6%	1.2%	2.4%	3.9%			
Site 6A							
1	0.59	0.61	0.52	0.61	0.583	0.043	7.3%
2	0.60	0.62	0.45	0.59	0.565	0.078	13.7%
3	0.62	0.61	0.53	0.63	0.598	0.046	7.6%
4	0.62	0.63	0.54	0.59	0.595	0.040	6.8%
5	0.60	0.63	0.53	0.59	0.588	0.042	7.1%
6	0.58	0.62	0.51	0.55	0.565	0.047	8.2%
7	0.57	0.61	0.51	0.54	0.563	0.046	8.1%
Mean	0.600	0.619	0.513	0.585	0.579		
S.D.	0.015	0.009	0.030	0.032			
C.O.V.	2.5%	1.5%	5.8%	5.4%			
B1	0.66	0.68	0.56	0.68	0.645	0.057	8.9%
2	0.65	0.69	0.49	0.64	0.618	0.088	14.2%
3	0.67	0.68	0.56	0.67	0.645	0.057	8.8%
4	0.66	0.69	0.57	0.65	0.643	0.051	8.0%
5	0.64	0.66	0.58	0.65	0.633	0.036	5.7%
6	0.64	0.68	0.58	0.61	0.628	0.043	6.8%
7	0.64	0.67	0.52	0.62	0.613	0.065	10.6%
Mean	0.651	0.679	0.551	0.645	0.632		
S.D.	0.012	0.011	0.034	0.025			
C.O.V.	1.9%	1.6%	6.1%	3.9%			

4 Dynaflect
Correlation
Geophone 4

	Dist 19	TTI	D-10 Old	D-10 New	Mean	S.D.	C.O.V.
Site 1							
A 1	0.33	0.33	0.31	0.34	0.328	0.013	3.8%
2	0.34	0.33	0.31	0.33	0.328	0.013	3.8%
3	0.34	0.34	0.30	0.34	0.330	0.020	6.1%
4	0.34	0.34	0.31	0.34	0.333	0.015	4.5%
5	0.35	0.34	0.33	0.33	0.338	0.014	2.8%
6	0.34	0.34	0.31	0.33	0.330	0.014	4.3%
7	0.34	0.35	0.33	0.30	0.330	0.022	6.5%
Mean	0.340	0.339	0.314	0.330	0.331		
S.D.	0.006	0.007	0.011	0.014			
C.O.V.	1.7%	2%	3.6%	4.3%			
B 1	0.35	0.34	0.31	0.32	0.330	0.018	5.5%
2	0.35	0.36	0.31	0.33	0.338	0.022	6.6%
3	0.35	0.36	0.32	0.36	0.348	0.019	5.4%
4	0.35	0.35	0.34	0.39	0.358	0.022	6.2%
5	0.36	0.37	0.33	0.36	0.355	0.017	4.9%
6	0.36	0.36	0.33	0.35	0.350	0.014	4 %
7	0.36	0.35	0.32	0.32	0.338	0.021	6.1%
Mean	0.354	0.356	0.323	0.347	0.345		
S.D.	0.005	0.010	0.011	0.026			
C.O.V.	1.5%	2.7%	3.4%	7.4%			
Site 2							
A 1	0.47	0.48	0.40	0.47	0.455	0.037	8.1%
2	0.47	0.48	0.45	0.49	0.473	0.017	3.6%
3	0.47	0.48	0.43	0.47	0.463	0.022	4.8%
4	0.50	0.49	0.46	0.50	0.488	0.019	3.9%
5	0.49	0.48	0.44	0.47	0.470	0.022	4.6%
6	0.50	0.50	0.43	0.45	0.470	0.036	7.6%
7	0.50	0.50	0.42	0.44	0.465	0.041	8.9%
Mean	0.486	0.487	0.433	0.470	0.469		
S.D.	0.015	0.010	0.020	0.021			
C.O.V.	3.1%	2%	4.6%	4.4%			
B 1	0.49	0.51	0.44	0.48	0.480	0.029	6.1%
2	0.51	0.46	0.43	0.51	0.478	0.039	8.3%
3	0.49	0.50	0.44	0.52	0.488	0.034	7 %
4	0.52	0.50	0.45	0.51	0.495	0.031	6.3%
5	0.54	0.50	0.44	0.49	0.493	0.041	8.3%
6	0.51	0.52	0.44	0.47	0.485	0.037	7.6%
7	0.50	0.51	0.45	0.46	0.480	0.029	6.1%
Mean	0.509	0.500	0.441	0.491	0.485		
S.D.	0.018	0.019	0.007	0.023			
C.O.V.	3.5%	3.8%	1.6%	4.6%			

Geophone 4

	Dist 19	TTI	D-10 Old	D-10 New	Mean	S.D.	C.O.V.
Site 3							
A 1	0.34	0.32	0.31	0.33	0.325	0.013	4.0%
2	0.34	0.34	0.31	0.32	0.328	0.015	4.6%
3	0.34	0.33	0.31	0.35	0.333	0.017	5.1%
4	0.35	0.34	0.32	0.32	0.333	0.015	4.5%
5	0.35	0.34	0.32	0.32	0.333	0.015	4.5%
6	0.35	0.34	0.33	0.30	0.330	0.022	6.5%
7	0.35	0.34	0.32	0.32	0.333	0.015	4.5%
Mean	0.346	0.336	0.317	0.323	0.331		
S.D.	0.005	0.008	0.008	0.015			
C.O.V.	1.5%	2.3%	2.4%	4.6%			
B 1	0.33	0.32	0.30	0.32	0.318	0.013	4.0%
2	0.33	0.33	0.29	0.34	0.323	0.022	6.9%
3	0.34	0.33	0.31	0.33	0.328	0.013	3.8%
4	0.34	0.34	0.30	0.32	0.325	0.019	5.9%
5	0.34	0.34	0.32	0.32	0.330	0.012	3.5%
6	0.34	0.33	0.33	0.30	0.325	0.017	5.3%
7	0.34	0.34	0.33	0.32	0.333	0.010	2.9%
Mean	0.337	0.333	0.311	0.322	0.326		
S.D.	0.005	0.008	0.016	0.012			
C.O.V.	1.4%	2.3%	5.1%	3.8%			
Site 4							
A1	.198	.180	.162	0.19	0.183	0.016	8.5%
2	.201	.186	.174	0.18	0.185	0.012	6.3%
3	.195	.189	.168	0.20	0.188	0.014	7.5%
4	.195	.186	.171	0.19	0.186	0.010	5.6%
5	.195	.186	.165	0.185	0.183	0.013	6.9%
6	.198	.183	.165	0.18	0.182	0.014	7.4%
7	.201	.186	.171	0.17	0.182	0.015	8.0%
Mean	0.198	0.185	0.168	0.185	0.184		
S.D.	0.003	0.003	0.004	0.010			
C.O.V.	1.4%	1.5%	2.5%	5.2%			
B1	.195	.183	.156	0.21	0.186	0.023	12.3%
2	.201	.183	.159	0.19	0.183	0.018	9.7%
3	.198	.186	.162	0.18	0.182	0.015	8.2%
4	.198	.192	.171	0.18	0.185	0.012	6.5%
5	.195	.186	.165	0.18	0.182	0.013	6.9%
6	.201	.189	.189	0.18	0.189	0.009	4.6%
7	.195	.188	.186	0.19	0.190	0.004	2.0%
Mean	0.198	0.186	0.170	0.188	0.186		
S.D.	0.003	0.003	0.013	0.011			
C.O.V.	1.4%	1.7%	7.7%	5.9%			

Geophone 4

	Dist 19	TTI	D-10 Old	D-10 New	Mean	S.D.	C.O.V.
Site 5							
A 1	.52	.56	.47	0.53	0.520	0.037	7.2%
2	.54	.53	.47	0.54	0.520	0.034	6.5%
3	.54	.51	.49	0.56	0.525	0.031	5.9%
4	.54	.52	.46	0.53	0.513	0.036	7 0%
5	.54	.53	.52	0.54	0.533	0.010	1.8%
6	.53	.56	.52	0.53	0.535	0.017	3.2%
7	.53	.51	.51	0.53	0.520	0.012	2.2%
Mean	0.543	0.531	0.491	0.5371	0.523		
S.D.	0.008	0.021	0.025	0.011			
C.O.V.	1.5%	4%	5.2%	2.1%			
B 1	.48	.47	.46	0.48	0.473	0.010	2 %
2	.52	.48	.42	0.50	0.480	0.043	9 %
3	.51	.48	.43	0.51	0.483	0.038	7.8%
4	.49	.48	.44	0.48	0.473	0.022	4.7%
5	.50	.48	.44	0.49	0.478	0.026	5.5%
6	.48	.48	.45	0.48	0.473	0.015	3.2%
7	.49	.48	.44	0.46	0.468	0.022	4.7%
Mean	0.496	0.479	0.440	0.485	0.475		
S.D.	0.015	0.004	0.013	0.016			
C.O.V.	3%	0.8%	2.9%	3.3%			
Site 6A							
1	.47	.46	.42	0.47	0.455	0.024	5.2%
2	.47	.46	.40	0.45	0.445	0.031	7.0%
3	.48	.46	.43	0.48	0.463	0.024	5.1%
4	.47	.47	.44	0.45	0.458	0.015	3.3%
5	.47	.48	.44	0.45	0.460	0.018	4.0%
6	.46	.47	.44	0.42	0.448	0.022	4.9%
7	.45	.46	.42	0.42	0.435	0.024	5.5%
Mean	0.467	0.466	0.427	0.442	0.452		
S.D.	0.010	0.008	0.015	0.025			
C.O.V.	2%	1.7%	3.5%	5.6%			
Spot B1	.53	.51	.44	0.53	0.503	0.043	8.5%
2	.52	.52	.44	0.50	0.495	0.038	7.6%
3	.43	.52	.48	0.51	0.485	0.040	8.3%
4	.52	.51	.46	0.51	0.500	0.027	5.4%
5	.50	.49	.47	0.50	0.490	0.014	2.9%
6	.50	.50	.47	0.48	0.488	0.015	3.1%
7	.50	.50	.45	0.48	0.483	0.024	4.9%
Mean	0.500	0.507	0.459	0.50	0.492		
S.D.	0.033	0.011	0.016	0.018			
C.O.V.	6.6%	2.2%	3.4%	3.5%			

4 Dynaflect
Correlation
Geophone 5

	Dist 19	TTI	D-10 Old	D-10 New	Mean	S.D.	C.O.V.
Site 1							
A 1	0.246	.240	.23	0.23	0.237	0.008	3.3%
2	0.24	.240	.24	0.22	0.235	0.010	4.3%
3	0.27	.237	.23	0.23	0.242	0.019	7.9%
4	0.27	.234	.23	0.23	0.241	0.019	8.1%
5	0.27	.237	.26	0.23	0.249	0.019	7.6%
6	0.27	.231	.25	0.22	0.243	0.022	9.0%
7	0.27	.237	.25	0.20	0.239	0.029	12.3%
Mean	0.262	0.237	0.241	0.223	0.241		
S.D.	0.013	0.003	0.012	0.011			
C.O.V.	5.1%	1.4%	5.0%	5.0%			
B 1	0.27	.246	.26	0.23	0.252	0.017	6.9%
2	0.27	.252	.24	0.23	0.248	0.017	6.9%
3	0.27	.246	.25	0.25	0.254	0.011	4.3%
4	0.27	.240	.25	0.24	0.250	0.014	5.7%
5	0.27	.249	.26	0.25	0.257	0.010	3.8%
6	0.27	.243	.26	0.24	0.253	0.014	5.6%
7	0.27	.252	.26	0.22	0.251	0.022	8.6%
Mean	0.270	0.247	0.254	0.237	0.252		
S.D.	0.000	0.004	0.008	0.011			
C.O.V.	0%	1.8%	3.1%	4.7%			
Site 2							
A 1	0.32	.33	.30	0.31	0.315	0.013	4.1%
2	0.33	.32	.30	0.32	0.318	0.013	4.0%
3	0.33	.33	.30	0.31	0.318	0.015	4.7%
4	0.35	.33	.32	0.33	0.333	0.013	3.8%
5	0.35	.34	.31	0.30	0.325	0.024	7.3%
6	0.34	.34	.31	0.30	0.323	0.021	6.4%
7	0.35	.34	.31	0.29	0.323	0.028	8.5%
Mean	0.339	0.333	0.307	0.309	0.322		
S.D.	0.012	0.008	0.008	0.013			
C.O.V.	3.6%	2.3%	2.5%	4.4%			
B 1	0.33	.35	.31	0.32	0.328	0.017	5.2%
2	0.36	.33	.30	0.34	0.333	0.025	7.5%
3	0.35	.35	.32	0.35	0.343	0.015	4.4%
4	0.36	.35	.32	0.35	0.345	0.017	5.0%
5	0.38	.35	.32	0.33	0.345	0.026	7.7%
6	0.36	.35	.33	0.32	0.340	0.018	5.4%
7	0.36	.35	.33	0.31	0.338	0.022	6.6%
Mean	0.357	0.347	0.319	0.331	0.339		
S.D.	0.015	0.008	0.011	0.016			
C.O.V.	4.2%	2.2%	3.4%	4.8%			

