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16. Abstract

This report covers a six-week study of the existing data on transformer bases and luminaire poles used by the Texas Department of Transportation. The purpose of this study was to determine the extent the extent to which static testing of various configurations can be replaced with analysis combined with the existing database. Several combinations were found for which the existing static test data is sufficient to accept these combinations of transformer base and luminaire pole for use by the TxDOT without further static testing. Although these results are promising, further research is needed before evaluation of other transformer bases and luminaire poles can be performed without the aid of static testing. This report is not intended for construction, bidding, or permit purposes.

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PRELIMINARY ANALYSIS OF TRANSFORMER BASES

Suchitra B. Shrestha
James R. Morgan
Hayes E. Ross, Jr.
Roger P. Bligh

Research Report 1963-1F

Sponsored by
Texas Department of Transportation

Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843-3135

NOVEMBER 1992
Revised AUGUST 1993

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	2.54	centimeters	cm
ft	feet	0.3048	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	6.452	centimeters squared	cm^2
ft^2	square feet	0.0929	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
mi^2	square miles	2.59	kilometers squared	km^2
ac	acres	0.395	hectares	ha
		MASS (weight)		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		VOLUME		
fl oz	fluid ounces	29.57	millimeters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0328	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

Note: Volumes greater than 1000 L shall be shown in m^3.

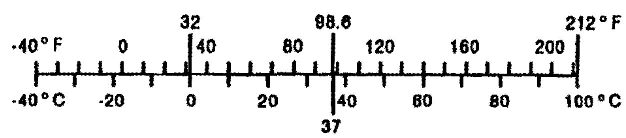
Symbol	When You Know	Multiply By	To Find	Symbol
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

These factors conform to the requirement of FHWA Order 5190.1A

*SI is the symbol for the International System of Measurements

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
yd	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
yd^2	kilometers squared	0.39	square miles	mi^2
ha	hectares (10,000 m^2)	2.53	acres	ac
		MASS (weight)		
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1000 kg)	1.103	short tons	T
		VOLUME		
mL	millimeters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



SUMMARY

This report covers a six-week study of the existing data on transformer bases and luminaire poles used by the Texas Department of Transportation (TxDOT). The purpose of this study was to determine the extent to which static testing of various configurations can be replaced with analysis of the database of existing static tests. Some trends are present in the data which indicate that static testing may not always be necessary. Although these results are promising, further research is needed before evaluation of other transformer bases and luminaire poles can be performed without the aid of static testing.

SUMMARY STATEMENT ON RESEARCH IMPLEMENTATION

The results of this study should be implemented.

ACKNOWLEDGMENTS

The researchers appreciate the support provided by the Department of Transportation. A study of this type must necessarily draw upon the expertise and judgment of TxDOT employees. In particular, Mr. Karl Burkett, who served as Technical Coordinator, and Mr. John Panak provided valuable information and assistance.

DISCLAIMER

KEY WORDS

Transformer Bases, Luminaire Poles, Static Testing

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INTRODUCTION

The purpose of this study was to determine the extent to which existing data from static tests of base/pole combinations can replace the need for additional static testing of various combinations of transformer bases and luminaire poles. This also would prove useful in the determination of which new transformer base is suitable for the maintenance replacement of old transformer bases given the pole height, diameter, bolt circle, etc. Several trends are present in the data which indicate that static testing may not always be necessary. Although these results are promising, further research is needed before evaluation of other transformer bases and luminaire poles can be performed without the aid of static testing.

TRANSFORMER BASES

Akron Foundry Company is the only manufacturer of breakaway transformer bases (t-bases). The t-bases can be categorized into two major groups with respect to their heights. The t-bases are being produced with heights of 20 in. and 17 in. Each of these can be further divided into four models based on the top and the bottom bolt circles as shown in Table 1. These differences result in different top and bottom widths and different weights. It is worth noting that the dimension and position of the t-base door with respect to the axis of loading can have a significant effect on the structural behavior of the t-base.

Union Metal has two models of 20-in. high t-bases (i.e., A2849-GlOlRl 1 and A2850-ClR10) which differ from the 20-in. high t-bases listed in Table 1. These t-bases are also manufactured by Akron Foundry Company, and their properties are shown in Table 2. These t-base models were designed after the American Association of State Highway and Transportation Officials published a standard in 1985. In order to satisfy the AASHTO requirements, t-bases of 20 in. height designed and manufactured by A. F. Company were modified by reducing the height from 20 in. to 17 in. However, it is noted that even though the Union Metal t-bases still have a height of 20 in., they have been approved by FHWA.

All of the t-base models shown in Tables 1 and 2 are made of aluminum alloy 356-T6.

TABLE 1. Parameters of Transformer Bases (A. F. Company)

Design Designation	Transformer Base		Door		Bolt Circle		Weight (lbs)	Material/ Specimen
	Height, H (in.)	Width top/bottom (in.)	Height,h (in.)	Width top/bottom (in.)	Top min.-max. (in.)	Bottom min.-max. (in.)		
TB1-AF1315	20	13.12/15.38	13.50	9.25/9.75	11-13	13-15	32.4	Alum. Alloy S356 T6
TB1-AF MODIFIED I.W.	20	13.12/15.38	13.50	9.25/9.75	11-13	$10\frac{1}{2}$-$12\frac{15}{16}$	33.1	Alum. Alloy S356 T6
TB2-AF1012 I.W.	20	12.06/13.00	13.50	9.25/9.75	10-12	10-12	25.4	Alum. Alloy S356 T6
TB3-AF1517	20	15.00/17.44	13.50	9.25/9.75	13-$15\frac{1}{8}$	15-$17\frac{1}{4}$	36.8	Alum. Alloy S356 T6
TB1-AF1315 17 I.W.	17	13.12/15.38	11.75	9.25/9.75	$10\frac{1}{2}$-$13\frac{1}{2}$-	13-15	26.2	Alum. Alloy S356 T6
TB1-AF MODIFIED-17 I.W.	17	13.12/15.38	11.75	9.25/9.75	$10\frac{1}{2}$-$13\frac{1}{2}$-	$10\frac{1}{2}$-$2\frac{15}{16}$	27.0	Alum. Alloy S356 T6
TB2-AF1012 17 I.W.	17	12.04/13.08	11.75	9.25/9.75	10-12	10-12	25.4	Alum. Alloy S356 T6
TB3-AF1517 17 I.W.	17	15.09/17.44	11.75	9.25/9.75	13-$15\frac{1}{8}$	15-$17\frac{1}{4}$	33.8	Alum. Alloy S356 T6

TABLE 2. Parameters of Transformer Bases (Union Metal)

Design Designation	Transformer Base		Door		Bolt Circle		Weight (lbs)	Material/ Specimen
	Height, H (in.)	Width top/bottom (in.)	Height,h (in.)	Width top/bottom (in.)	Top min.-max. (in.)	Bottom min.-max. (in.)		
A2849-G101R11	20	$12\frac{5}{8}/14\frac{5}{8}$	13.93	7.95/9.43	$11\text{-}12\frac{1}{2}$	$15\text{-}15\frac{1}{2}$	28.7	Alum. Alloy S356 T6
A2850-C1R10	20	13/14	13.97	$7\frac{31}{32}/9\frac{3}{8}$	$10\frac{1}{2}\text{-}12\frac{1}{2}$	$10\frac{1}{2}\text{-}12\frac{1}{2}$	33.0	Alum. Alloy S356 T6

LUMINAIRE POLES

A variety of luminaire poles are being produced with a range of size and load capacity. Various poles are used to perform static tests of t-bases. A summary of physical and geometric properties is presented in Tables 3, 4 and 5 for data obtained from Valmont Industries, Union Metal, and P & K Products, respectively. The breaking moment capacity of the t-bases has been compared to the plastic moment capacity of the poles. The philosophy behind these tests is that the breaking moment capacities of the t-bases should be greater than or equal to the plastic moment capacity of the poles. It should be noted that the luminaire poles, as produced, are not the same as design poles. Sometimes the design poles are referred to as theoretical poles, that is, these poles satisfy all of the requirements of AASHTO. The produced pole may be significantly different depending on available materials and fabrication methods.

The luminaire poles, while manufactured by different companies, are all designed in accordance with AASHTO. Therefore, there are no discrepancies in the determination of allowable and design moments, shear stresses, and axial stresses. However, the approach taken in finding the plastic moment of poles differs. For instance, Valmont Industries, Inc. calculates the plastic moment as the product of the coefficient 1.38 and allowable moment. This approach is correct for compact sections for which the allowable stress is equal to 0.66 times yield stress: $F_b = 0.66\ F_y$. However, use of this coefficient is not appropriate for the case of non-compact tubes. On the other hand, Union Metal replaces the allowable moment with the design moment which is the resultant of two moment components normal to each other. This approach of determining the appropriate coefficient is more generally correct. The plastic moment M_p of a pole can be calculated using two different approaches as follows:

$$\mathbf{M_p = S * F_y}$$

where S = section modulus; F_y = yield stress.

$$\mathbf{M_p = M_{allow} * N}$$

where M_{allow} = allowable moment; N = coefficient that is calculated as

$$N = \frac{F_y * K_p}{1.4 * F_b}$$

where K_p, = shape factor; 1.4 = factor of safety.

It is noted that the second method is true only for load groups II and III (i.e., when allowable stresses are increased by 140%). The plastic moments given in Tables 3 through 5 have been computed using one of the two methods described above. It can easily be determined which method was used by comparing the results of **S** $*F_y$ with the value listed in the table.

Both steel and aluminum are being used in the fabrication of luminaire poles. The mechanical properties of the materials and the strength of the poles in terms of moment capacity are given in Tables 3 through 5.

TABLE 3. Pole Data (Valmont Industries)

Design Designation (1)	Pole Size: Length[a] (ft) (2)	Pole Size: Base Outer Dia. (in.) (3)	Pole Size: Wall Thickness (in.) (4)	Material/ Specification (5)	Tensile Yield (psi) (6)	Section Modulus (in.) (7)	Allowable Moment (ft-lb) (8)	Plastic Moment, M_p, (ft-lb) (9)	Design (Working) Moment[b] (ft-lb) (10)	Combined Stress Ratio[b] (CSR) (11)
	45.0	11.00	0.1345	Steel A595	55,000	12.466	48,727	Non compact	38,299	0.87
	40.0	10.97	0.1196	Steel A595	55,000	11.053	41,511	Non compact	31,996	0.84
	40.0	10.25	0.1196	Steel A595	55,000	9.635	37,032	Non compact	32,239	0.94
	40.0	10.23	0.1196	Steel A595	55,000	9.597	36,911	Non compact	32,207	0.97
	35.0	10.00	0.1196	Steel A595	55,000	9.165	35,546	Non compact	26,975	0.82
	35.0	9.55	0.1196	Steel A595	55,000	8.350	32,910	Non compact	27,056	0.90
	35.0	9.39	0.1196	Steel A595	55,000	8.069	32,001	Non compact	27,115	0.93
	25.0	7.89	0.1196	Steel A595	55,000	5.669	24,007	32,998	17,058	0.76

[a] Without arm.

[b] For a 90 mph wind speed, using 12 ft double arms.

TABLE 4. Pole Data (Union Metal)

Design Designation (1)	Pole Size: Length[a] (ft) (2)	Pole Size: Base Outer Dia. (in.) (3)	Pole Size: Wall Thickness (in.) (4)	Material/ Specification (5)	Tensile Yield (psi) (6)	Section Modulus (in.) (7)	Allowable Moment (ft-lb) (8)	Plastic Moment, M_p, (ft-lb) (9)	Design (Working) Moment[b] (ft-lb) (10)	Combined Stress Ratio[b] (CSR) (11)
N/A	43.25	10.00	0.139	Steel/	55,000	10.160	43,755	61,738	37,553	1.00
N/A	N/A	9.00	0.1196	Steel/	55,000	7.404	29,999	43,097	N/A	N/A
N/A	33.25	8.50	0.128	Steel/	55,000	7.043	29,827	41,161	25,651	0.99

[a] Without arm.

[b] For a 90 mph wind speed, using 12 ft double arms.

Note: Union Metal makes poles with wall thickness of 0.1196 in. and 0.1793 in.
Wall thicness of 0.139 and 0.128 are theoretical thickness to get 100% stress ratio.

TABLE 5. Pole Data (P & K Product)

Design Designation (1)	Pole Size			Material/ Specification (5)	Tensile Yield (psi) (6)	Section Modulus (in.) (7)	Allowable Moment (ft-lb) (8)	Plastic Moment, M_p, (ft-lb) (9)	Design (Working) Moment[b,d] (ft-lb) (10)	Combined Stress Ratio[b,d] (CSR) (11)
	Length[a] (ft) (2)	Base Outer Dia. (in.) (3)	Wall Thickness (in.) (4)							
RTBOX407 AT22877	34.08	10.00	0.25	A. Alloy 6063-T6	25,000	18.210	32,505[c]	48,181	25,798	0.846

[a] Without arm.
[b] For a 90 mph wind speed, using 12 ft double arms; Based on 40 ft luminaire mounting height; Shaft mounted on TB.
[c] 6063-T4 Al. Alloy 0.375 wall or less, using 4043 weld wire, heat-treated to T6 temper after welding.
[d] Calculation based upon a cobra-head type luminaire: EPA = 2.40 sq. ft; Wt. = 55 lb.

TESTS OF TRANSFORMER BASES

An attempt was made to verify all transformer base test data obtained from TxDOT, to fill in missing information, and to obtain any available information on additional tests. Tables 6a through 10 contain the results of static load tests on various combinations of transformer bases and luminaire poles. These data were obtained from Akron Foundry (Tables 6a and 6b), Valmont Industries (Tables 7a and 7b), Union Metal (Table 8), JEM Engineering and Manufacturing (Table 9), and C. R. Briden (Table 10). Where available, chemical and physical data for the transformer bases are presented (Tables 11a through 14). All available data is reported as obtained from the manufacturers. It should be noted that, in some instances such as the chemical and physical data supplied by Akron Foundry (see Table 11a), the data appears to be representative of "typical" values rather than actual test values.

It should be noted that not all of the tests resulted in a failure of the transformer base. In those tests where "none" or "N/A" is listed in the last column of Tables 6a through 10, the t-base and pole were able to sustain load at the maximum stroke available in the test fixture, and no failure occurred.

There was incomplete data to determine the effect of using shims at the four corners between a rigid support surface and the bottom of a t-base. Consequently, this option was ignored in this analysis.

TABLE 6a. TB Static Test Data (A. F. Company)

Test No. (1)	Date (2)	Tested By (3)	Tested For (4)	Design Designation (5)	Pole[a] Wall Thickness (in.) (6)	Pole[a] Outer Dia. (in.) (7)	Pole Base Plate Thickness (in.) (8)	Pole Base Plate Length (in.) (9)	Pole Base Plate Width (in.) (10)
174	2-1-86	A.F. Comp.	A.F. Comp.	TB3-AF1517	N/A	10.0	1.50	15	15
175	2-1-86	A.F. Comp.	A.F. Comp.	TB3-AF1517	N/A	10.0	1.50	15	15
176	2-1-86	A.F. Comp.	A.F. Comp.	TB3-AF1517	N/A	10.0	1.50	15	15
177	2-1-86	A.F. Comp.	A.F. Comp.	TB3-AF1517	N/A	10.0	1.50	15	15
178	2-1-86	A.F. Comp.	A.F. Comp.	TB3-AF1517	N/A	10.0	1.50	15	15
179	2-1-86	A.F. Comp.	A.F. Comp.	TB3-AF1517	N/A	10.0	1.50	15	15
180	2-1-86	A.F. Comp.	A.F. Comp.	TB3-AF1517	N/A	10.0	1.50	13	13
181	2-1-86	A.F. Comp.	A.F. Comp.	TB3-AF1517	N/A	10.0	1.50	13	13
182	2-1-86	A.F. Comp.	A.F. Comp.	TB3-AF1517	N/A	10.0	1.50	15	15
1	5-31-88	A.F. Comp.	A.F. Comp.	TB3 AF1517 -17 I.W.	N/A	10.0	1.50	15	15
2	5-31-88	A.F. Comp.	A.F. Comp.	TB3 AF1517 -17 I.W.	N/A	10.0	1.50	15	15
3	5-31-88	A.F. Comp.	A.F. Comp.	TB3 AF1517 -17 I.W.	N/A	10.0	1.50	15	15
4	5-31-88	A.F. Comp.	A.F. Comp.	TB3 AF1517 -17 I.W.	N/A	10.0	1.50	15	15
5	5-31-88	A.F. Comp.	A.F. Comp.	TB3 AF1517 -17 I.W.	N/A	10.0	1.50	15	15

[a] Steel Valmont test pole (608 lbs) with adapter no. 1 and 2.

TABLE 6a (Continued). TB Static Test Data (A. F. Company)

Test No. (1)	Date (2)	Top: Bolt Circle (in.) (11)	Top: Bolt Dia. (in.) (12)	Top: Washer O.D.-I.D.-t (in.-in.-in.) (13)	Bottom: Bolt Circle (in.) (14)	Bottom: Bolt Dia. (in.) (15)	Bottom: Washer O.D.-I.D.-t (in.-in.-in.) (16)	Failure Load (lbs) (17)	Moment Arm (ft) (18)	Breaking Moment (ft-lbs) (19)	Door Orientation[a] (20)	Failure and Other Remarks (21)
174	2-1-86	15.12	1.25	$2^{3}/_{4}$-$1^{5}/_{16}$-$^{1}/_{2}$	17.25	1.25	$2^{3}/_{4}$-$1^{5}/_{16}$-$^{1}/_{2}$	2500	26.729	66,822.5	DNA	At the weld
175	2-1-86	15.12	1.25	$2^{3}/_{4}$-$1^{5}/_{16}$-$^{1}/_{2}$	17.25	1.25	$2^{3}/_{4}$-$1^{5}/_{16}$-$^{1}/_{2}$	2500	26.729	66,822.5	DNA	None
176	2-1-86	15.12	1.25	$2^{3}/_{4}$-$1^{5}/_{16}$-$^{1}/_{2}$	17.25	1.25	$2^{3}/_{4}$-$1^{5}/_{16}$-$^{1}/_{2}$	2500	26.729	66,822.5	DNA	None
177	2-1-86	15.12	1.25	$2^{3}/_{4}$-$1^{5}/_{16}$-$^{1}/_{2}$	17.25	1.25	$2^{3}/_{4}$-$1^{5}/_{16}$-$^{1}/_{2}$	2500	26.729	66,822.5	DNA	None
178	2-1-86	15.12	1.25	$2^{3}/_{4}$-$1^{5}/_{16}$-$^{1}/_{2}$	17.25	1.25	$2^{3}/_{4}$-$1^{5}/_{16}$-$^{1}/_{2}$	2050	26.729	54,794.5	DDT	At top tens. cor.
179	2-1-86	15.12	1.25	$2^{3}/_{4}$-$1^{5}/_{16}$-$^{1}/_{2}$	17.25	1.25	$2^{3}/_{4}$-$1^{5}/_{16}$-$^{1}/_{2}$	2020	26.729	58,803.8	DDT	At top tens. cor.
180	2-1-86	13	1.25	$2^{3}/_{4}$-$1^{5}/_{16}$-$^{1}/_{2}$	17.25	1.25	$2^{3}/_{4}$-$1^{5}/_{16}$-$^{1}/_{2}$	1650	26.000	42,900.0	DDT	At top tens. cor.
181	2-1-86	13	1.25	$2^{3}/_{4}$-$1^{5}/_{16}$-$^{1}/_{2}$	15	1.25	$2^{3}/_{4}$-$1^{5}/_{16}$-$^{1}/_{2}$	1760	26.000	45,760.0	DDT	At top tens. cor.
182	2-1-86	15.12	1.00	$2^{3}/_{4}$-$1^{1}/_{16}$-$^{1}/_{2}$	17.25	1.25	$2^{3}/_{4}$-$1^{5}/_{16}$-$^{1}/_{2}$	2500	26.729	66,822.0	DDT	None
1	5-31-88	15.12	N/A	N/A	17.25	N/A	N/A	2500	26.49	66,225	DNA	None
2	5-31-88	15.12	N/A	N/A	17.25	N/A	N/A	2500	26.49	66,225	DNA	None
3	5-31-88	15.12	N/A	N/A	17.25	N/A	N/A	2500	26.49	66,225	DDC	None
4	5-31-88	15.12	N/A	N/A	17.25	N/A	N/A	2500	26.49	66,225	DDC	None
5	5-31-88	15.12	N/A	N/A	17.25	N/A	N/A	2500	26.49	66,225	DDC	None

[a] DNA=door on neutral axis; DDT= door in diagonal tension; DDC= door in diagonal compression.