Geophone 5

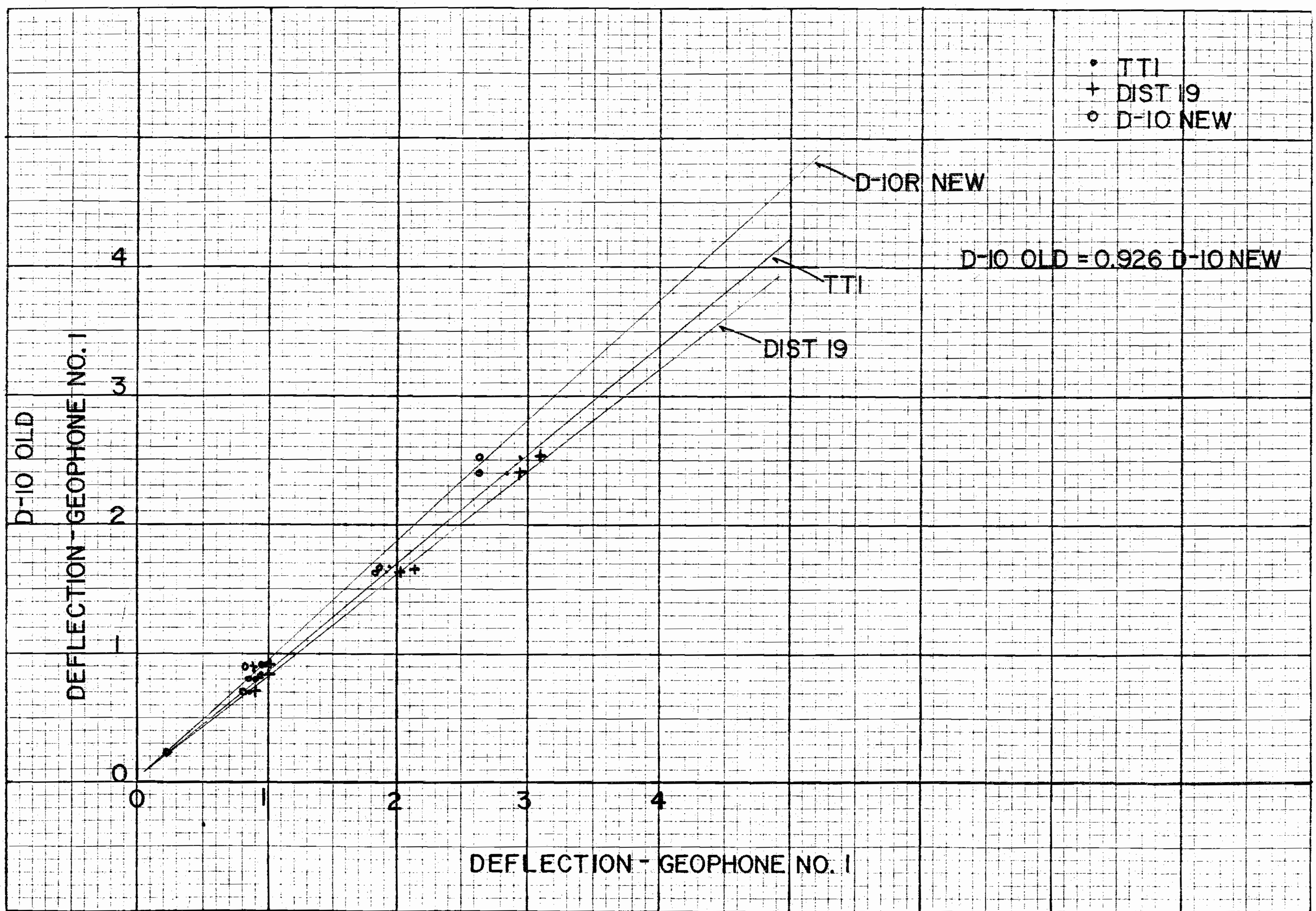
	Dist 19	TTI	D-10 Old	D-10 New	Mean	S.D.	C.O.V.
Site 3							
A 1	0.27	.252	.24	0.24	0.251	0.014	5.6%
2	0.27	.258	.26	0.24	0.257	0.012	4.9%
3	0.28	.258	.25	0.26	0.262	0.013	4.9%
4	0.27	.258	.26	0.24	0.257	0.012	4.9%
5	0.28	.255	.27	0.24	0.261	0.018	6.7%
6	0.27	.252	.26	0.23	0.253	0.017	6.7%
7	0.27	.249	.27	0.23	0.255	0.019	7.5%
Mean	0.273	0.255	0.259	0.240	0.257		
S.D.	0.005	0.004	0.011	0.010			
C.O.V.	1.8%	1.4%	4.1%	4.2%			
B 1	0.27	.246	.25	0.24	0.252	0.013	5.2%
2	0.27	.252	.25	0.25	0.256	0.010	3.8%
3	0.27	.234	.25	0.25	0.251	0.015	5.9%
4	0.27	.255	.25	0.24	0.254	0.013	4.9%
5	0.27	.252	.26	0.24	0.256	0.013	5.0%
6	0.27	.246	.27	0.23	0.254	0.020	7.7%
7	0.27	.252	.27	0.24	0.258	0.015	5.7%
Mean	0.270	0.248	0.257	0.242	0.254		
S.D.	0.000	0.007	0.010	0.007			
C.O.V.	0%	2.9%	3.7%	2.9%			
Site 4A							
1	.186	.162	.144	0.16	0.163	0.017	10.6%
2	.177	.162	.147	0.16	0.162	0.012	7.6%
3	.177	.165	.147	0.18	0.167	0.015	9.0%
4	.183	.165	.153	0.17	0.168	0.012	7.4%
5	.183	.168	.150	0.16	0.165	0.014	8.4%
6	.180	.168	.147	0.16	0.164	0.014	8.5%
7	.180	.168	.147	0.15	0.163	0.014	8.6%
Mean	0.181	0.165	0.149	0.163	0.165		
S.D.	0.003	0.003	0.003	0.010			
C.O.V.	1.8%	1.6%	2.3%	5.8%			
B1	.186	.168	.147	0.19	0.173	0.020	11.4%
2	.186	.168	.150	0.19	0.174	0.018	10.6%
3	.183	.174	.156	0.17	0.171	0.011	6.6%
4	.183	.177	.153	0.17	0.171	0.013	7.6%
5	.186	.162	.150	0.18	0.170	0.017	9.7%
6	.189	.174	.159	0.16	0.171	0.014	8.2%
7	.183	.168	.174	0.17	0.174	0.007	3.8%
Mean	0.185	0.170	0.156	0.175	0.172		
S.D.	0.002	0.005	0.009	0.011			
C.O.V.	1.2%	3.0%	5.8%	6.5%			

Geophone 5

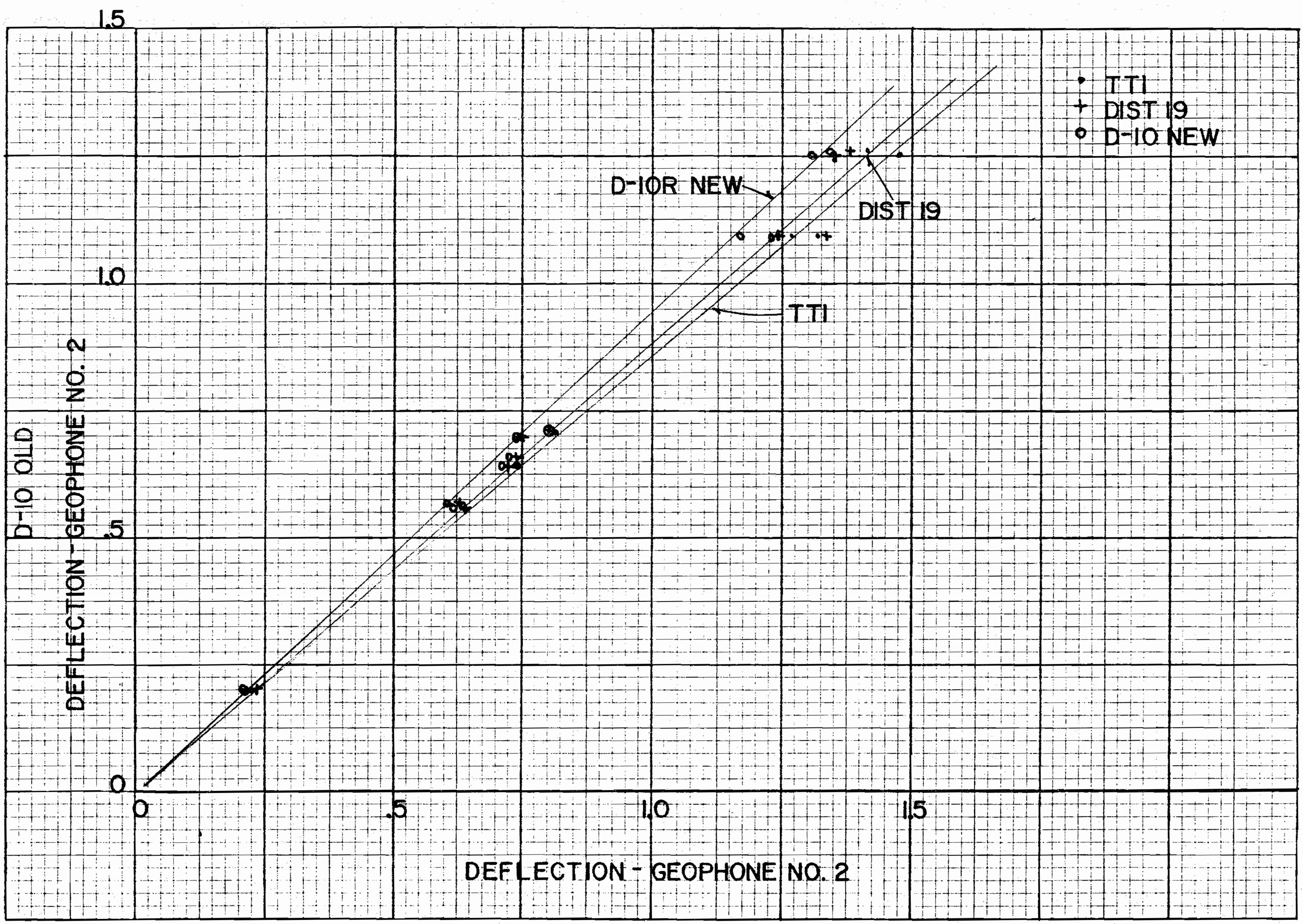
	Dist 19	TTI	D-10 Old	D-10 New	Mean	S.D.	C.O.V.
Site 5							
A 1	.43	.47	.40	0.43	0.433	0.029	6.6%
2	.46	.44	.40	0.44	0.435	0.025	5.8%
3	.46	.42	.41	0.45	0.435	0.024	5.5%
4	.45	.44	.39	0.43	0.428	0.026	6.1%
5	.45	.44	.44	0.44	0.443	0.005	1.1%
6	.45	.46	.43	0.43	0.443	0.015	3.4%
7	.45	.42	.43	0.44	0.435	0.013	3.0%
Mean	0.450	0.441	0.414	0.437	0.436		
S.D.	0.010	0.019	0.019	0.008			
C.O.V.	2.2%	4.2%	4.6%	1.7%			
B 1	.39	.38	.38	0.39	0.385	0.006	1.5%
2	.43	.40	.35	0.40	0.395	0.033	8.4%
3	.41	.39	.35	0.41	0.390	0.028	7.3%
4	.42	.39	.36	0.38	0.388	0.025	6.4%
5	.42	.39	.37	0.39	0.393	0.021	5.2%
6	.41	.39	.36	0.38	0.385	0.021	5.4%
7	.41	.38	.37	0.37	0.383	0.019	4.9%
Mean	0.413	0.389	0.363	0.388	0.388		
S.D.	0.013	0.007	0.011	0.013			
C.O.V.	3%	1.8%	3.1%	3.5%			
Site 6A							
1	.36	.34	.32	0.35	0.343	0.017	5.0%
2	.36	.35	.31	0.34	0.340	0.022	6.4%
3	.37	.35	.33	0.36	0.353	0.017	4.8%
4	.37	.35	.33	0.33	0.345	0.019	5.6%
5	.36	.36	.33	0.33	0.345	0.017	5.0%
6	.35	.36	.33	0.31	0.338	0.022	6.6%
7	.35	.35	.33	0.31	0.335	0.019	5.7%
Mean	0.360	0.351	0.326	0.333	0.343		
S.D.	0.008	0.007	0.008	0.019			
C.O.V.	2.3%	2.0%	2.4%	5.7%			
Spot B1	.40	.38	.35	0.40	0.383	0.024	6.2%
2	.40	.39	.34	0.37	0.375	0.026	7.1%
3	.40	.39	.37	0.38	0.385	0.013	3.4%
4	.40	.39	.37	0.38	0.385	0.013	3.4%
5	.39	.38	.36	0.38	0.378	0.013	3.3%
6	.38	.39	.37	0.36	0.375	0.013	3.4%
7	.39	.38	.36	0.36	0.373	0.015	4.0%
Mean	0.394	0.386	0.360	0.375	0.379		
S.D.	0.008	0.005	0.012	0.014			
C.O.V.	2.0%	1.4%	3.2%	3.7%			