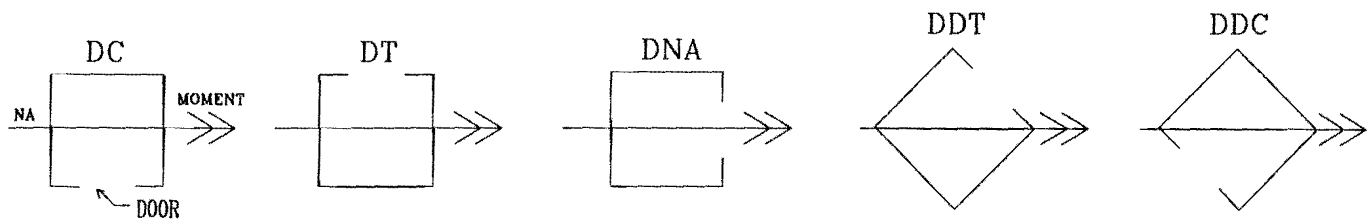

TABLE 6b. TB Static Test Data (A. F. Company)

Test No. (1)	Date (2)	Tested By (3)	Tested For (4)	Design Designation (5)	Pole[a] Wall Thickness (in.) (6)	Pole[a] Outer Dia. (in.) (7)	Pole Base Plate Thickness (in.) (8)	Pole Base Plate Length (in.) (9)	Pole Base Plate Width (in.) (10)
1	5-31-90	A.F. Comp.	A.F. Comp.	TB1-17	N/A	10.0	1.38	15	15
2	5-31-90	A.F. Comp.	A.F. Comp.	TB1-17	N/A	10.0	1.38	15	15
3	5-31-90	A.F. Comp.	A.F. Comp.	TB1-17	N/A	10.0	1.38	15	15
4	5-31-90	A.F. Comp.	A.F. Comp.	TB1-17	N/A	10.0	1.38	15	15
5	5-31-90	A.F. Comp.	A.F. Comp.	TB1-17	N/A	10.0	1.38	15	15
6	5-31-90	A.F. Comp.	A.F. Comp.	TB1-17	N/A	10.0	1.38	15	15
1	5-31-90	A.F. Comp.	A.F. Comp.	TB2-17	N/A	10.0	1.38	13	13
2	5-31-90	A.F. Comp.	A.F. Comp.	TB2-17	N/A	10.0	1.38	13	13
3	5-31-90	A.F. Comp.	A.F. Comp.	TB2-17	N/A	10.0	1.38	13	13
4	5-31-90	A.F. Comp.	A.F. Comp.	TB2-17	N/A	10.0	1.38	13	13
5	5-31-90	A.F. Comp.	A.F. Comp.	TB2-17	N/A	10.0	1.38	13	13
1	5-31-90	A.F. Comp.	A.F. Comp.	TB3-17	N/A	10.0	1.38	15	15
2	5-31-90	A.F. Comp.	A.F. Comp.	TB3-17	N/A	10.0	1.38	15	15
3	5-31-90	A.F. Comp.	A.F. Comp.	TB3-17	N/A	10.0	1.38	15	15
4	5-31-90	A.F. Comp.	A.F. Comp.	TB3-17	N/A	10.0	1.38	15	15
5	5-31-90	A.F. Comp.	A.F. Comp.	TB3-17	N/A	10.0	1.38	15	15

[a] Steel Valmont test pole (608 lbs). Adopter no.2 is used for TB1-17 and TB3-17 and adopter no. 3 for TB2-17.

TABLE 6b (Continued). TB Static Test Data (A. F. Company)

Test No. (1)	Date (2)	Top: Bolt Circle (in.) (11)	Top: Bolt Dia. (in.) (12)	Top: Washer O.D.-I.D.-t (in.-in.-in.) (13)	Bottom: Bolt Circle (in.) (14)	Bottom: Bolt Dia. (in.) (15)	Bottom: Washer O.D.-I.D.-t (in.-in.-in.) (16)	Failure Load (lbs) (17)	Moment Arm (ft) (18)	Breaking Moment (ft-lbs) (19)	Door Orien-tation[a] (20)	Failure and Other Remarks (21)
1	5-31-90	13.50	1.00	2 3/4-1 1/16-1/2	15.00	1.00	2 3/4-1 1/16-1/2	2,000	26.490	52,980	DT	At bott. tens. corn.
2	5-31-90	13.50	1.00	2 3/4-1 1/16-1/2	15.00	1.00	2 3/4-1 1/16-1/2	1,900	26.490	50,331	DNA	At bott. tens. side
3	5-31-90	13.50	1.00	2 3/4-1 1/16-1/2	15.00	1.00	2 3/4-1 1/16-1/2	1,900	26.490	50,331	DC	Bottom. tens. side
4	5-31-90	13.50	1.00	2 3/4-1 1/16-1/2	15.00	1.00	2 3/4-1 1/16-1/2	2,000	26.490	52,982	DDT	At top tens. corn.
5	5-31-90	13.50	1.00	2 3/4-1 1/16-1/2	15.00	1.00	2 3/4-1 1/16-1/2	2,000	26.490	52,982	DDC	At top tens. corn.
6	5-31-90	13.50	1.00	2 3/4-1 1/16-1/2	15.00	1.00	2 3/4-1 1/16-1/2	2,000	26.490	52,982	DDT	At top tens. corn.
1	5-31-90	12.00	1.00	2 1/2-1 1/16-3/8	12.00	1.00	2 3/4-1 1/16-1/2	1,700	26.469	44,997	DT	Bottom. tens. side
2	5-31-90	12.00	1.00	2 1/2-1 1/16-3/8	12.00	1.00	2 3/4-1 1/16-1/2	1,600	26.469	42,350	DNA	Bottom. tens. side
3	5-31-90	12.00	1.00	2 1/2-1 1/16-3/8	12.00	1.00	2 3/4-1 1/16-1/2	1,700	26.469	44,997	DC	Bottom. tens. side
4	5-31-90	12.00	1.00	2 1/2-1 1/16-3/8	12.00	1.00	2 3/4-1 1/16-1/2	1,600	26.469	42,350	DDT	Bottom. tens. side
5	5-31-90	12.00	1.00	2 1/2-1 1/16-3/8	12.00	1.00	2 3/4-1 1/16-1/2	1,600	26.469	42,350	DDC	Bottom. tens. side
1	5-31-90	15.12	1.25	2 3/4-1 5/16-1/2	17.25	1.25	2 3/4-1 5/16-1/2	2,550	26.490	67,550	DT	Bottom. tens. side
2	5-31-90	15.12	1.25	2 3/4-1 5/16-1/2	17.25	1.25	2 3/4-1 5/16-1/2	2,600	26.490	68,874	DNA	Bottom. tens. side
3	5-31-90	15.12	1.25	2 3/4-1 5/16-1/2	17.25	1.25	2 3/4-1 5/16-1/2	2,500	26.490	66,225	DC	Bottom. tens. side
4	5-31-90	15.12	1.25	2 3/4-1 5/16-1/2	17.25	1.25	2 3/4-1 5/16-1/2	2,400	26.490	63,576	DDT	Bottom. tens. side
5	5-31-90	15.12	1.25	2 3/4-1 5/16-1/2	17.25	1.25	2 3/4-1 5/16-1/2	2,700	26.490	71,523	DDC	Bottom. tens. side

[a] DNA=door on neutral axis; DDT= door in diagonal tension; DDC= door in diagonal compression.

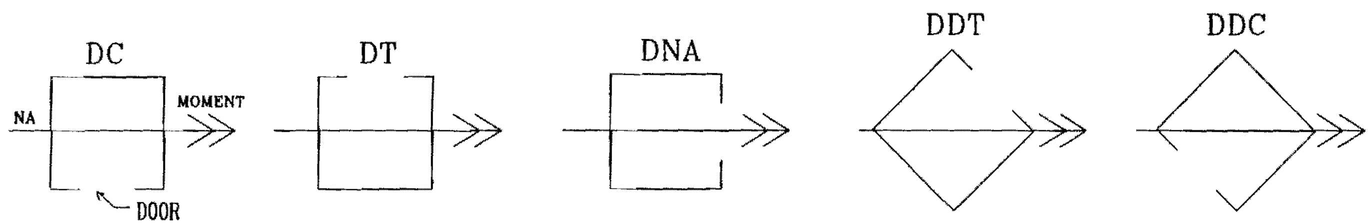

TABLE 7a. TB Static Test Data (Valmont Industries)

					Pole		Pole Base Plate		
Test No. (1)	Date (2)	Tested By (3)	Tested For (4)	Design Designation (5)	Wall Thickness (in.) (6)	Outer Dia. (in.) (7)	Thickness (in.) (8)	Length (in.) (9)	Width (in.) (10)
115-3	4-7-86	Valmont	Valmont	TB3 AF1517 (MO83)	0.1793	11.00	1.5	15	15
115-4	4-7-86	Valmont	Valmont	TB3 AF1517 (MO83)	0.1793	11.00	1.5	15	15
132-A	10-7-89	Valmont	Texas DOT	TB1 AF1315 (MO74)	0.1793	9.50	1.0	13	13
132-B	10-7-89	Valmont	Texas DOT	TB1 AF1315 (MO74)	0.1793	9.50	1.0	13	13
1	7-6-90	Valmont	Texas DOT	TB3 AF1517 -17 I.W.	0.1793	11.625	1.25	15	15
2	7-6-90	Valmont	Texas DOT	TB3 AF1517 -17 I.W.	0.1793	11.625	1.25	15	15
3	7-9-90	Valmont	Texas DOT	TB3 AF1517 -17 I.W.	0.1793	11.625	1.25	15	15
4	7-11-90	Valmont	Texas DOT	TB3 AF1517 -17 I.W.	0.1793	11.625	1.25	15	15
5	7-11-90	Valmont	Texas DOT	TB3 AF1517 -17 I.W.	0.1793	11.625	1.25	15	15
6	7-11-90	Valmont	Texas DOT	TB3 AF1517 -17 I.W.	0.1793	11.625	1.25	15	15
3	4-25-90	Nebraska Testing Corp.	Valmont Industries	TB1-AF1315 -17 I.W.	0.1793	10.0	1.25	13.125	13.125
4	4-30-90	Nebraska Testing Corp.	Valmont Industries	TB1-AF1315 -17 I.W.	0.1793	10.0	1.25	13.125	13.125
5	5-1-90	Nebraska Testing Corp.	Valmont Industries	TB1-AF1315 -17 I.W.	0.1793	10.0	1.25	13.125	13.125
6	5-2-90	Nebraska Testing Corp.	Valmont Industries	TB1-AF1315 -17 I.W.	0.1793	10.0	1.25	13.125	13.125

TABLE 7a (Continued). TB Static Test Data (Valmont Industries)

		Top			Bottom							
Test No. (1)	Date (2)	Bolt Circle (in.) (11)	Bolt Dia. (in.) (12)	Washer O.D.-I.D.-t (in.-in.-in.) (13)	Bolt Circle (in.) (14)	Bolt Dia. (in.) (15)	Washer O.D.-I.D.-t (in.-in.-in.) (16)	Failure Load (lbs) (17)	Moment Arm (ft) (18)	Breaking Moment (ft-lbs) (19)	Door Orien-tatio[b] (20)	Failure and Other Remarks (21)
115-3	4-7-86	15	1.25	2.9-1 5/16-9/16	17.25	1.25	2.9-1 5/16-9/16	1660	35.00	58,100	DDC	Bott. flange weld
115-4	4-7-86	15	1.25	2.9-1 5/16-9/16	17.25	1.25	2.9-1 5/16-9/16	1768	35.00	61,880	DDC	Bott. flange weld
132-A	10-7-89	13	1.00	2.5-1 1/16-6/16	14	1.00	2 3/4-1 1/16-1/2	1139	34.58	39,390	DDC	Top wall tens. side
132-B	10-7-89	13	1.00	2.5-1 1/16-6/16	14	1.00	2 3/4-1 1/16-1/2	1160	34.58	40,116	DDC	Top wall tens. side
1	7-6-90	15.125	1.25	2 3/4-1 5/16-1/2	17.25	N/A	2 3/4-N/A-1/2	1460	44.00	64,240[a]	DT	N/A
2	7-6-90	15.125	1.25	2 3/4-1 5/16-1/2	17.25	N/A	2 3/4-N/A-1/2	1790	43.90	78,574[a]	DC	N/A
3	7-9-90	15.125	1.25	2 3/4-1 5/16-1/2	17.25	N/A	2 3/4-N/A-1/2	1540	43.75	67,375[a]	DNA	N/A
4	7-11-90	15.125	1.25	2 3/4-1 5/16-1/2	17.25	N/A	2 3/4-N/A-1/2	1254	43.66	54,750[a]	DDT up	N/A
5	7-11-90	15.125	1.25	2 3/4-1 5/16-1/2	17.25	N/A	2 3/4-N/A-1/2	1109	43.66	48,419[a]	DDT down	N/A
6	7-11-90	15.125	1.25	2 3/4-1 5/16-1/2	17.25	N/A	2 3/4-N/A-1/2	1372	43.54	59,739[a]	DDC down	N/A
3	4-25-90	13.5	1.00	2.5-1 1/16-6/16	15	1.00	2 3/4-1 1/16-1/2	1310	43.95	57,575	DC	At bottom weld
4	4-30-90	13.5	1.00	2.5-1 1/16-6/16	15	1.00	2 3/4-1 1/16-1/2	1230	43.87	53,960	DT	Through wall
5	5-1-90	13.5	1.00	2.5-1 1/16-6/16	15	1.00	2 3/4-1 1/16-1/2	1180	43.76	51,637	DDC	At the top
6	5-2-90	13.5	1.00	2.5-1 1/16-6/16	15	1.00	2 3/4-1 1/16-1/2	1050	43.64	45,822	DDT	Through wall

[a] Moment arm is taken from the top of a base.
[b] DDC= door in diagonal compression; DT= door in tension; DC= door in compression; DNA=door on neutral axis; DDT= door in diagonal tension.

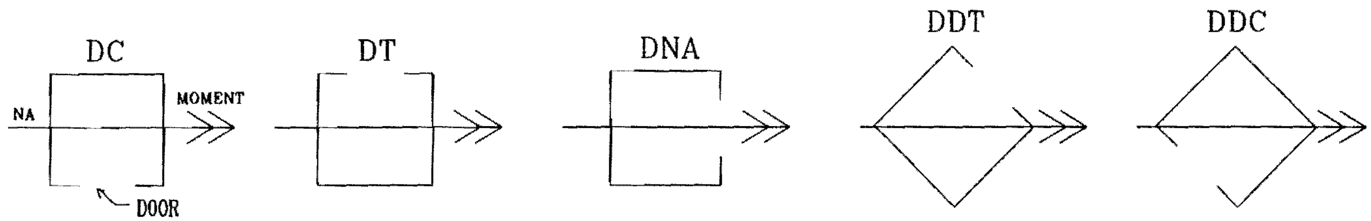

TABLE 7b. TB Static Test Data (Valmont Industries)

Test No. (1)	Date (2)	Tested By (3)	Tested For (4)	Design Designation (5)	Pole: Wall Thickness (in.) (6)	Pole: Outer Dia. (in.) (7)	Pole Base Plate: Thickness (in.) (8)	Pole Base Plate: Length (in.) (9)	Pole Base Plate: Width (in.) (10)
1	8-06-91	Valmont	Valmont	TB2-17 (M104)	0.1793	9.25	1.0	12.00	12.0
2	8-06-91	Valmont	Valmont	TB2-17 (M104)	0.1793	9.25	1.0	12.00	12.0
3	8-06-91	Valmont	Valmont	TB2-17 (M104)	0.1793	9.25	1.0	12.00	12.0
4	8-06-91	Valmont	Valmont	TB2-17 (M104)	0.1793	9.25	1.0	12.00	12.0
5	8-06-91	Valmont	Valmont	TB2-17 (M104)	0.1793	7.50	1.0	9.75	9.75
6	8-07-91	Valmont	Valmont	TB2-17 (M104)	0.1793	7.50	1.0	9.75	9.75
7	8-07-91	Valmont	Valmont	TB2-17 (M104)	0.1793	7.50	1.0	9.75	9.75
8	8-07-91	Valmont	Valmont	TB2-17 (M104)	0.1793	7.50	1.0	9.75	9.75
9	9-13-91	Valmont	Valmont	TB2-17 (M104)	0.1793	7.00	0.875	10.875	10.875
10	9-13-91	Valmont	Valmont	TB2-17 (M104)	0.1793	7.00	0.875	10.875	10.875
11	9-18-91	Valmont	Valmont	TB2-17 (M104)	0.1793	8.00	0.875	11.5	11.5
12	9-18-91	Valmont	Valmont	TB2-17 (M104)	0.1793	7.00	0.875	10.875	10.875
13	9-18-91	Valmont	Valmont	TB2-17 (M104)	0.1793	7.00	0.875	10.875	10.875
14	9-18-91	Valmont	Valmont	TB2-17 (M104)	0.1793	7.00	0.875	10.875	10.875

TABLE 7b (Continued). TB Static Test Data (Valmont Industries)

Test No. (1)	Date (2)	Top: Bolt Circle (in.) (11)	Top: Bolt Dia. (in.) (12)	Top: Washer O.D.-I.D.-t (in.-in.-in.) (13)	Bottom: Bolt Circle (in.) (14)	Bottom: Bolt Dia. (in.) (15)	Bottom: Washer O.D.-I.D.-t (in.-in.-in.) (16)	Failure Load (lbs) (17)	Moment Arm (ft) (18)	Breaking Moment (ft-lbs) (19)	Door Orien-tation[a] (20)	Failure and Other Remarks (21)
1	8-06-91	12.0	1.00	2.5-1 1/16-6/16	12.0	1.00	2 3/4-1 1/16-1/2	886	36.98	32,764	DDC	Bott. wall tens. side
2	8-06-91	12.0	1.00	2.5-1 1/16-6/16	12.0	1.00	2 3/4-1 1/16-1/2	850	36.98	31,433	DDC	Bott. wall tens. side
3	8-06-91	12.0	1.00	2.5-1 1/16-6/16	12.0	1.00	2 3/4-1 1/16-1/2	874	36.98	32,321	DC	Bott. wall tens. side
4	8-06-91	12.0	1.00	2.5-1 1/16-6/16	12.0	1.00	2 3/4-1 1/16-1/2	853	36.98	31,544	DC	Bott. wall tens. side
5	8-06-91	10.0	1.00	2.5-1 1/16-6/16	10.0	1.00	2 3/4-1 1/16-1/2	865	26.23	22,689	DDC	Bott. wall tens. side
6	8-07-91	10.0	1.00	2.5-1 1/16-6/16	10.0	1.00	2 3/4-1 1/16-1/2	853	26.23	22,374	DDC	Top wall tens. side
7	8-07-91	10.0	1.00	2.5-1 1/16-6/16	10.0	1.00	2 3/4-1 1/16-1/2	907	26.23	23,791	DDC	Top wall tens. side
8	8-07-91	10.0	1.00	2.5-1 1/16-6/16	10.0	1.00	2 3/4-1 1/16-1/2	780	26.23	20,459	DDC	Top wall tens. side
9	9-13-91	10.0	1.00	2.5-1 1/16-6/16	10.0	1.00	2 3/4-1 1/16-1/2	925	19.50	18,038	DDC	Top wall tens. side
10	9-13-91	10.0	1.00	2.5-1 1/16-6/16	10.0	1.00	2 3/4-1 1/16-1/2	1,157	19.50	22,562	DDC	Bott. wall tens. side
11	9-18-91	11.0	1.00	2.5-1 1/16-6/16	11.0	1.00	2 3/4-1 1/16-1/2	858	31.50	27,027	DDC	Top wall tens. side
12	9-18-91	10.0	1.00	2.5-1 1/16-6/16	10.0	1.00	2 3/4-1 1/16-1/2	1,143	19.50	22,289	DDC	Top wall tens. side
13	9-18-91	10.0	1.00	2.5-1 1/16-6/16	10.0	1.00	2 3/4-1 1/16-1/2	1,016	19.50	19,812	DDC	Top wall tens. side
14	9-18-91	10.0	1.00	2.5-1 1/16-6/16	10.0	1.00	2 3/4-1 1/16-1/2	1,109	19.50	21,626	DDC	Top wall tens. side

[a] DC= door in compression; DDC= door in diagonal compression.

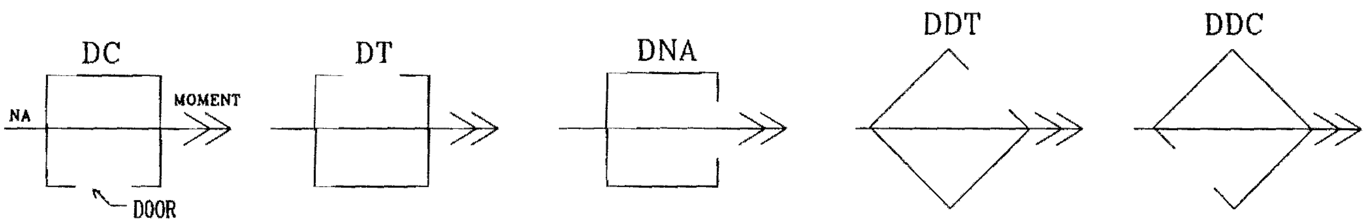

TABLE 8. TB Static Test Data (Union Metal)

Test No. (1)	Date (2)	Tested By (3)	Tested For (4)	Design Designation (5)	Pole: Wall Thickness (in.) (6)	Pole: Outer Dia. (in.) (7)	Pole Base Plate: Thickness (in.) (8)	Pole Base Plate: Length (in.) (9)	Pole Base Plate: Width (in.) (10)
00201	3-6-91	Union Metal	Union Metal	TB3-AF1517-17 I.W.	0.25	10.0	1.25	15	15
00202	3-6-91	Union Metal	Union Metal	TB3-AF1517-17 I.W.	0.25	10.0	1.25	15	15
00203	3-6-91	Union Metal	Union Metal	TB3-AF1517-17 I.W.	0.25	10.0	1.25	15	15
00204	3-6-91	Union Metal	Union Metal	TB3-AF1517-17 I.W.	0.25	10.0	1.25	15	15
00205	3-6-91	Union Metal	Union Metal	TB3-AF1517-17 I.W.	0.25	10.0	1.25	15	15
00206	3-6-91	Union Metal	Union Metal	TB3-AF1517-17 I.W.	0.25	8.50	1.25	15	15
00207	3-6-91	Union Metal	Union Metal	TB3-AF1517-17 I.W.	0.25	8.50	1.25	15	15
00208	3-6-91	Union Metal	Union Metal	TB3-AF1517-17 I.W.	0.25	8.50	1.25	15	15
00209	3-6-91	Union Metal	Union Metal	TB3-AF1517-17 I.W.	0.25	8.50	1.25	15	15
00210A	3-6-91	Union Metal	Union Metal	TB3-AF1517-17 I.W.	0.25	8.50	1.25	15	15
00210B	3-6-91	Union Metal	Union Metal	TB3-AF1517-17 I.W.	0.25	8.50	1.25	15	15
00211	3-6-91	Union Metal	Union Metal	TB3-AF1517-17 I.W.	0.25	8.50	1.25	15	15
00212	3-6-91	Union Metal	Union Metal	TB3-AF1517-17 I.W.	0.25	8.50	1.25	15	15
00213	3-6-91	Union Metal	Union Metal	TB3-AF1517-17 I.W.	0.25	8.50	1.25	15	15
UMST-4	September1990	Southwest Research Inst.	Union Metal	A2849-G101R11	0.1196	9.00	1.00	12.50	12.50
UMST-1	September1990	Southwest Research Inst.	Union metal	A2850-C1R10	0.1196	9.00	1.00	12.50	12.50

TABLE 8 (Continued). TB Static Test Data (Union Metal)