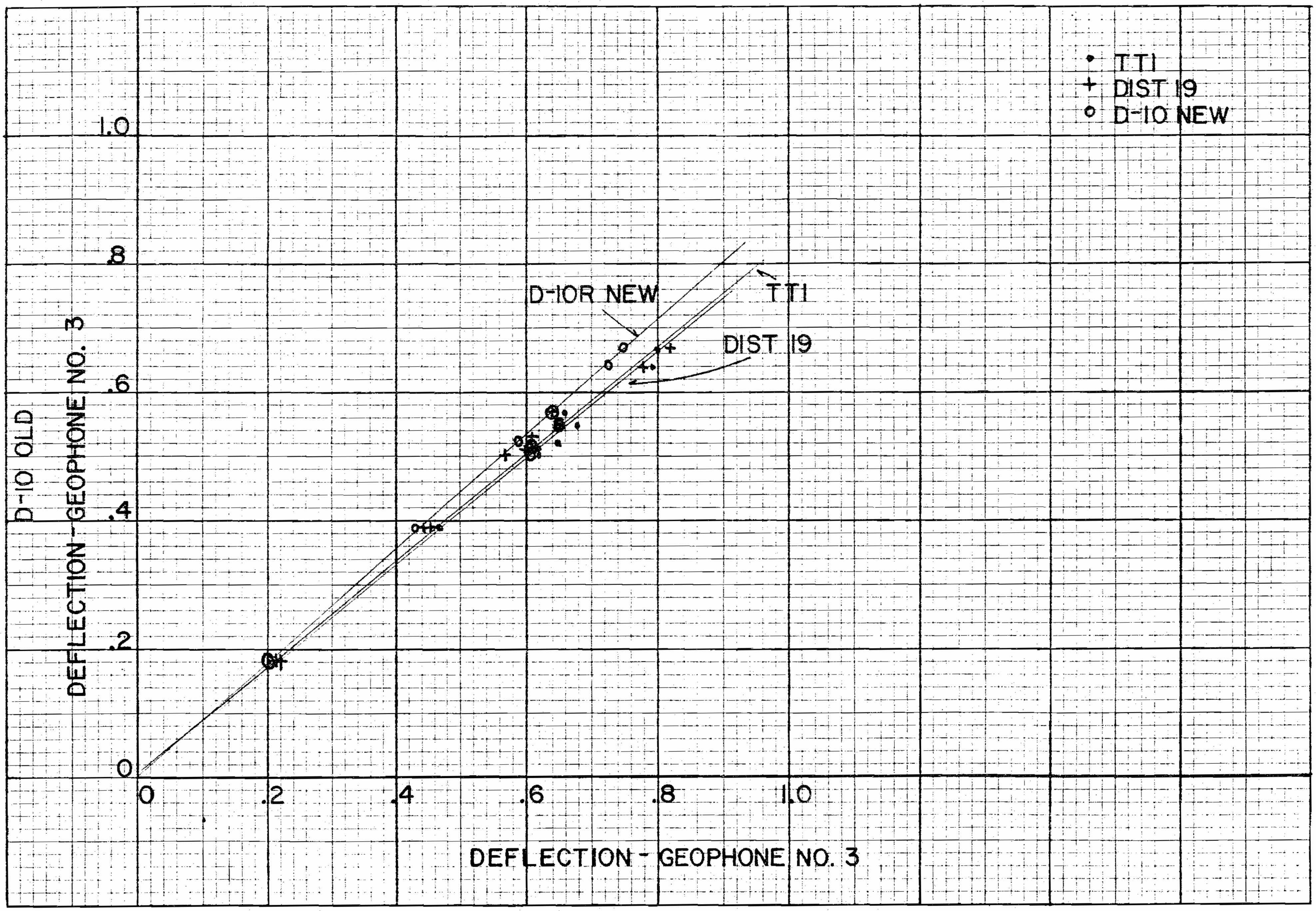
APPENDIX F

Correlation of D-10R, Old Dynaflect
with Three Other Dynaflects

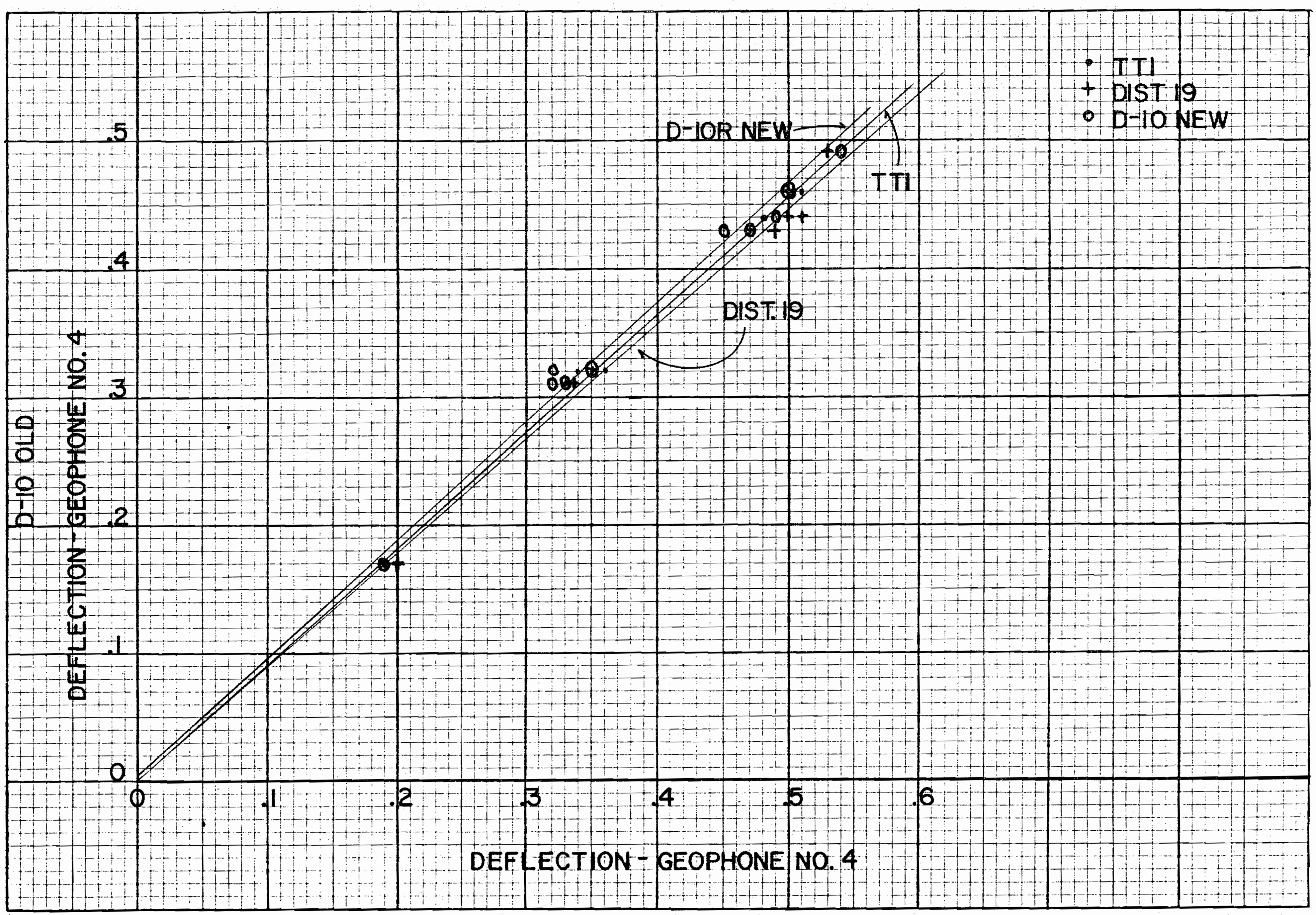


• TTI
+ DIST 19
○ D-10 NEW
D-10R NEW
TTI
DIST 19
D-10 OLD = 0.926 D-10 NEW
D-10 OLD
DEFLECTION - GEOPHONE NO. 1
0
1
2
3
4
DEFLECTION - GEOPHONE NO. 1

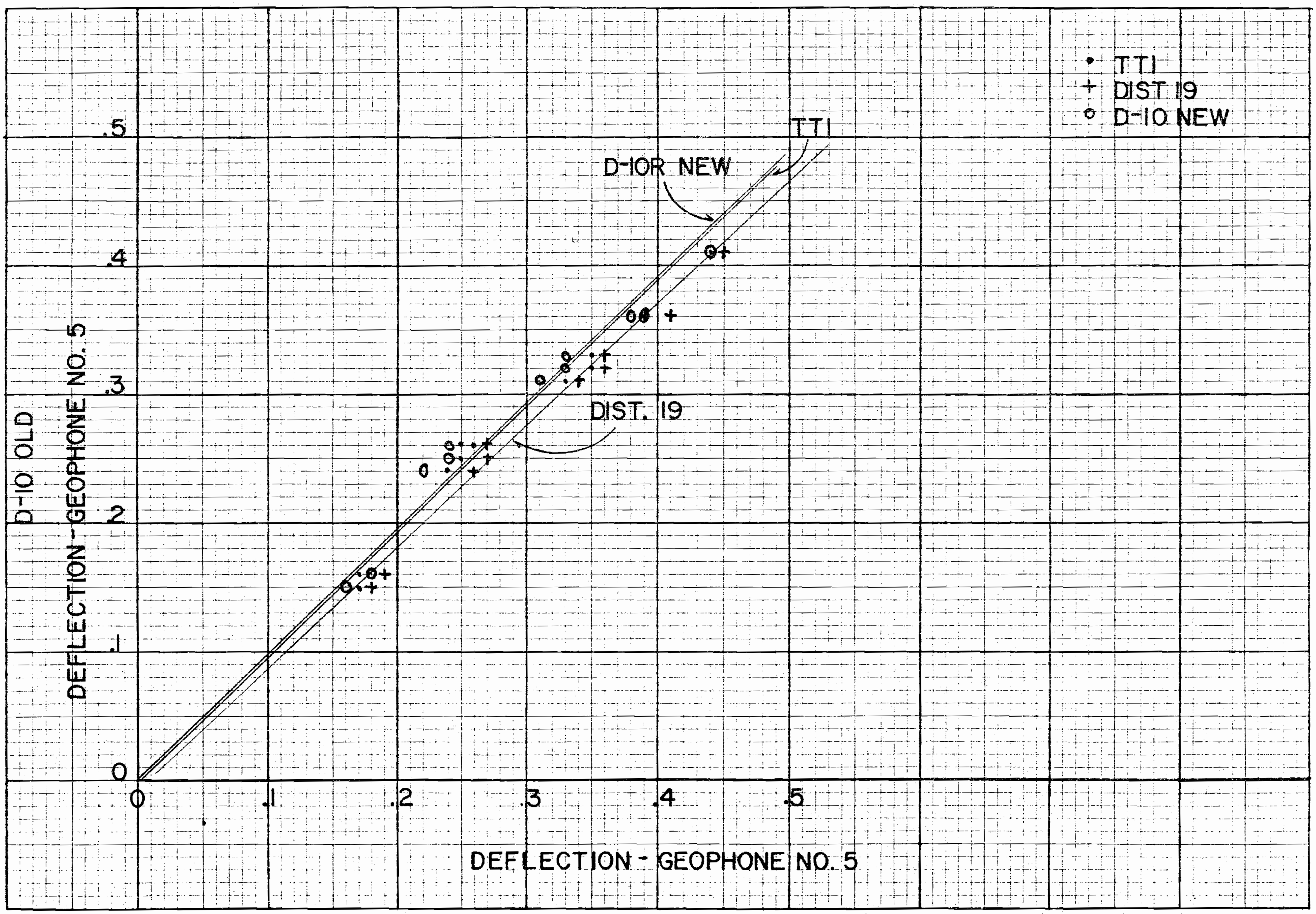

TTI
DIST 19
D-10 NEW
D-10R NEW
DIST 19
TTI
D-10 OLD
DEFLECTION - GEOPHONE NO. 2
DEFLECTION - GEOPHONE NO. 2
1.5
1.0
.5
0
0
.5
1.0
1.5



• TTI
+ DIST 19
o D-10 NEW
D-10R NEW
TTI
DIST 19
D-10 OLD
DEFLECTION - GEOPHONE NO. 3
1.0
.8
.6
.4
.2
0
0
.2
.4
.6
.8
1.0
DEFLECTION - GEOPHONE NO. 3



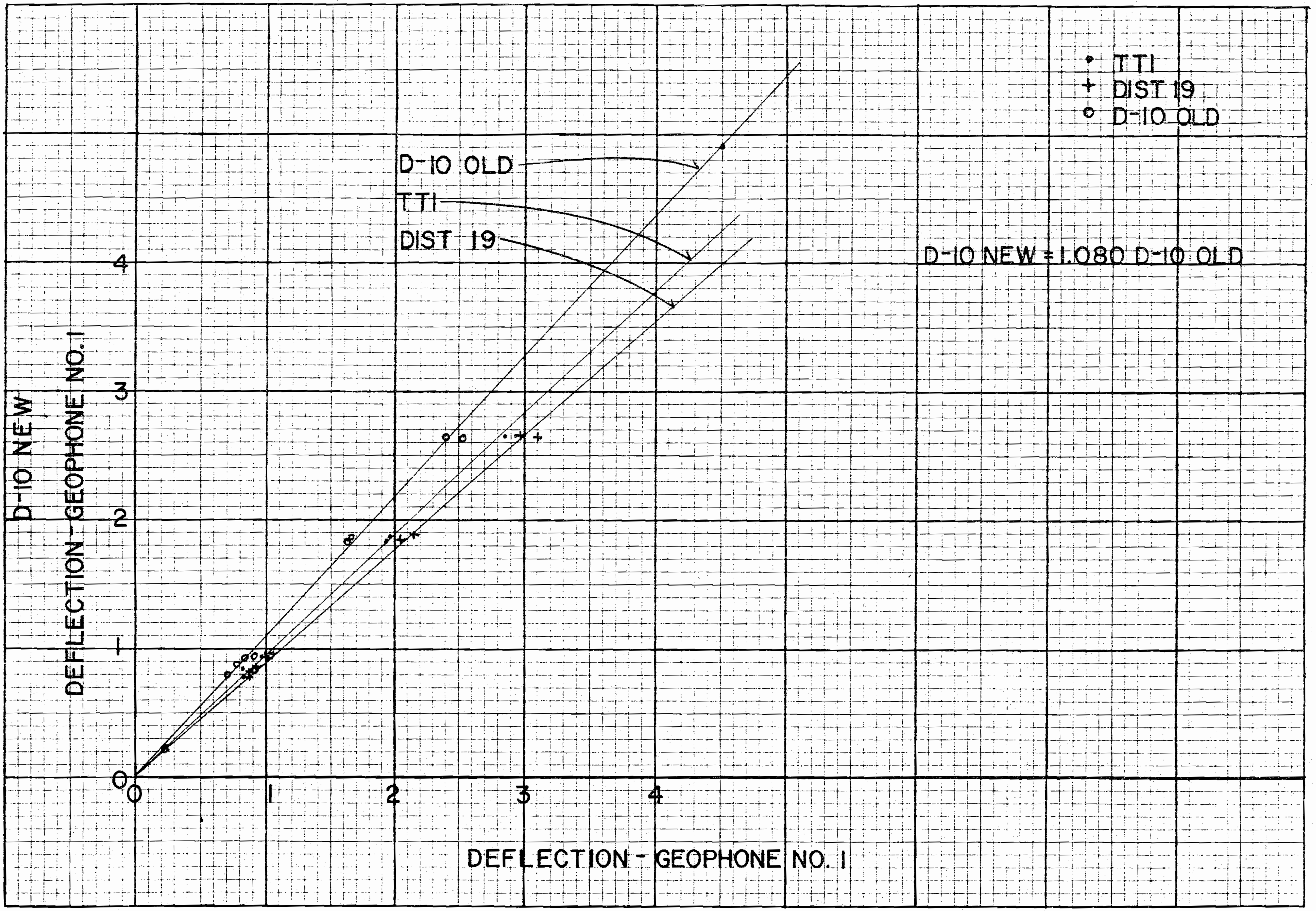
• TTI
+ DIST 19
o D-10 NEW
D-10R NEW
TTI
DIST. 19
D-10 OLD
DEFLECTION - GEOPHONE NO. 4
0
.1
.2
.3
.4
.5
.6
DEFLECTION - GEOPHONE NO. 4



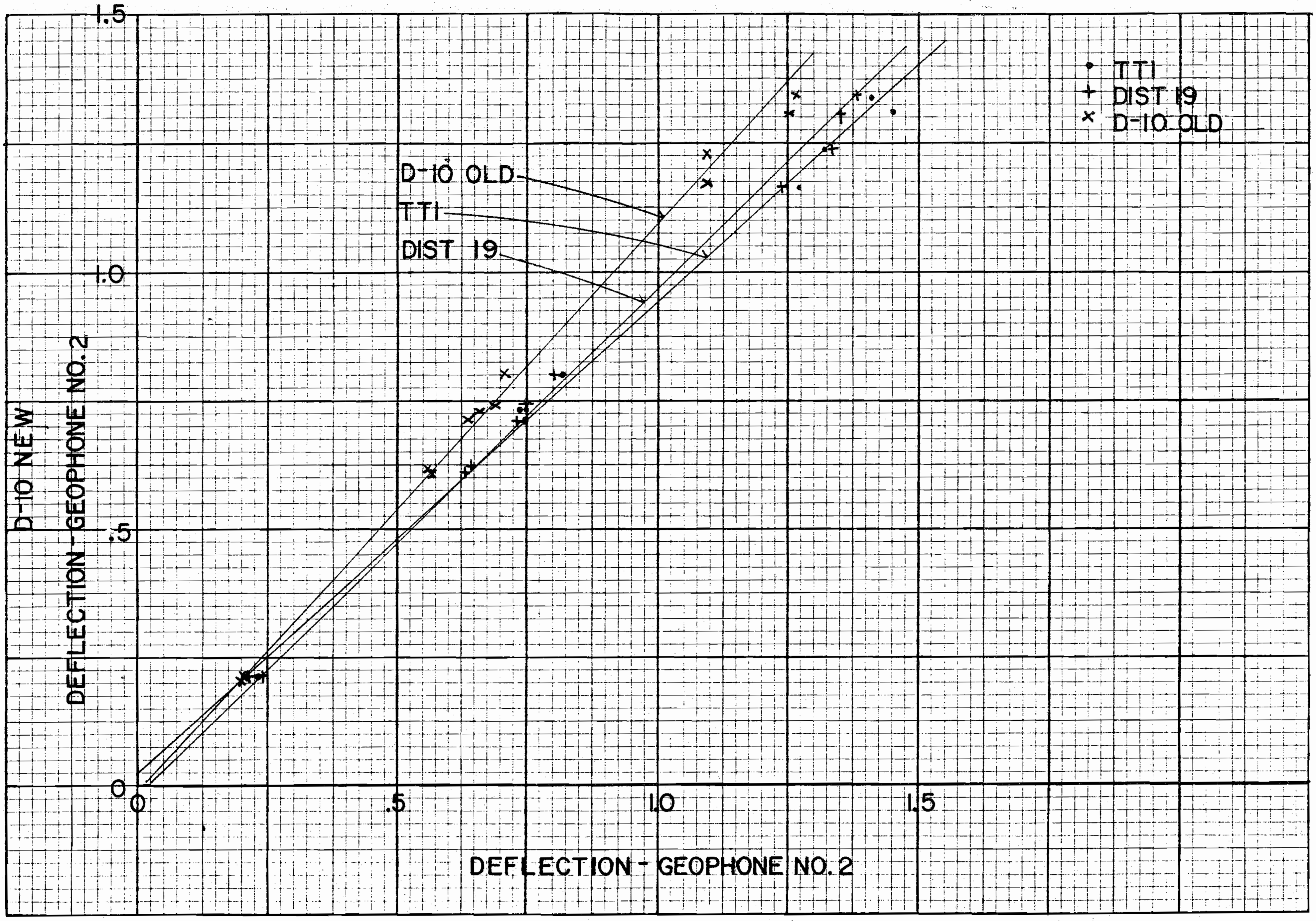
• TTI
+ DIST 19
o D-10 NEW
TTI
D-10R NEW
DIST. 19
D-10 OLD
DEFLECTION - GEOPHONE NO. 5
DEFLECTION - GEOPHONE NO. 5
0
.1
.2
.3
.4
.5

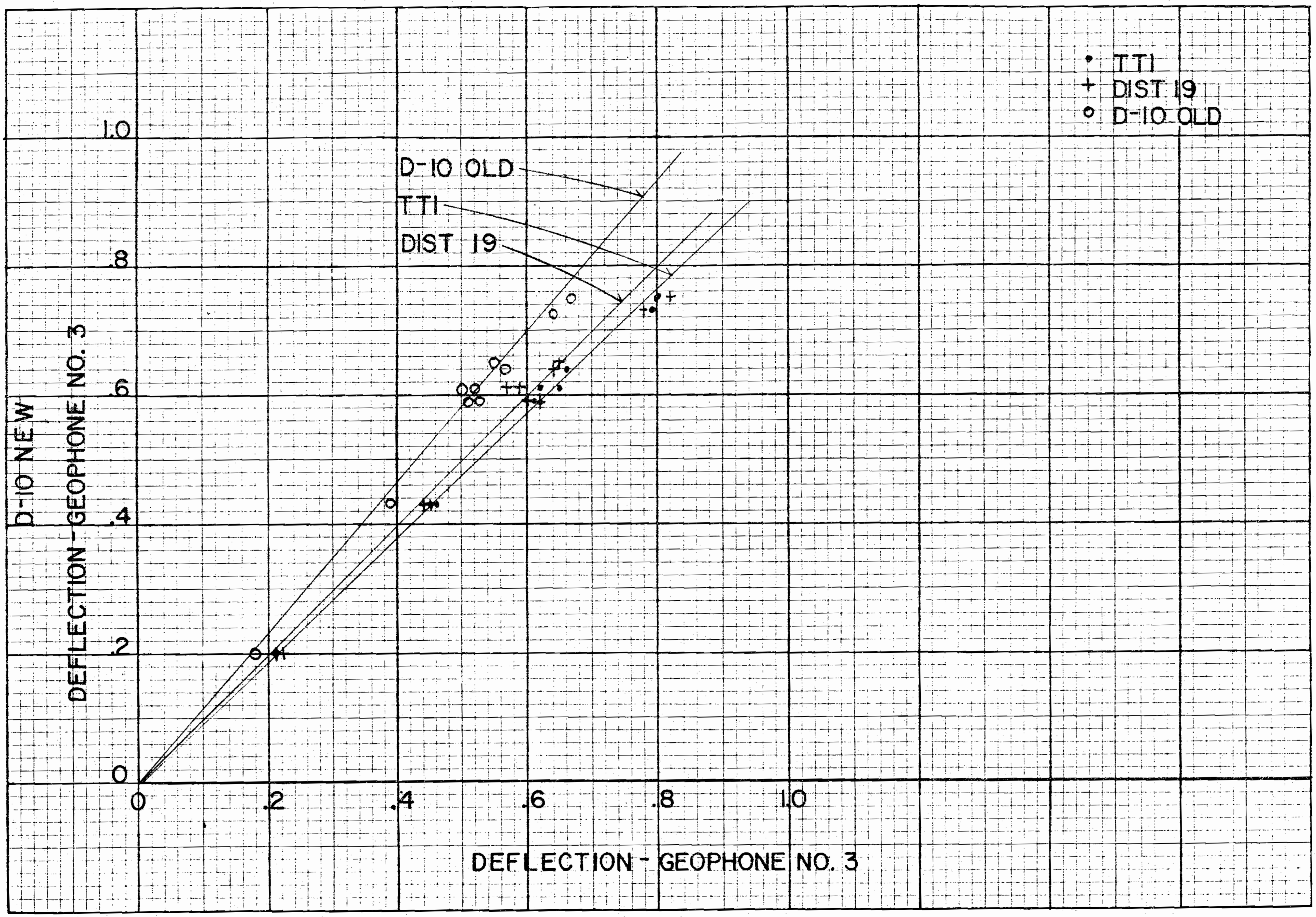
APPENDIX G

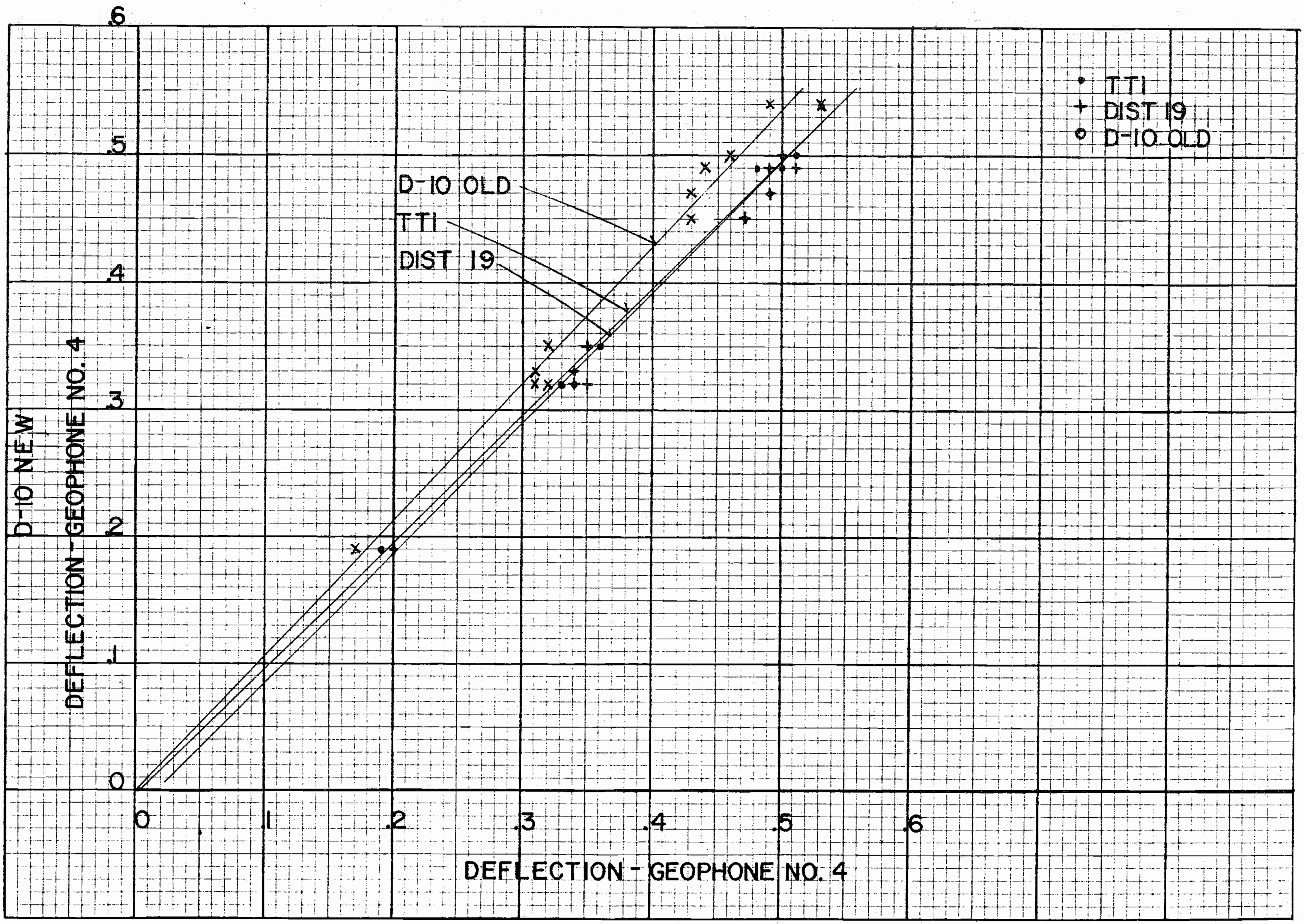
Correlation of D-10 New Dynaflect with Three Other Dynaflects

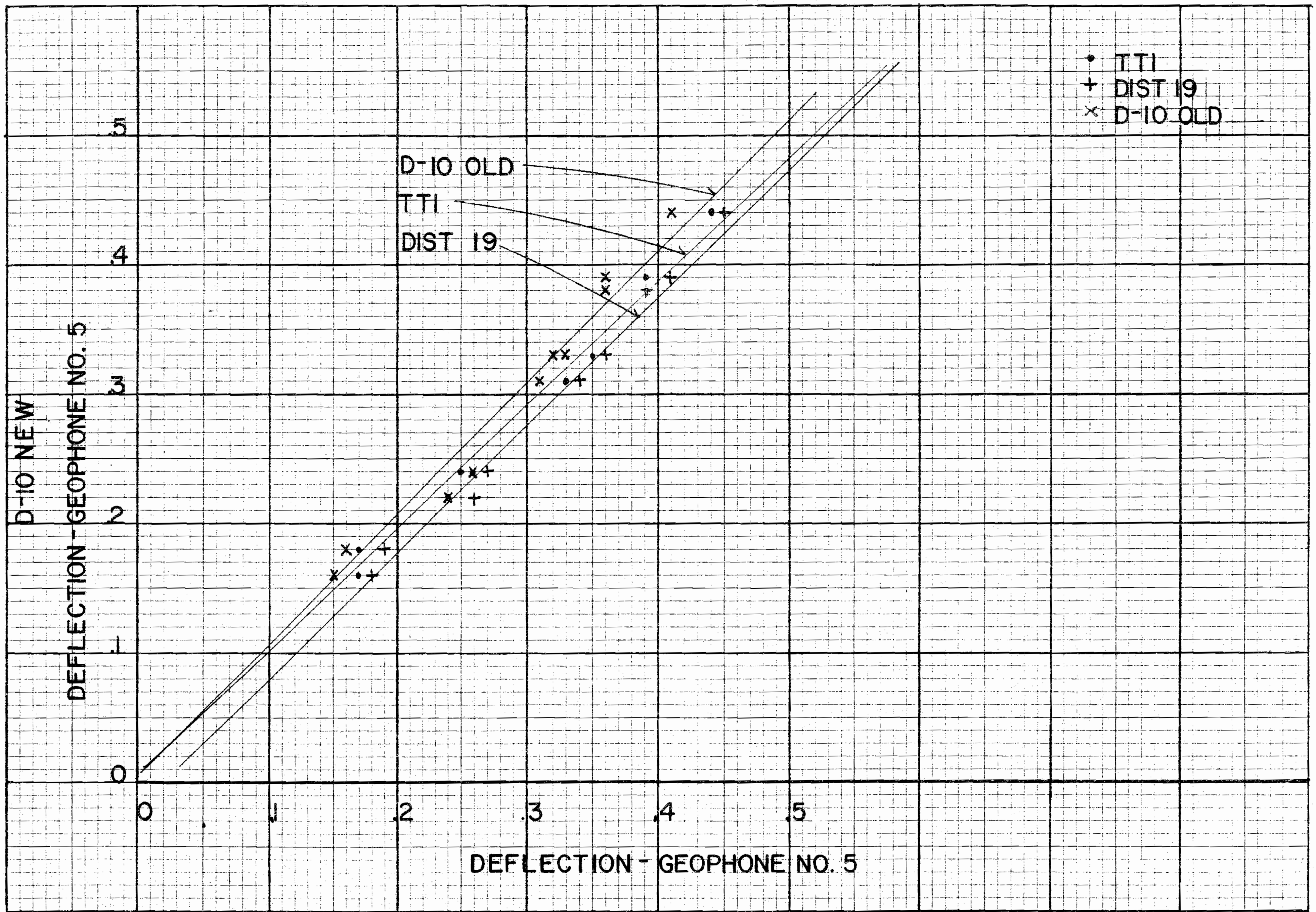


• TTI
+ DIST 19
o D-10 OLD
D-10 OLD
TTI
DIST 19
D-10 NEW = 1.080 D-10 OLD
D-10 NEW
DEFLECTION - GEOPHONE NO. 1
0
1
2
3
4
DEFLECTION - GEOPHONE NO. 1


1.5
1.0
.5
0
0
.5
1.0
1.5
D-10 NEW
DEFLECTION - GEOPHONE NO. 2
DEFLECTION - GEOPHONE NO. 2
D-10 OLD
TTI
DIST 19
TTI
DIST 19
D-10 OLD

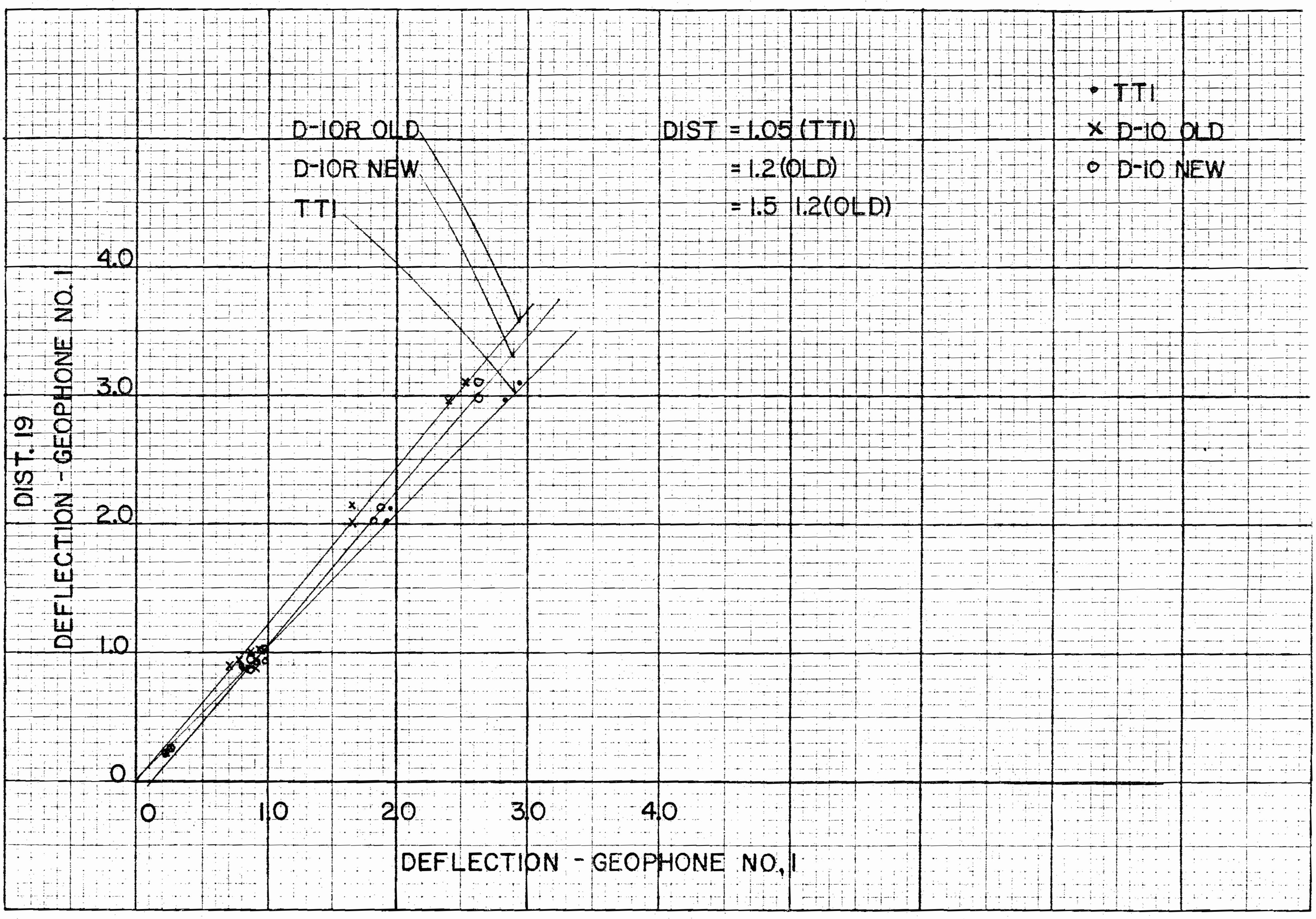

• TTI
+ DIST 19
o D-10 OLD
D-10 OLD
TTI
DIST 19
1.0
.8
.6
.4
.2
0
0
.2
.4
.6
.8
1.0
D-10 NEW
DEFLECTION - GEOPHONE NO. 3
DEFLECTION - GEOPHONE NO. 3