Test No. (1)	Date (2)	Top: Bolt Circle (in.) (11)	Top: Bolt Dia. (in.) (12)	Top: Washer O.D.-I.D.-t (in.-in.-in.) (13)	Bottom: Bolt Circle (in.) (14)	Bottom: Bolt Dia. (in.) (15)	Bottom: Washer O.D.-I.D.-t (in.-in.-in.) (16)	Failure Load (lbs) (17)	Moment Arm (ft) (18)	Breaking Moment (ft-lbs) (19)	Door Orientation[a] (20)	Failure and Other Remarks (21)
00201	3-6-91	15	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	17.25	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	3500	20	70,000	DT	Bottom lugs on tension side
00202	3-6-91	15	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	17.25	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	3700	20	74,000	DNA	Bottom lugs on tension side
00203	3-6-91	15	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	17.25	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	4000	20	80,000	DC	Bottom lugs on tension side
00204	3-6-91	15	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	17.25	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	3400	20	68,000	DDT	Bottom lug on tension corner
00205	3-6-91	15	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	17.25	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	3550	20	71,000	DDC	Top lug on tenson corner
00206	3-6-91	15	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	17.25	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	3400	20	68,000	DT	Bottom lugs on tension side
00207	3-6-91	15	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	17.25	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	3800	20	76,000	DNA	Top lugs on tension side
00208	3-6-91	15	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	17.25	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	3200	20	64,000	DC	Bottom lugs on tension side
00209	3-6-91	15	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	17.25	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	3250	20	65,000	DDT	Top lug on tension corner
00210A	3-6-91	15	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	17.25	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	800	20	16,000	DDC	Bad Heat Treatment
00210B	3-6-91	15	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	17.25	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	800	20	16,000	DDC	Bad Heat Treatment
00211	3-6-91	15	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	17.25	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	3500	20	70,000	DDC	Top lug on tension corner
00212	3-6-91	15	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	17.25	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	3000	20	60,000	DDC	Top lug on tension corner
00213	3-6-91	15	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	17.25	1.25	$2\frac{3}{4}$-$1\frac{5}{16}$-$\frac{1}{2}$	3250	20	65,000	DDC	Top lug on tension corner
UMST-4	Sept., 90	12.5	1.00	N/A	15	1.25	N/A	901	38.66	34,832	DC	At the top seam in the weld
UMST-1	Sept., 90	12.5	1.00	N/A	12.5	1.25	N/A	1070	38.66	41,373	DC	At the top of the base

[a]DT= door in tension; DNA=door on neutral axis; DC= door in compression; DDT= door in diagonal tension; DDC= door in diagonal compression.

Note: A 0.0625" thick shim was installed at each corner of the t-base and the test fixture.

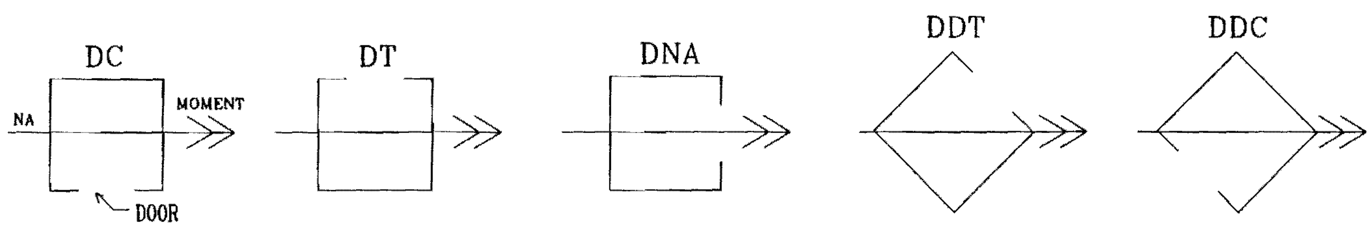

TABLE 9. TB Static Test Data (JEM)

Test No. (1)	Date (2)	Tested By (3)	Tested For (4)	Design Designation (5)	Pole		Pole Base Plate		
					Wall Thickness (in.) (6)	Outer Dia. (in.) (7)	Thickness (in.) (8)	Length (in.) (9)	Width (in.) (10)
1	4-19-91	Akron F. Co.	JEM	TB1-17	0.3125	7.50	1.25	13.0	13.0
2	4-19-91	Akron F. Co.	JEM	TB1-17	0.3125	7.50	1.25	13.0	13.0
3	4-19-91	Akron F. Co.	JEM	TB1-17	0.3125	7.50	1.25	13.0	13.0
4	4-19-91	Akron F. Co.	JEM	TB1-17	0.3125	7.50	1.25	13.0	13.0
5	4-19-91	Akron F. Co.	JEM	TB1-17	0.3125	7.50	1.25	13.0	13.0
1	4-19-91	Akron F. Co.	JEM	TB3-17	3 Ga.	10.13	1.50	15.0	15.0
2	4-19-91	Akron F. Co.	JEM	TB3-17	3 Ga.	10.13	1.50	15.0	15.0
3	4-19-91	Akron F. Co.	JEM	TB3-17	3 Ga.	10.13	1.50	15.0	15.0
4	4-19-91	Akron F. Co.	JEM	TB3-17	3 Ga.	10.13	1.50	15.0	15.0
5	4-19-91	Akron F. Co.	JEM	TB3-17	3 Ga.	10.13	1.50	15.0	15.0
6	4-19-91	Akron F. Co.	JEM	TB3-17	3 Ga.	10.13	1.50	15.0	15.0

TABLE 9 (Continued). TB Static Test Data (JEM)

Test No. (1)	Date (2)	Top: Bolt Circle (in.) (11)	Top: Bolt Dia. (in.) (12)	Top: Washer O.D.-I.D.-t (in.-in.-in.) (13)	Bottom: Bolt Circle (in.) (14)	Bottom: Bolt Dia. (in.) (15)	Bottom: Washer O.D.-I.D.-t (in.-in.-in.) (16)	Failure Load (lbs) (17)	Moment Arm (ft) (18)	Breaking Moment (ft-lbs) (19)	Door Orientation[a] (20)	Failure and Other Remarks (21)
1	4-19-91	13	1.00	$2\frac{3}{4}-1\frac{1}{16}-\frac{1}{2}$	15	1.00	$2\frac{3}{4}-1\frac{1}{16}-\frac{1}{2}$	1910	25.730	49,144.3	DT	At bottom tension side
2	4-19-91	13	1.00	$2\frac{3}{4}-1\frac{1}{16}-\frac{1}{2}$	15	1.00	$2\frac{3}{4}-1\frac{1}{16}-\frac{1}{2}$	2050	25.730	52,746.5	DNA	At bottom tension side
3	4-19-91	13	1.00	$2\frac{3}{4}-1\frac{1}{16}-\frac{1}{2}$	15	1.00	$2\frac{3}{4}-1\frac{1}{16}-\frac{1}{2}$	2000	25.730	51,460.0	DC	At bottom tension side
4	4-19-91	13	1.00	$2\frac{3}{4}-1\frac{1}{16}-\frac{1}{2}$	15	1.00	$2\frac{3}{4}-1\frac{1}{16}-\frac{1}{2}$	1750	25.730	45,027.5	DDT	At top tension corner
5	4-19-91	13	1.00	$2\frac{3}{4}-1\frac{1}{16}-\frac{1}{2}$	15	1.00	$2\frac{3}{4}-1\frac{1}{16}-\frac{1}{2}$	1975	25.730	50,816.5	DDC	At top tension corner
1	4-19-91	15	1.25	$2\frac{3}{4}-1\frac{5}{16}-\frac{1}{2}$	17.25	1.25	$2\frac{3}{4}-1\frac{5}{16}-\frac{1}{2}$	2750	25.646	70,526.5	DT	At bottom tension side
2	4-19-91	15	1.25	$2\frac{3}{4}-1\frac{5}{16}-\frac{1}{2}$	17.25	1.25	$2\frac{3}{4}-1\frac{5}{16}-\frac{1}{2}$	2200	25.646	56,421.2	DNA	At bottom tension side
3	4-19-91	15	1.25	$2\frac{3}{4}-1\frac{5}{16}-\frac{1}{2}$	17.25	1.25	$2\frac{3}{4}-1\frac{5}{16}-\frac{1}{2}$	2650	25.646	67,961.9	DC	At bottom tension side
4	4-19-91	15	1.25	$2\frac{3}{4}-1\frac{5}{16}-\frac{1}{2}$	17.25	1.25	$2\frac{3}{4}-1\frac{5}{16}-\frac{1}{2}$	2700	25.646	69,244.2	DDT	At bottom tension corner
5	4-19-91	15	1.25	$2\frac{3}{4}-1\frac{5}{16}-\frac{1}{2}$	17.25	1.25	$2\frac{3}{4}-1\frac{5}{16}-\frac{1}{2}$	2440	25.646	62,576.2	DDC	At top tension corner
6	4-19-91	15	1.25	$2\frac{3}{4}-1\frac{5}{16}-\frac{1}{2}$	17.25	1.25	$2\frac{3}{4}-1\frac{5}{16}-\frac{1}{2}$	2650	25.646	67,961.9	DC	At bottom tension corner

[a]DT= door in tension; DNA=door on neutral axis; DC= door in compression; DDT= door in diagonal tension; DDC= door in diagonal compression.

Note: A 0.06" thick shim was installed at each corner between the t-base and the test fixture.

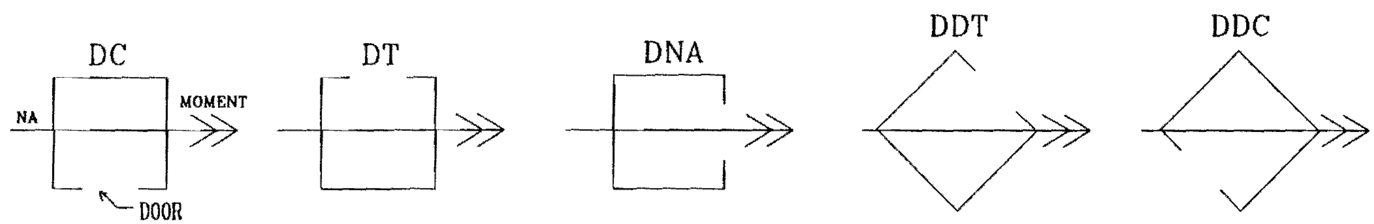

TABLE 10 TB Static Test Data (C. R. Briden)

Test No. (1)	Date (2)	Tested By (3)	Tested For (4)	Design Designation (5)	Pole[a] Wall Thickness (in.) (6)	Pole[a] Outer Dia. (in.) (7)	Pole Base Plate[b] Thickness (in.) (8)	Pole Base Plate[b] Length (in.) (9)	Pole Base Plate[b] Width (in.) (10)
SKA-6149	5-08-92	C. R. Briden	N/A	SB-8/TB3-17	0.25	12	3	15	15

[a] With 0.25 in. wall × 36 in. long internal reinforcing sleeve;
[b] 356-T6 cast Al. Alloy Shoe Base type "SB-8'.