TTI
DIST 19
D-10 OLD
D-10 OLD
TTI
DIST 19
D-10 NEW
DEFLECTION - GEOPHONE NO. 4
DEFLECTION - GEOPHONE NO. 4
0
.1
.2
.3
.4
.5
.6

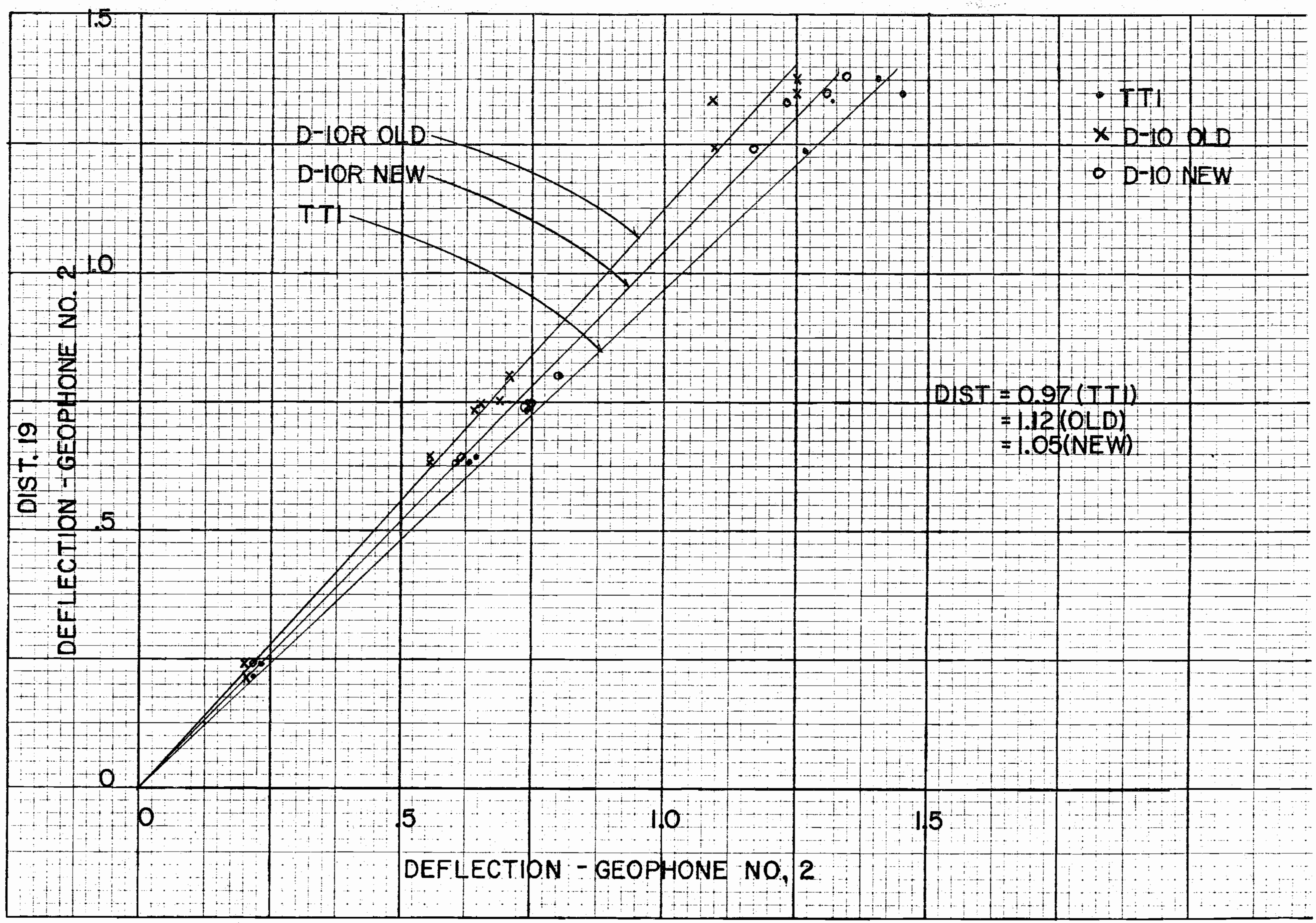

TTI
DIST 19
D-10 OLD
D-10 OLD
TTI
DIST 19
D-10 NEW
DEFLECTION - GEOPHONE NO. 5
0
.1
.2
.3
.4
.5
DEFLECTION - GEOPHONE NO. 5