TABLE 10 (Continued). TB Static Test Data (C. R. Briden)

Test No. (1)	Date (2)	Top Bolt Circle (in.) (11)	Top Bolt Dia. (in.) (12)	Top Washer O.D.-I.D.-t (in.-in.-in.) (13)	Bottom Bolt Circle (in.) (14)	Bottom Bolt Dia. (in.) (15)	Bottom Washer O.D.-I.D.-t (in.-in.-in.) (16)	Failure Load (lbs) (17)	Moment Arm[a] (ft) (18)	Breaking Moment (ft-lbs) (19)	Door Orien-tation[b] (20)	Failure and Other Remarks (21)
SKA-6149	5-08-92	15	1.25	$2\frac{3}{4}-1\frac{5}{16}-\frac{1}{2}$	17.25	1.25	$2\frac{3}{4}-1\frac{5}{16}-\frac{1}{2}$	2,510	25.0	62,750	DNA	Failed through top side section of base.

[a] Measured from the point of load to top of transformer base;
[b] DNA=door on neutral axis;
Note: A 0.06" thick shim was installed at each corner between the t-base and the test fixture.

TABLE 11a. Chemical and Physical Test Report of Transformer Base Material Specification S356T6 (A. F. Company) -- see Table 6a

Test No. (1)	Date (2)	Meets Chemical Analysis ? (3)	Ultimate Stress (psi) (4)	Yield Stress (psi) (5)	Elongation % (6)	Brinell Hardness (7)
174	2-1-86	YES	33,000	22,000	3%	80-82
175	2-1-86	YES	33,000	22,000	3%	80-82
176	2-1-86	YES	33,000	22,000	3%	80-82
177	2-1-86	YES	33,000	22,000	3%	80-82
178	2-1-86	YES	33,000	22,000	3%	80-82
179	2-1-86	YES	33,000	22,000	3%	80-82
180	2-1-86	YES	33,000	22,000	3%	80-82
181	2-1-86	YES	33,000	22,000	3%	80-82
182	2-1-86	YES	33,000	22,000	3%	80-82
1	5-31-88	YES	33,000	22,000	3%	80-82
2	5-31-88	YES	33,000	22,000	3%	80-82
3	5-31-88	YES	33,000	22,000	3%	80-82
4	5-31-88	YES	33,000	22,000	3%	80-82
5	5-31-88	YES	33,000	22,000	3%	80-82

TABLE 11b. Chemical and Physical Test Report of Transformer Base Material Specification S356T6[a] (A. F. Company) -- does not correspond to previous data

Test No. (1)	Date (2)	Batch No. (3)	Tensile Stress (psi) (4)	Yield Stress 0.2% (psi) (5)	Elongation % (6)
TB1-17 (Diameter = 0.25)					
1	6-30-92	0120614	40,900	28,500	6.9
2	6-30-92	0120614	39,300	32,100	3.5
3	6-30-92	0400607	43,900	32,500	8.0
4	6-30-92	0300607	42,600	29,550	8.5
5	6-30-92	0150607	38,000	28,950	3.6
6	6-30-92	0480531	43,850	34,000	5.2
7	6-30-92	0260531	41,250	31,600	6.5
8	6-30-92	0120607	38,000	29,700	5.4
9	6-30-92	0480531	40,450	29,150	8.8
10	6-30-92	0270607	43,600	32,600	8.7
TB3-20 (Diameter = 0.25)					
1	6-30-92	0260614	40,400	28,850	10.6
2	6-30-92	0260614	41,500	30,000	9.8
APA2849-1 (Diameter = 0.25)					
1	6-30-92	0270607	39,350	30,700	4.2
2	6-30-92	0270607	40,150	30,800	5.1
3	6-30-92	0270607	41,100	30,100	6.5
4	6-30-92	0230621	42,600	28,550	9.7

[a] Test is performed by Al-Fe Heat Treating, Inc. for Akron Foundry Co.

TABLE 12. Chemical and Physical Test Report of Transformer Base[a] Material Specification S356T6 (Union Metal) -- see Table 8

Test No. (1)	Date (2)	Meets Chemical Analysis ? (3)	Ultimate Stress (psi) (4)	Yield Stress (psi) (5)	Elongation % (6)	Brinell Hardness (7)
00201	3-6-91					
00202	3-6-91					
00203	3-6-91					
00204	3-6-91					
00205	3-6-91	YES	30556	22368	3.0	70
00206	3-6-91					
00207	3-6-91					
00208	3-6-91					
00209	3-6-91					
00210A	3-6-91	YES	26565	18195	3.5	65
00210B	3-6-91					
00211	3-6-91	YES	26935	21548	2.5	70
00212 Side	3-6-91	YES	31709	23446	3.0	Not Checked
00212 Corner	3-6-91	YES	34128	23501	4.0	74
00213	3-6-91	YES	31168	23504	3.0	Not Checked
UMST-4	September 1990					
UMST-1	September 1990					

[a] Material tests conducted by Hark Laboratories, Inc. for Union Metal.
Note: Material test were not done on all bases tessted.

TABLE 13. Chemical and Physical Test Report of Transformer Base Material Specification S356T6 (JEM) -- see Table 9

Test No. (1)	Date (2)	Meets Chemical Analysis ? (3)	Ultimate Stress (psi) (4)	Yield Stress (psi) (5)	Elongation % (6)	Brinell Hardness (7)
1	4-19-91		35,744	24,592	5.0	84
2	4-19-91					
3	4-19-91					
4	4-19-91					
5	4-19-91					
1	4-19-91		37,875	28,538	5.0	82
2	4-19-91					
3	4-19-91					
4	4-19-91					
5	4-19-91					
6	4-19-91					

TABLE 14. Chemical and Physical Test Report of Transformer Base Material Specification S356T6 (C. R. Briden) -- see Table 10

Test No. (1)	Date (2)	Meets Chemical Analysis ? (3)	Ultimate Stress (psi) (4)	Yield Stress (psi) (5)	Elongation % (6)	Brinell Hardness (7)
SKA-6149	5-08-92	YES	38,500	29,000	3% in 2 in.	N/A

EVALUATION OF TRANSFORMER BASE DATA

There is a great deal of scatter in the data presented herein. Figures 1 through 5 present comparisons of breaking moment for varying base plate thickness, pole diameter, base plate width, bottom bolt circle, and top bolt circle for all of the data obtained in Tables 6a through 10. Based on these comparisons, one would conclude that apparent trends exist and that construction of design curves is an obtainable goal. This is especially true if data resulting from improper heat treatment (solid diamond in Figures 1 through 5) is removed from consideration. Similarly, if one speculates that the actual breaking moment for those tests in which no failure occurred due to lack of stroke in the test fixture would be significantly higher than the results shown by the inverted triangles, the trends would become more obvious.

It should be noted, however, that the above comparisons include all data regardless of t-base type. In addition, many of the tests had more than one variable which changed (e.g. thicker base plate may also have larger diameter pole, larger bolt circles, etc.), making it difficult to assess the effect of an individual variable on the capacity of the t-base. Figures 6 through 10 represent comparisons of data for which all variables remain constant except that shown on the abscissa. For example, for the data in Figure 6, although the pole diameter varies from 7.5 in. to 10 in., the base plate dimensions are essentially constant. The key on these figures contains the identity of the testing agency as well as the orientation of the door during the testing (DC = door in compression, DT = door in tension, DNA = door on neutral axis, DDC = door in diagonal compression, and DDT = door in diagonal tension). Unfortunately, unlike Figures 1 through 5, there are no clear trends evident in this data.

A number of contributing factors may explain the apparent disagreement between the two sets of figures. These factors include but are not limited to the following: the lack of a statistical experimental design (i.e., limited repeated tests and limited tests with only a single parameter varied); variability in testing procedures used by different laboratories; ambiguous definitions of terms (e.g., breaking moment calculated at the top of the t-base versus elsewhere); inconsistent methods used to report the data (TB2 data was obtained from fewer sources); variability in material properties (while "within the specification"); unknown and unreported factors; and the possible combined effects of the various factors (e.g., a larger thinner base plate or a smaller pole on a larger base plate).

Confusion regarding the interpretation of these data have lead some vendors to a "system only" approach wherein transformer bases and poles are not supplied independently but rather as a system which has been validated by static testing. Another approach is that taken by Valmont Industries placing limitations on the application of transformer bases as a result of evaluating test data:

> "TB1-17: We limit the size of the pole base plate to 13-1/8 in. square and 1-1/4 in. thick. We use a 13-1/2 in. top bolt circle and a 15 in. bottom bolt circle with the akron 2-1/2 in. diameter by 3/8 in. thick washer under the top flange and the 2-3/4 in. by 1/2 in. thick washer on the bottom flange. Under these conditions we allow a bending moment at the top of the t-base of 24,100 ft-lb. Along with the FHWA approved pole weight of 950 lb and mounting height of 55 ft-5 in.
>
> TB2-17: Using a 12-1/8 in. square and 1 in. thick base plate with a 12 in. to 12-1/2 in. top bolt circle and a 12 in. bottom bolt circle and (in all cases) the 2-1/2 in. diameter by 3/8 in. thick washer at the top and the 2-3/4 in. by 1/2 in. thick washer at the bottom - allowable bending moment at the top of t-base = 21,450 ft-lb. Along with a maximum pole weight of 550 lb and maximum mounting height of 40 ft-10 in.
>
> Using an 11-1/2 in. square and 7/8 in. thick base plate with an 11 in. top and bottom bolt circle, allowable bending moment at the top of the t-base = 17,800 ft-lb.
>
> Using an 10-7/8 in. square and 7/8 in. thick base plate with an 10 in. top and bottom bolt circle, allowable bending moment at the top of the t-base = 14,160 ft-lb.
>
> TB3-17: Using a 15-1/8 in. square and 1-1/4 in. thick base plate with a 15-1/8 in. top bolt circle and a 17-1/4 in. bottom bolt circle and (in all cases) the 2-3/4 in. by 1/2 in. washers top and bottom, allowable bending moment at the top of the t-base = 32,850 ft-lb. Along with a maximum pole weight of 900 lb and maximum mounting height of 55 ft-5 in.
>
> Using a 12-1/2 in. square and 1 in. thick base plate with a 13 in. top bolt circle and a 15 in. bottom bolt circle, allowable bending moment at the top of the t-base = 22,410 ft-lb. Along with a maximum pole weight of 778 lb and maximum mounting height of 50 ft-0 in."

It should be noted that these are allowable bending moments as opposed to breaking moments as listed in the tables. According to the Aluminum Association, a factor of safety of 1.5 is applied to the 3 test average to obtain the allowable bending moment (unless tests are not within

10% of the average). Neither of these alternatives, while constituting sound engineering practice, effects an optimum solution for a particular situation.