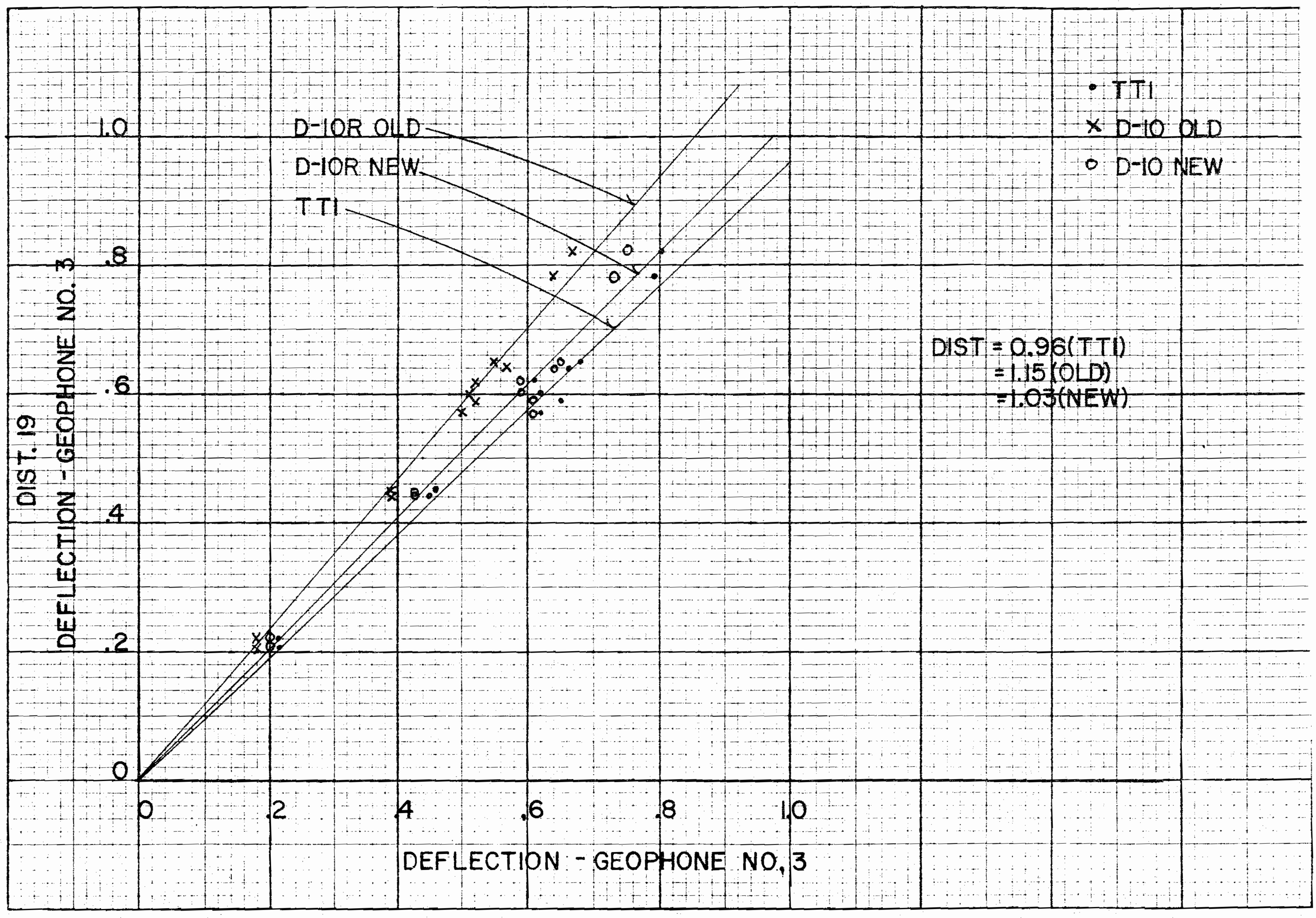
APPENDIX H

Correlation of the District 19 Dynaflect with Three Other Dynaflects

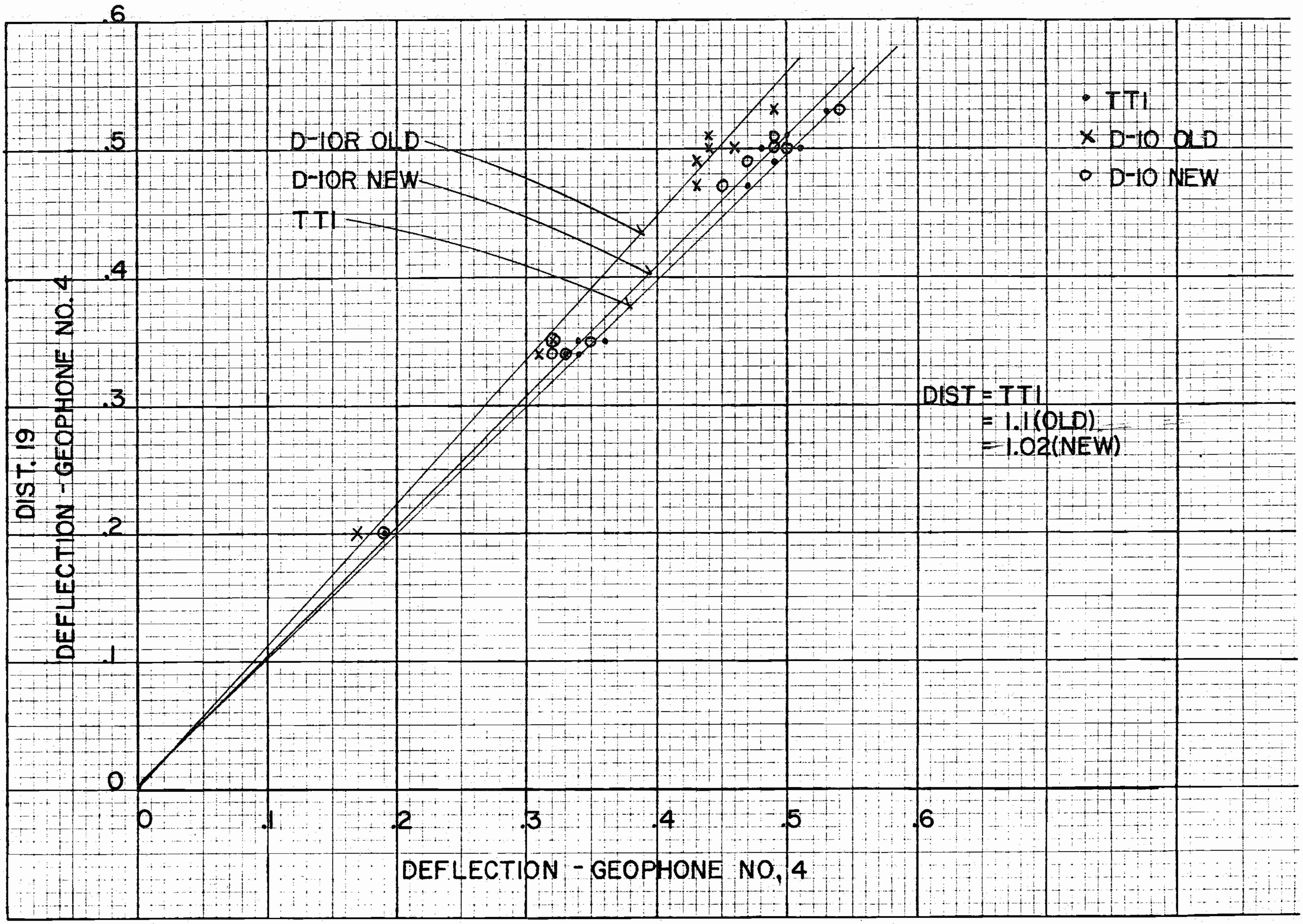


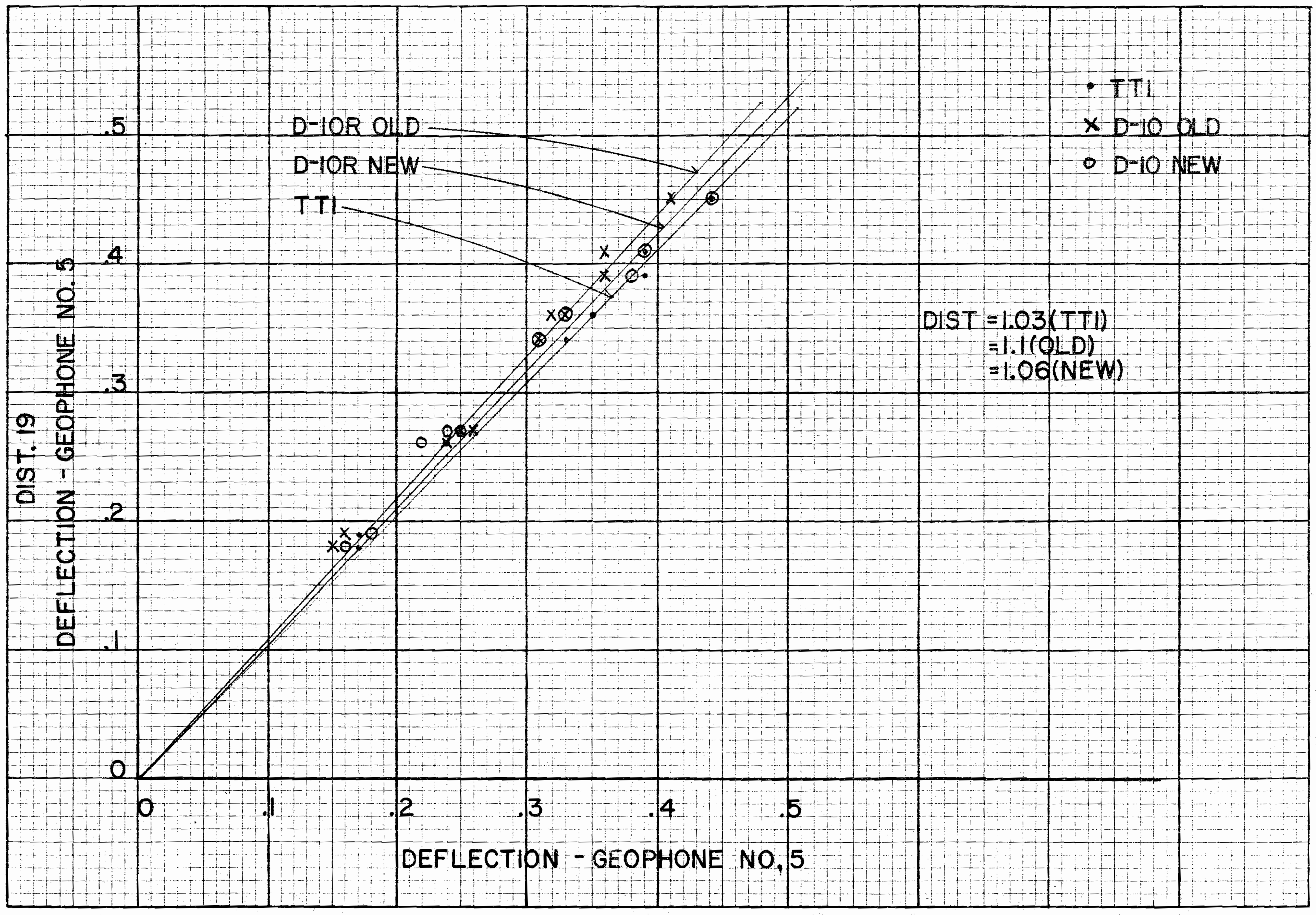
D-10R OLD
D-10R NEW
TTI
DIST = 1.05 (TTI)
= 1.2 (OLD)
= 1.5 1.2(OLD)
• TTI
× D-10 OLD
o D-10 NEW
DIST. 19
DEFLECTION - GEOPHONE NO. 1
4.0
3.0
2.0
1.0
0
0
1.0
2.0
3.0
4.0
DEFLECTION - GEOPHONE NO. 1


1.5
1.0
.5
0
DIST. 19
DEFLECTION - GEOPHONE NO. 2
D-10R OLD
D-10R NEW
TTI
• TTI
× D-10 OLD
o D-10 NEW
DIST = 0.97 (TTI)
= 1.12 (OLD)
= 1.05 (NEW)
0
.5
1.0
1.5
DEFLECTION - GEOPHONE NO. 2



D-10R OLD
D-10R NEW
TTI
• TTI
× D-10 OLD
o D-10 NEW
DIST = 0.96(TTI)
= 1.15(OLD)
= 1.03(NEW)
DIST. 19
DEFLECTION - GEOPHONE NO. 3
1.0
.8
.6
.4
.2
0
0
.2
.4
.6
.8
1.0
DEFLECTION - GEOPHONE NO. 3

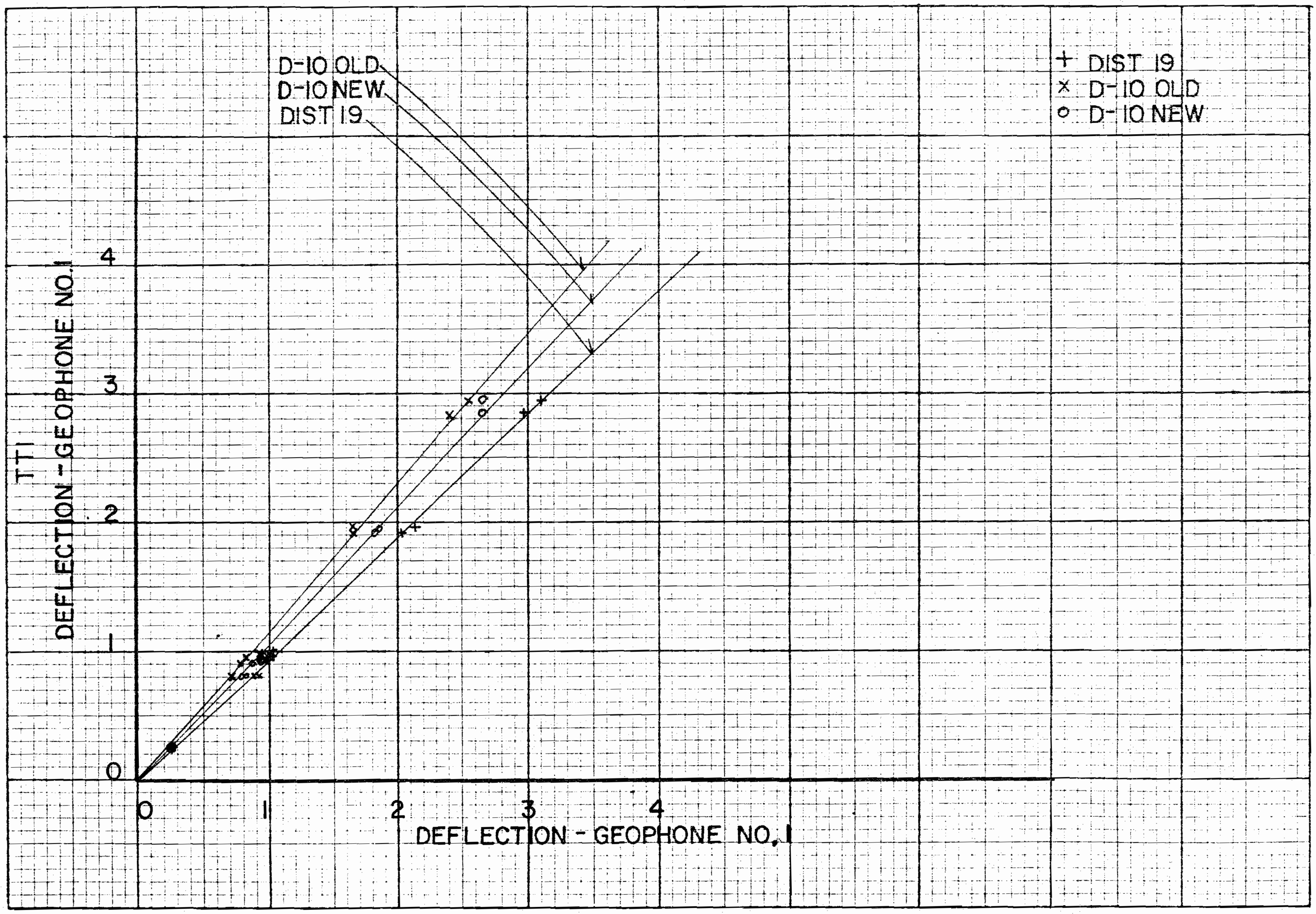

D-10R OLD
D-10R NEW
TTI
• TTI
× D-10 OLD
o D-10 NEW
DIST = TTI
= 1.1(OLD)
= 1.02(NEW)
DIST. 19
DEFLECTION - GEOPHONE NO. 4
DEFLECTION - GEOPHONE NO. 4
0
.1
.2
.3
.4
.5
.6



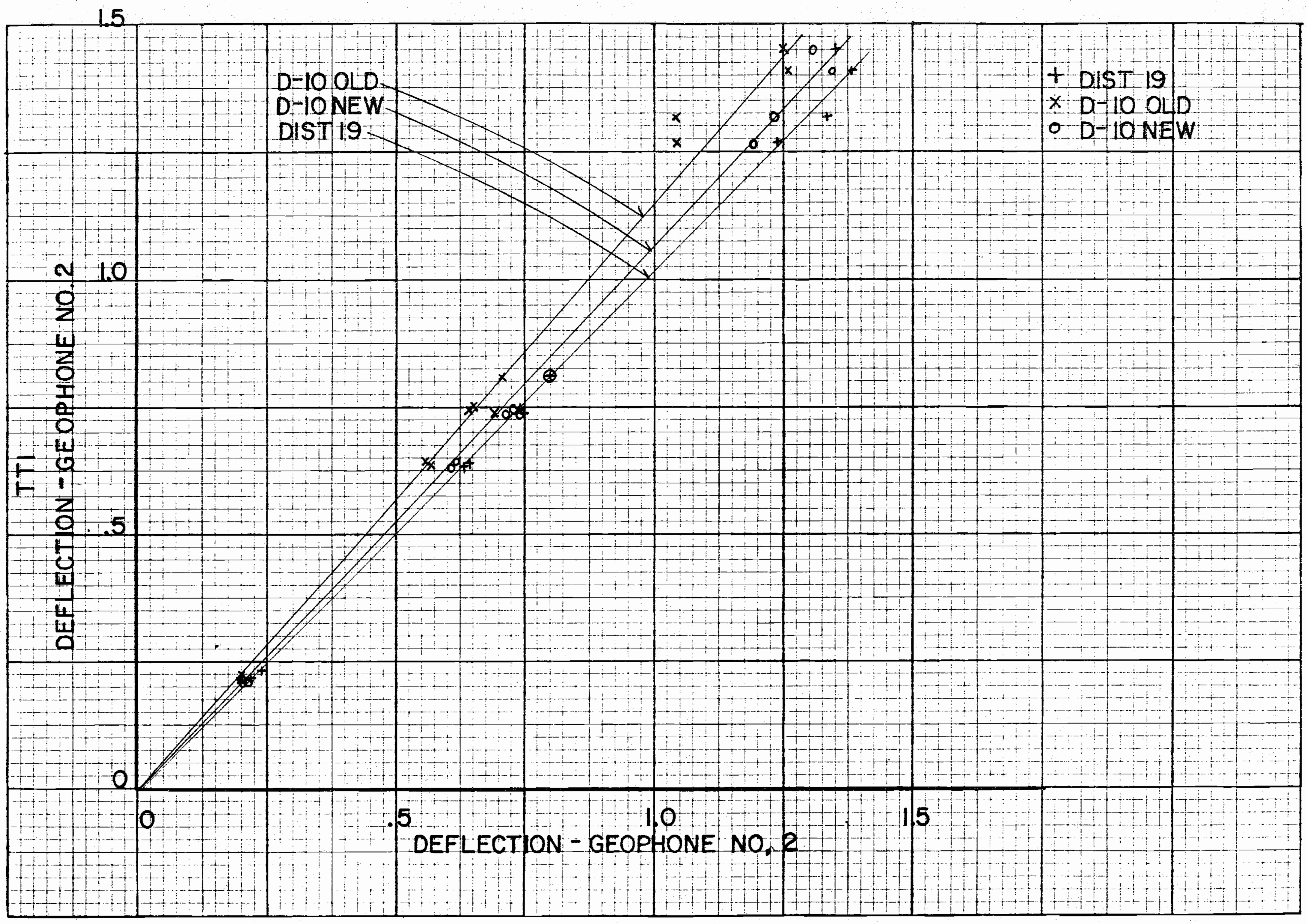
• TTI
× D-10 OLD
o D-10 NEW
D-10R OLD
D-10R NEW
TTI
DIST =1.03(TTI)
=1.1(OLD)
=1.06(NEW)
DIST. 19
DEFLECTION - GEOPHONE NO. 5
DEFLECTION - GEOPHONE NO. 5
0
.1
.2
.3
.4
.5

APPENDIX I

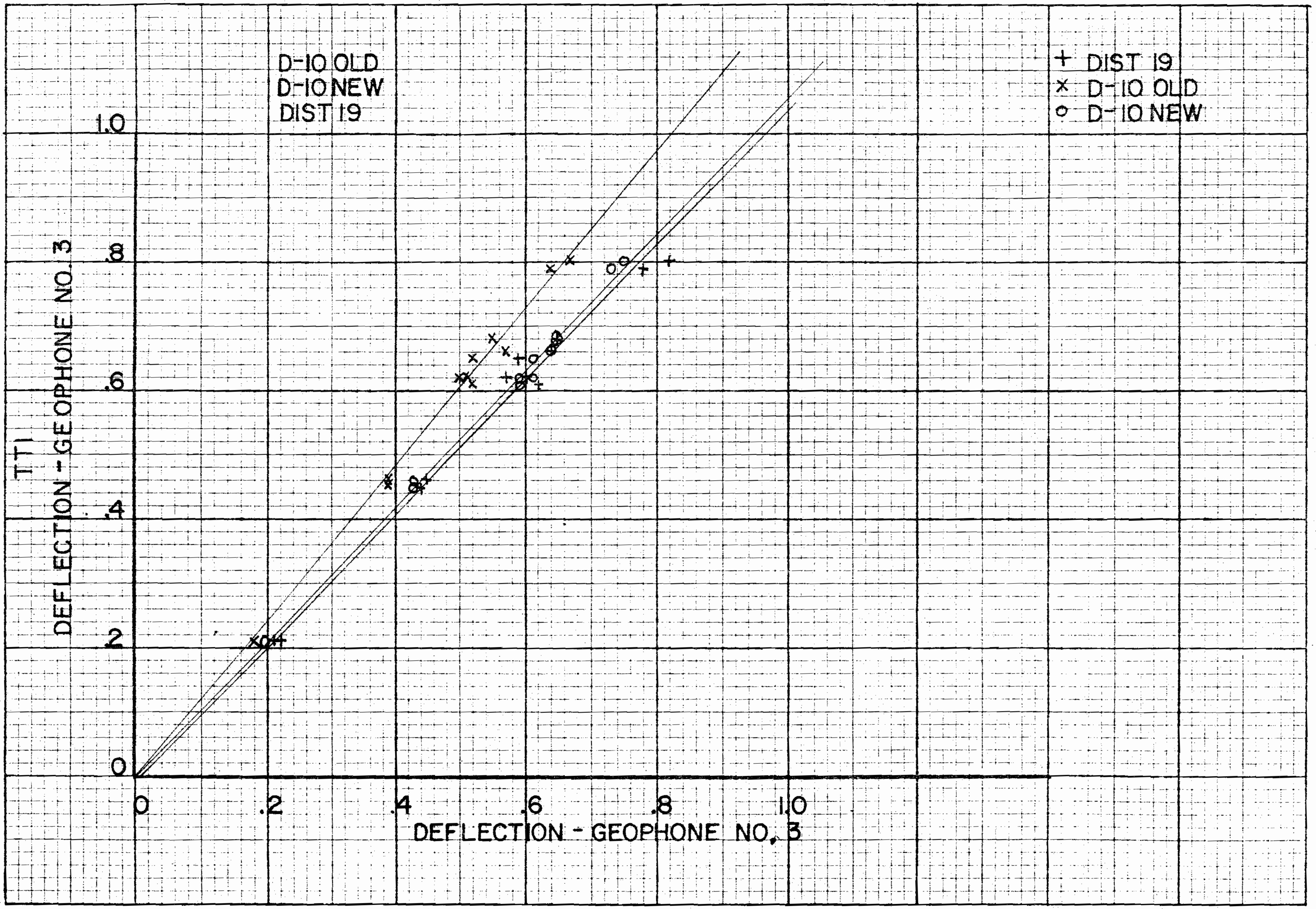
Correlation of the TTI Dynaflect with Three Other Dynaflects

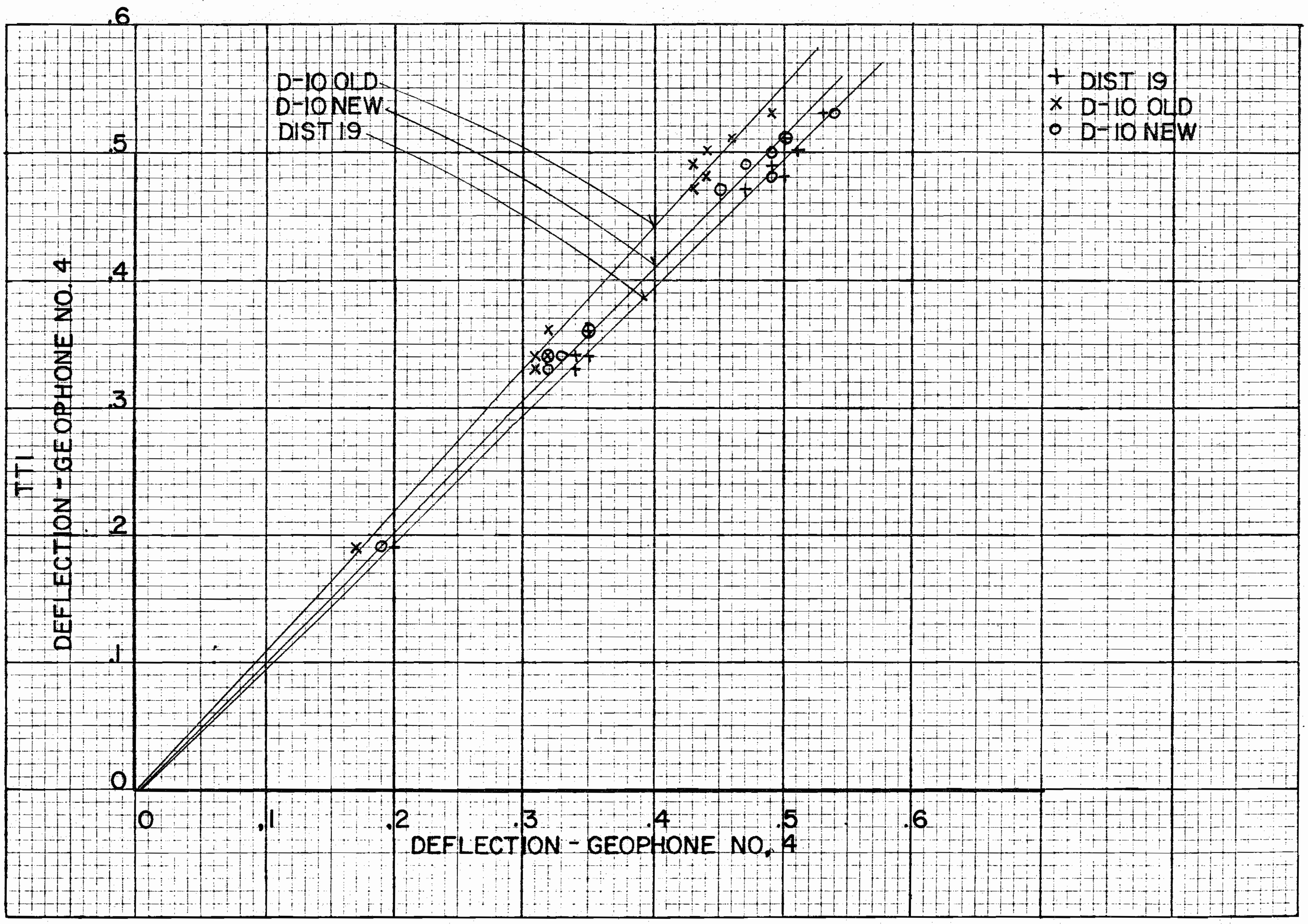


D-10 OLD
D-10 NEW
DIST 19
+ DIST 19
× D-10 OLD
○ D-10 NEW
TTI
DEFLECTION - GEOPHONE NO.1
0
1
2
3
4
DEFLECTION - GEOPHONE NO. 1

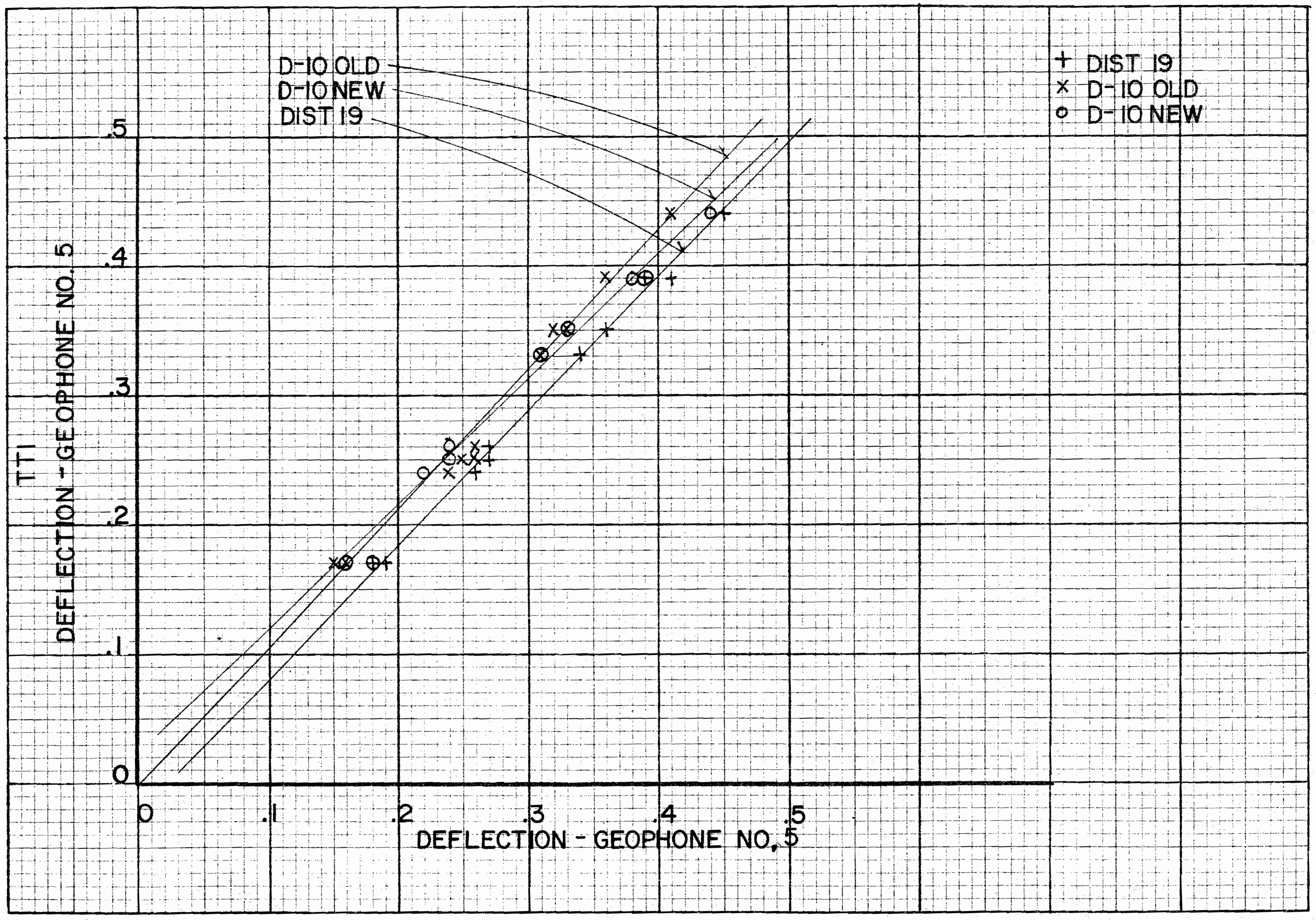


1.5
1.0
.5
0
0
.5
1.0
1.5
D-10 OLD
D-10 NEW
DIST 19
+ DIST 19
× D-10 OLD
o D-10 NEW
TTI
DEFLECTION - GEOPHONE NO. 2
DEFLECTION - GEOPHONE NO. 2


D-10 OLD
D-10 NEW
DIST 19
+ DIST 19
× D-10 OLD
○ D-10 NEW
TTI
DEFLECTION - GEOPHONE NO. 3
1.0
.8
.6
.4
.2
0
0
.2
.4
.6
.8
1.0
DEFLECTION - GEOPHONE NO. 3

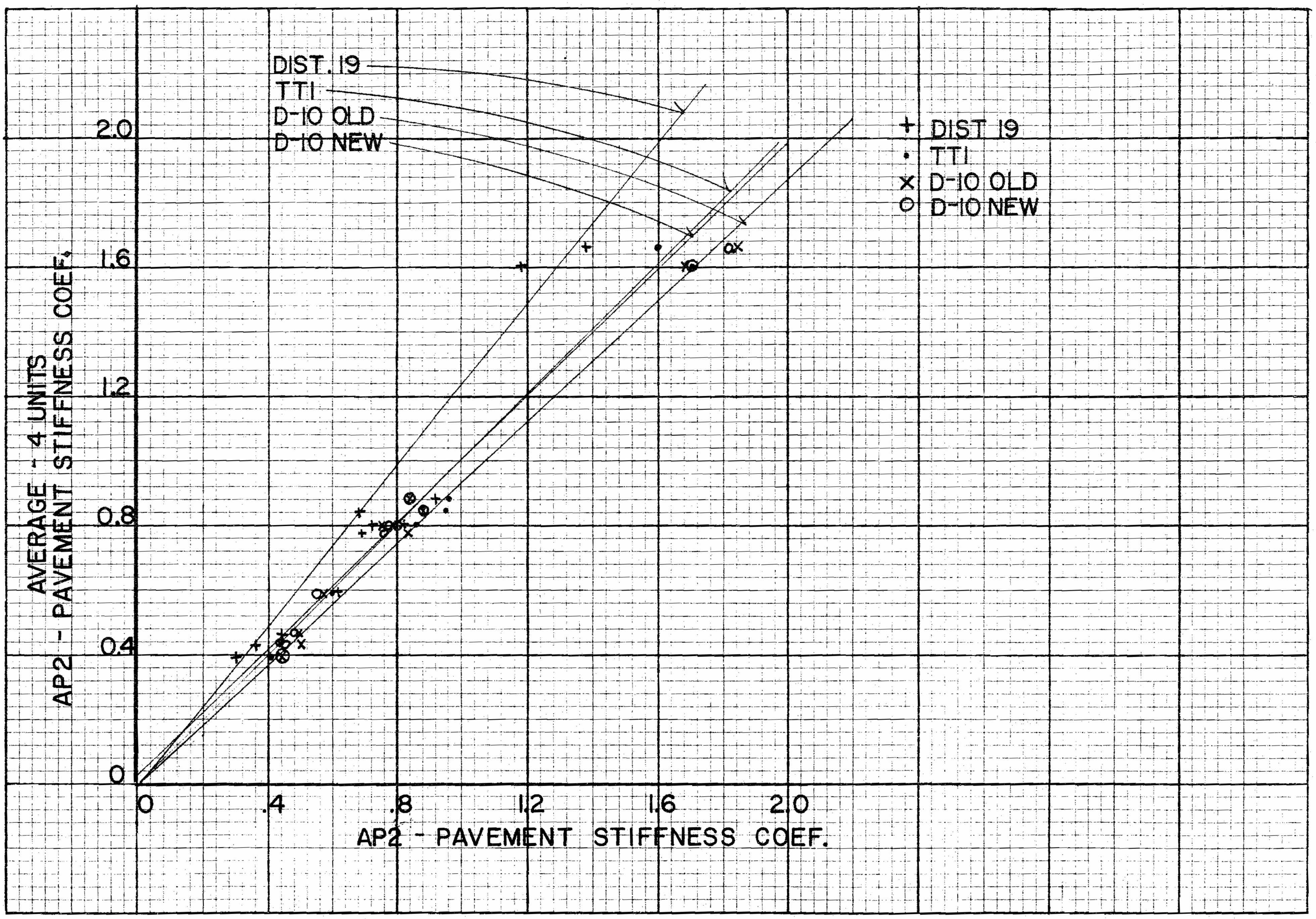


D-10 OLD
D-10 NEW
DIST 19
+ DIST 19
× D-10 OLD
o D-10 NEW
TTI
DEFLECTION - GEOPHONE NO. 4
0
.1
.2
.3
.4
.5
.6
DEFLECTION - GEOPHONE NO. 4


D-10 OLD
D-10 NEW
DIST 19
+ DIST 19
× D-10 OLD
o D-10 NEW
TTI
DEFLECTION - GEOPHONE NO. 5
0
.1
.2
.3
.4
.5
DEFLECTION - GEOPHONE NO. 5