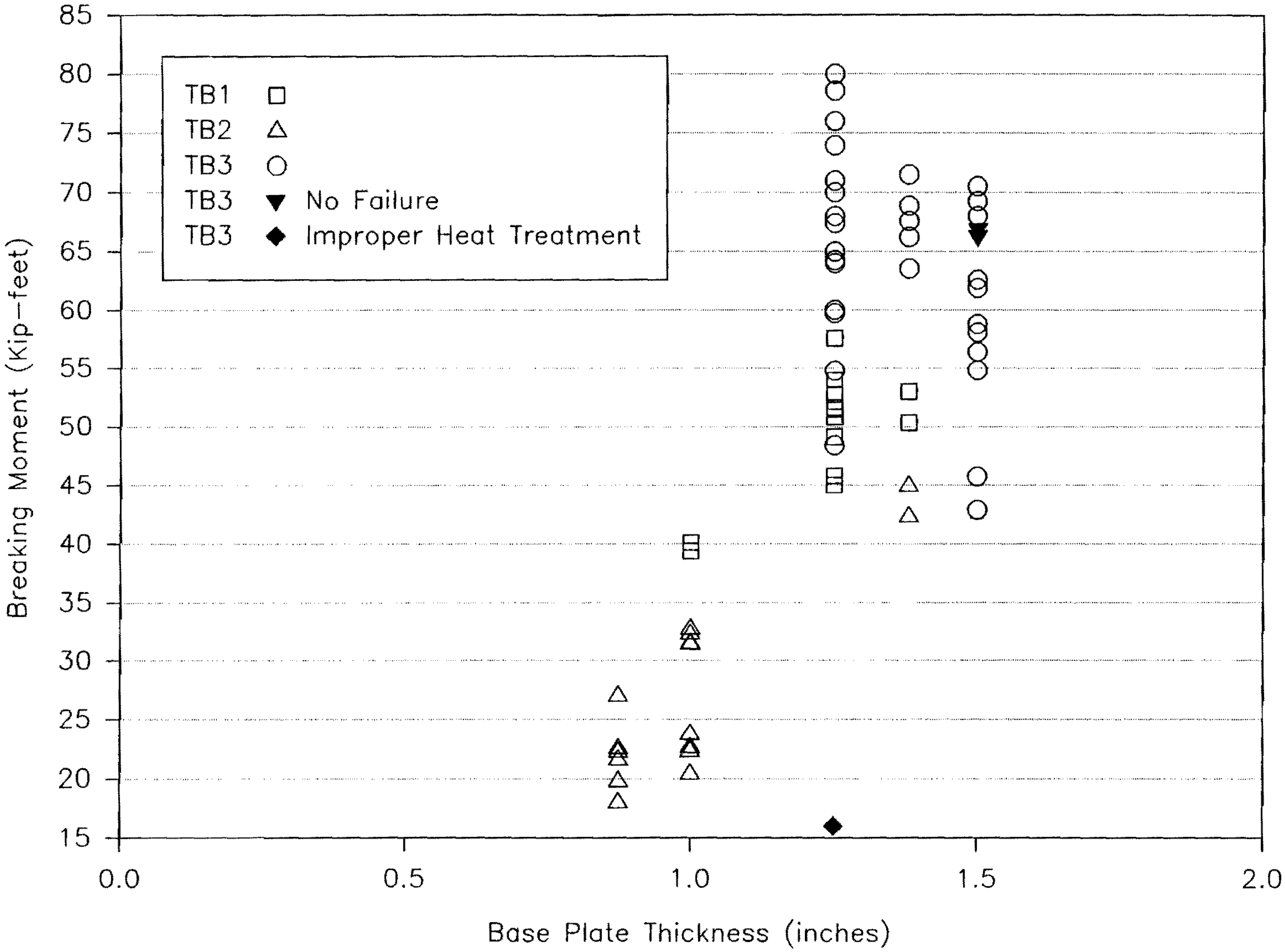

Figure 1. Relationship between Base Plate Thickness and Base Breaking Moment.

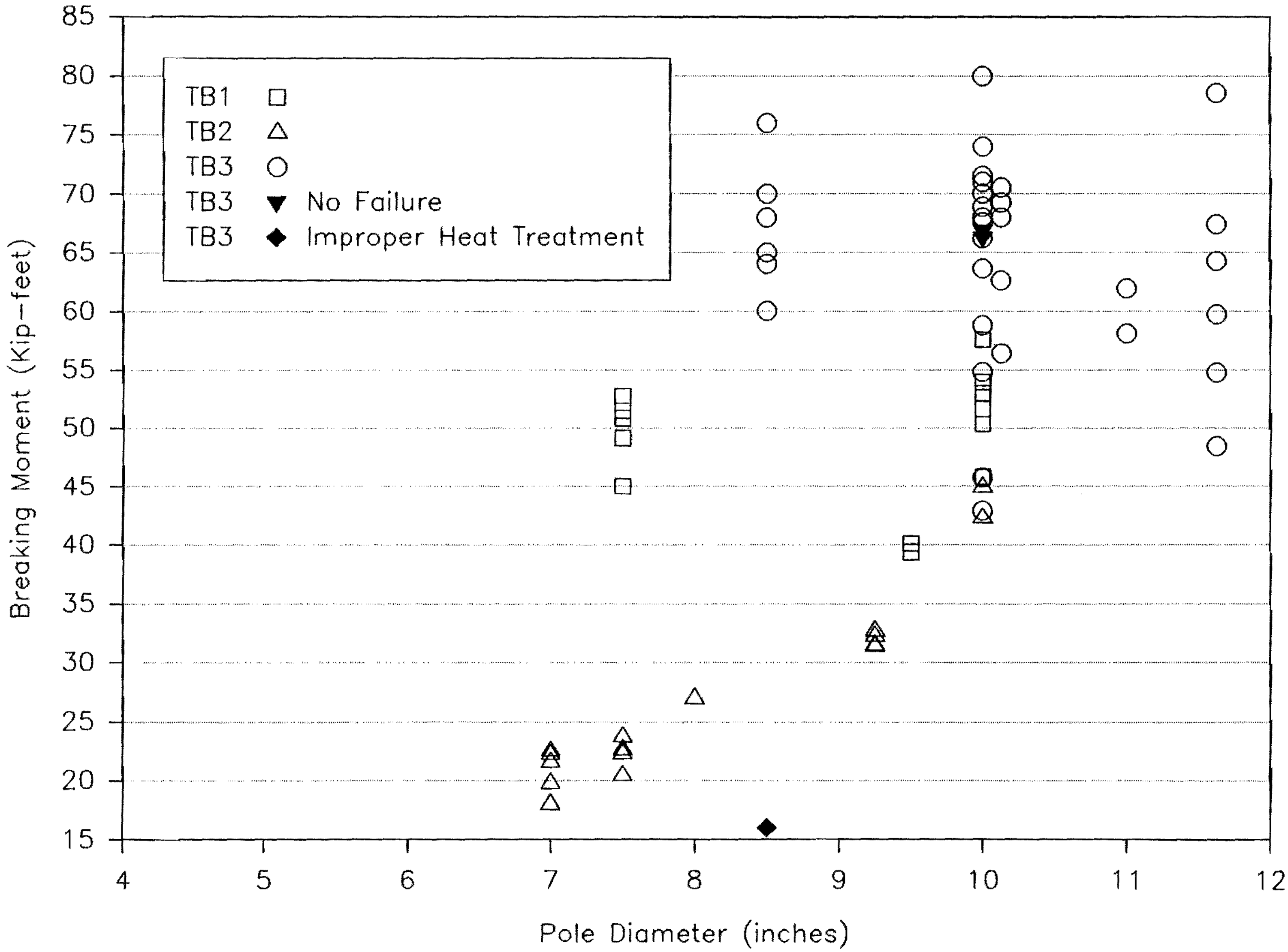

Figure 2. Relationship between Pole Diameter and Base Breaking Moment.

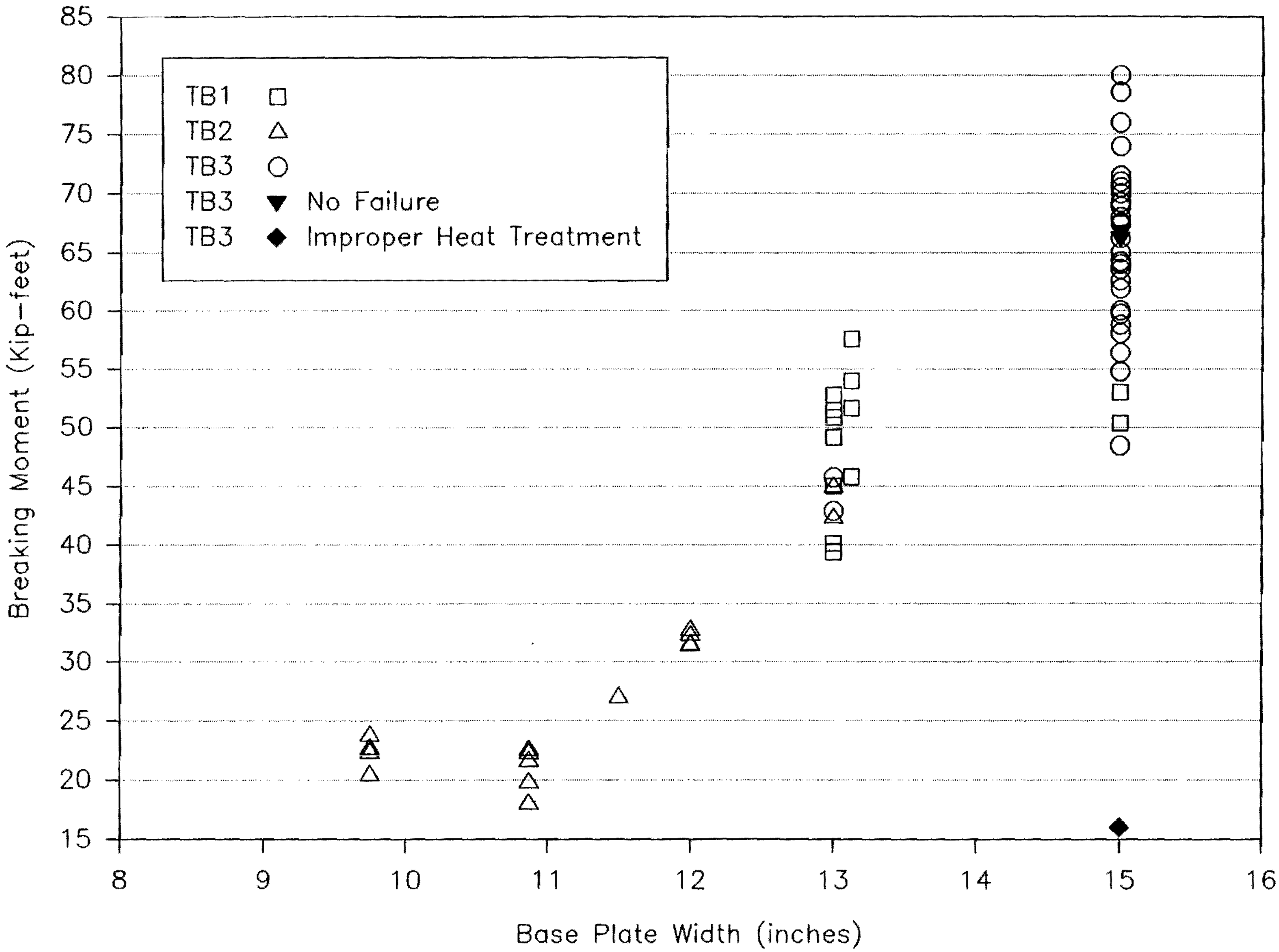

Figure 3. Relationship between Base Plate Width and Base Breaking Moment.