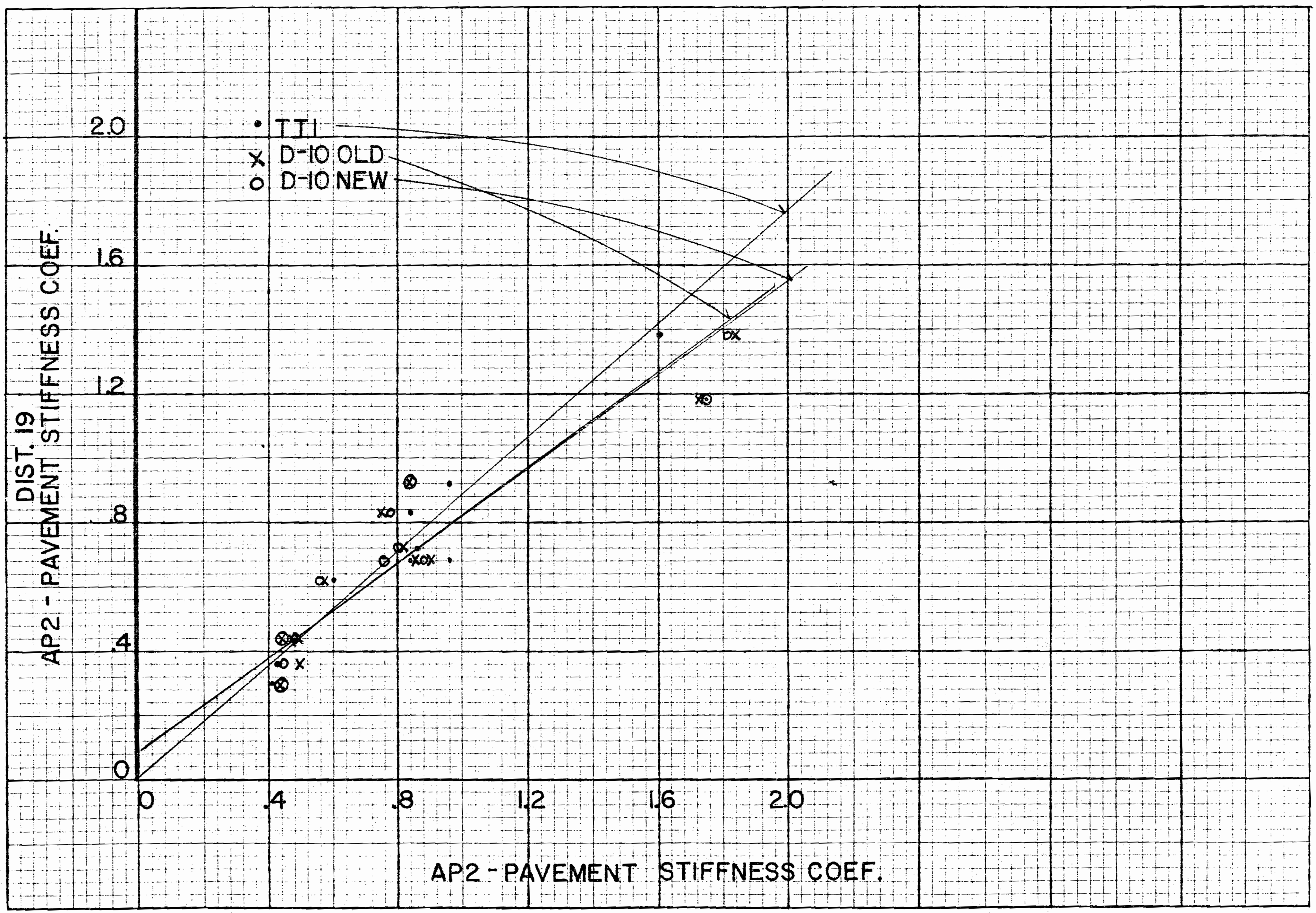
APPENDIX J

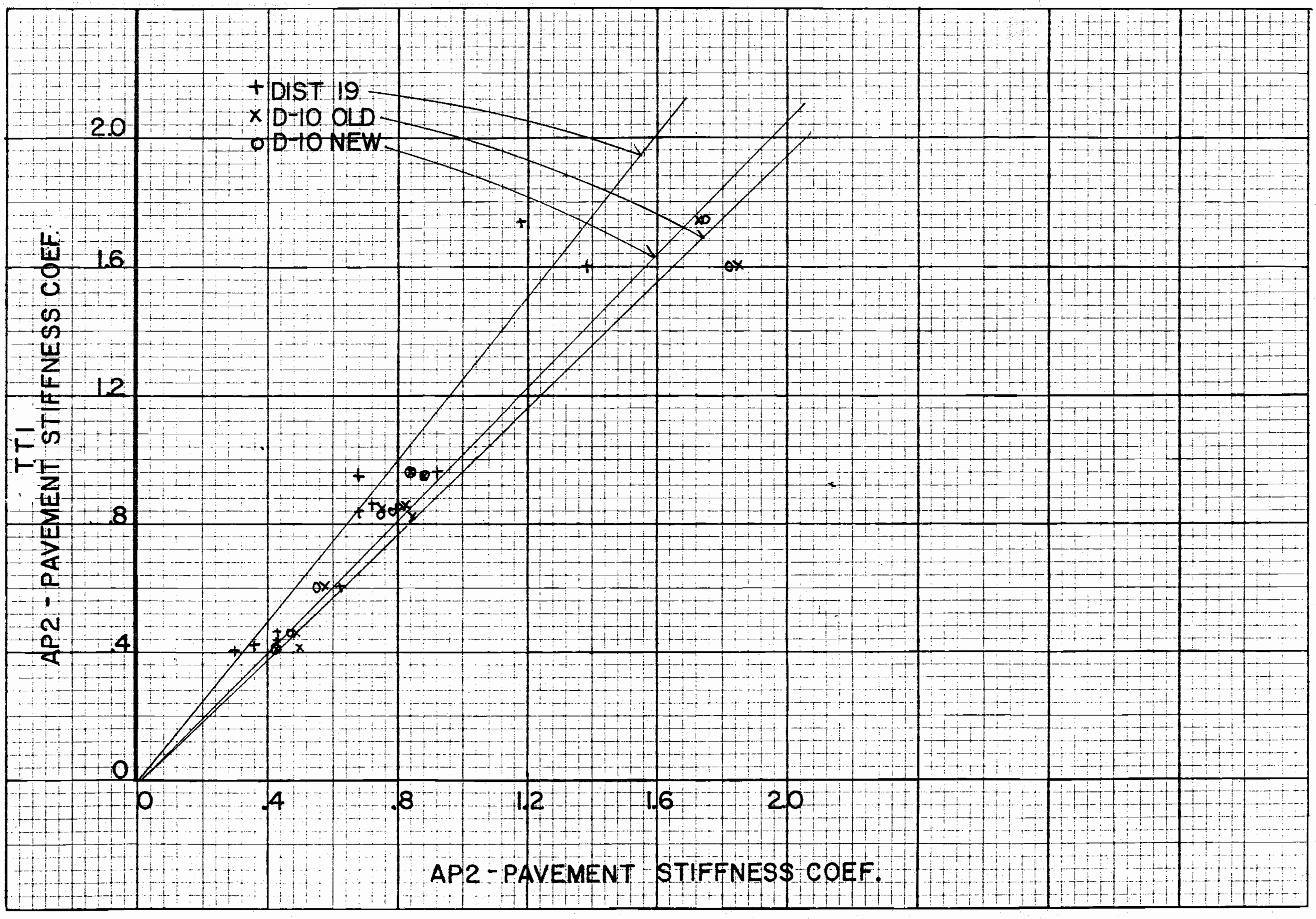
Correlation of the Average "Pavement Stiffness Coefficient" with the Individual "Pavement Stiffness Coefficient" from Each of the Four Units


DIST. 19
TTI
D-10 OLD
D-10 NEW
+ DIST 19
• TTI
× D-10 OLD
⊙ D-10 NEW
AVERAGE - 4 UNITS
AP2 - PAVEMENT STIFFNESS COEF.
2.0
1.6
1.2
0.8
0.4
0
0
.4
.8
1.2
1.6
2.0
AP2 - PAVEMENT STIFFNESS COEF.

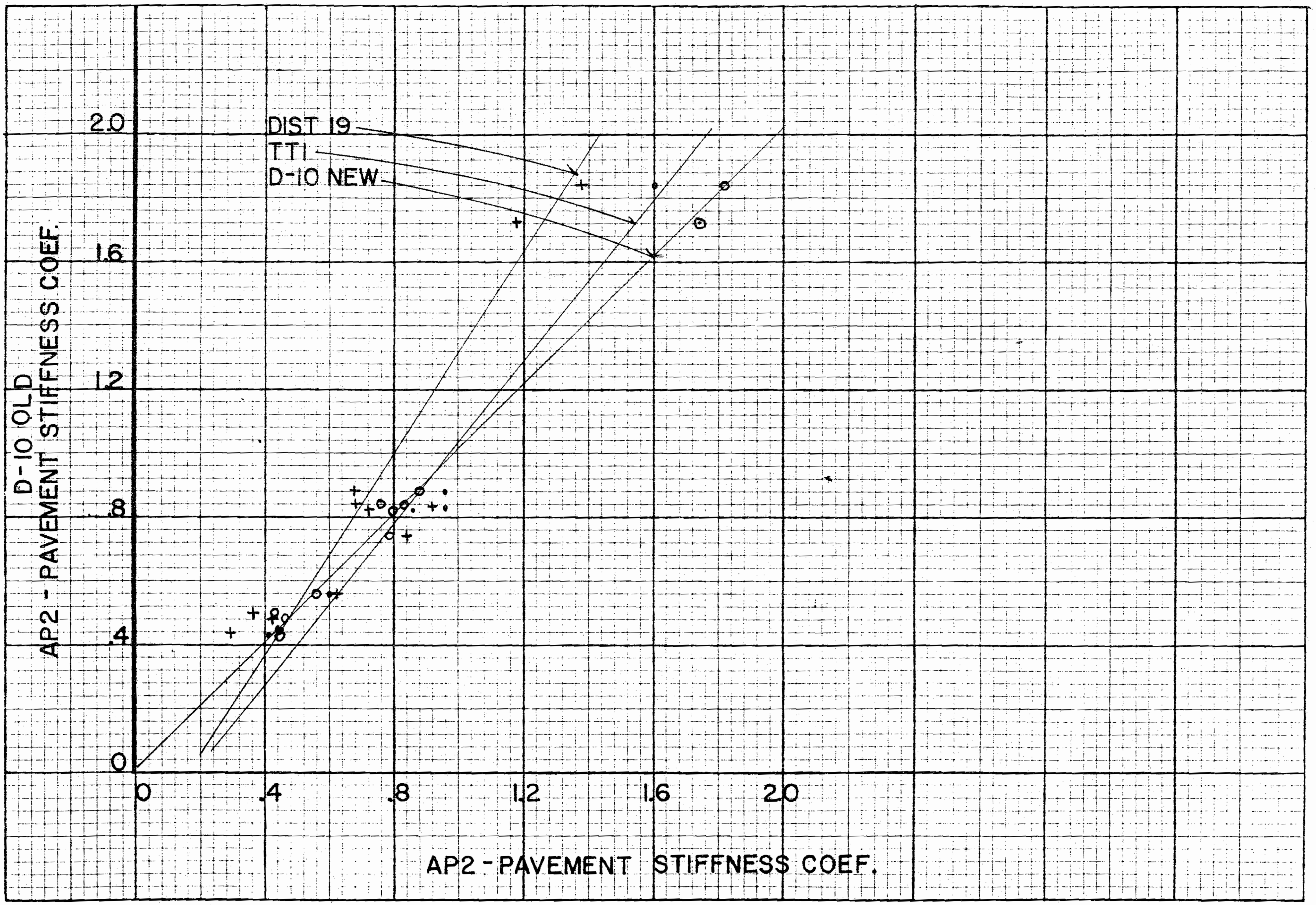
APPENDIX K

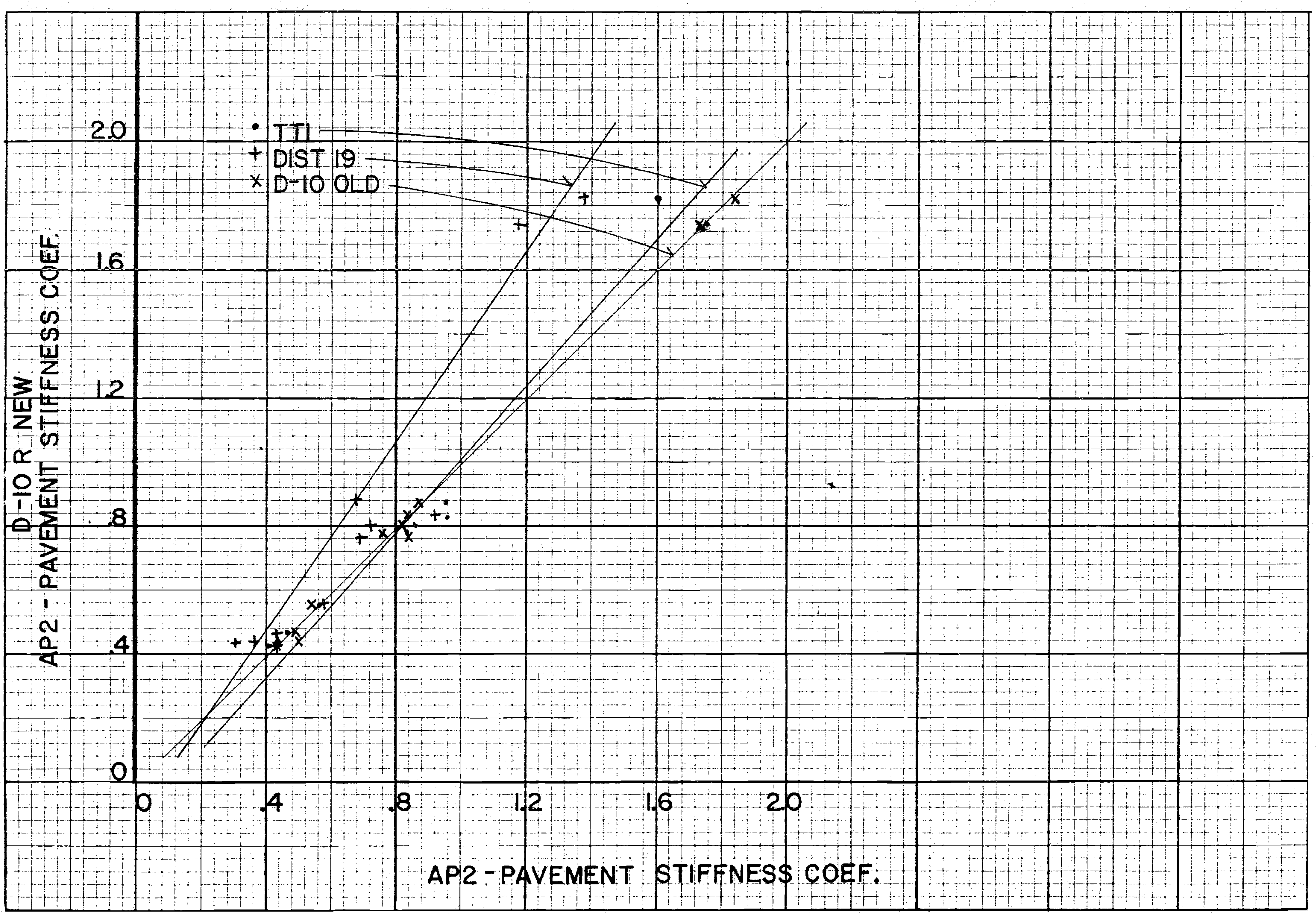
Correlation of Each Dynaflect With the Other Using the Variable - "Pavement Stiffness Coefficient"


• TTI
x D-10 OLD
o D-10 NEW
DIST. 19
AP2 - PAVEMENT STIFFNESS COEF.
2.0
1.6
1.2
.8
.4
0
0
.4
.8
1.2
1.6
2.0
AP2 - PAVEMENT STIFFNESS COEF.



+ DIST 19
x D-10 OLD
o D-10 NEW
TTI
AP2 - PAVEMENT STIFFNESS COEF.
2.0
1.6
1.2
.8
.4
0
0
.4
.8
1.2
1.6
2.0
AP2 - PAVEMENT STIFFNESS COEF.


DIST 19
TTI
D-10 NEW
D-10 OLD
AP2 - PAVEMENT STIFFNESS COEF.
2.0
1.6
1.2
.8
.4
0
0
.4
.8
1.2
1.6
2.0
AP2 - PAVEMENT STIFFNESS COEF.


TTI
DIST 19
D-10 OLD
D-10 R NEW
AP2 - PAVEMENT STIFFNESS COEF.
2.0
1.6
1.2
.8
.4
0
0
.4
.8
1.2
1.6
2.0
AP2 - PAVEMENT STIFFNESS COEF.