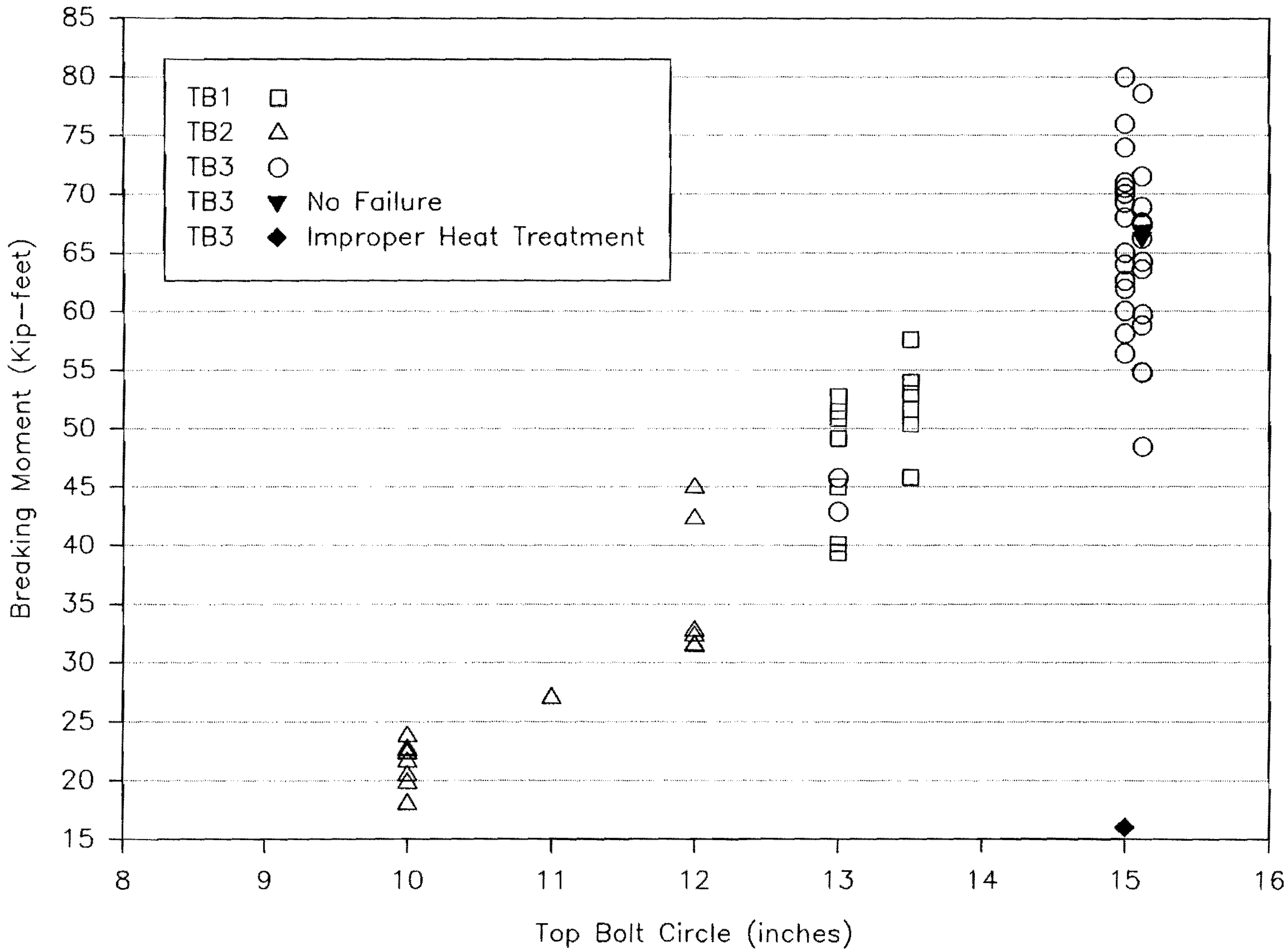

Figure 4. Relationship between Top Bolt Circle and Base Breaking Moment.

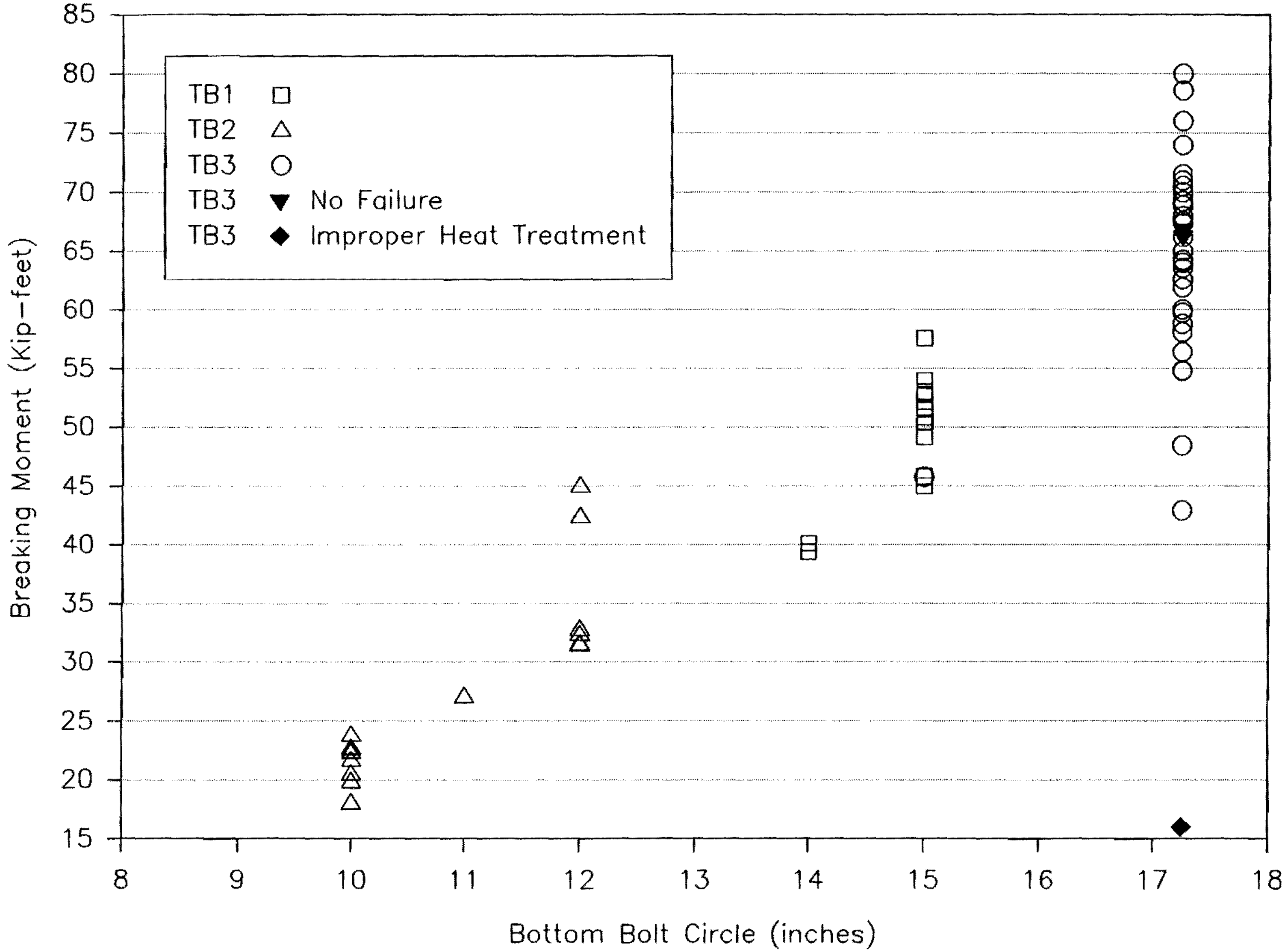

Figure 5. Relationship between Bottom Bolt Circle and Base Breaking Moment.

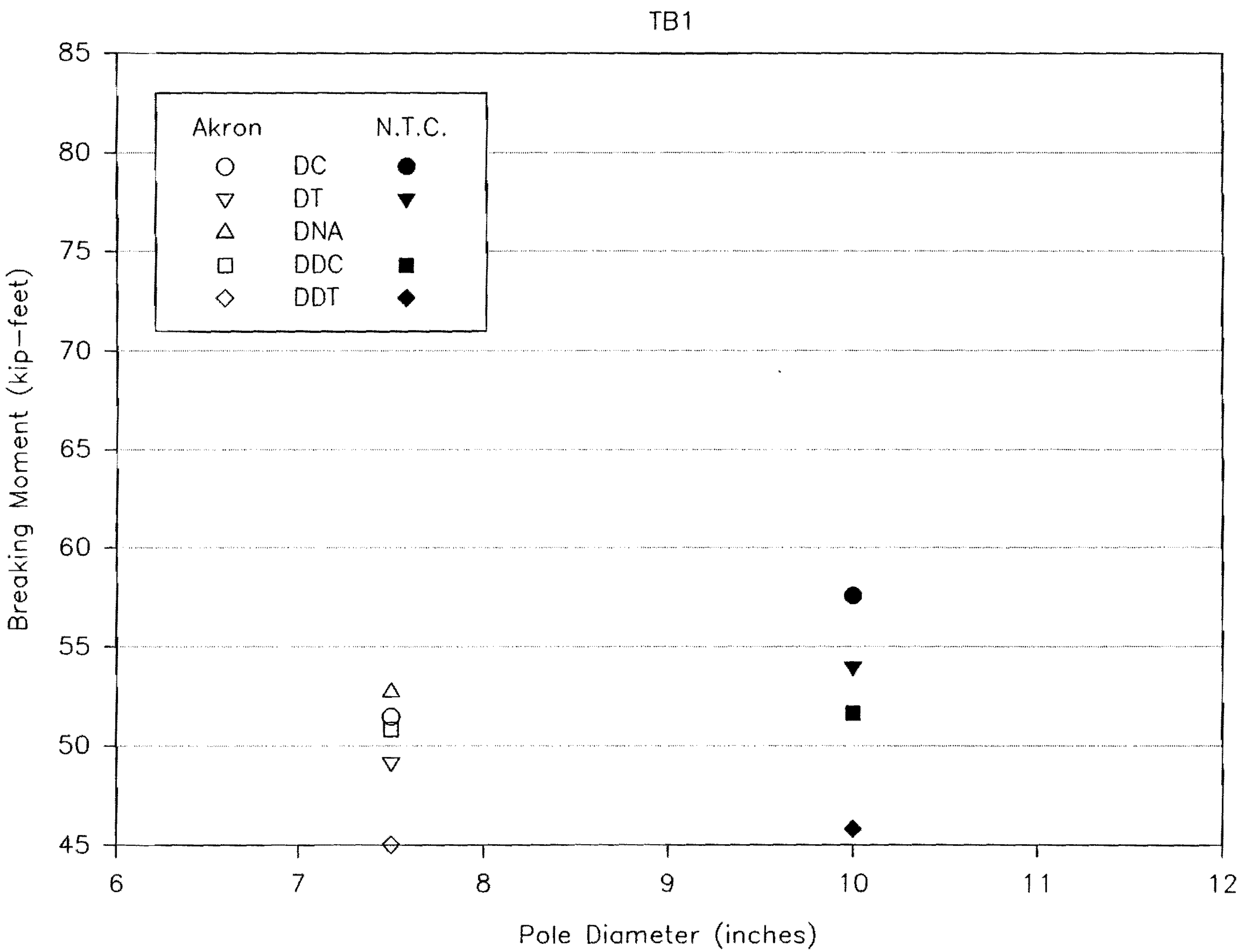

Figure 6. Relationship between Pole Diameter and Base Breaking Moment for Type TB1.

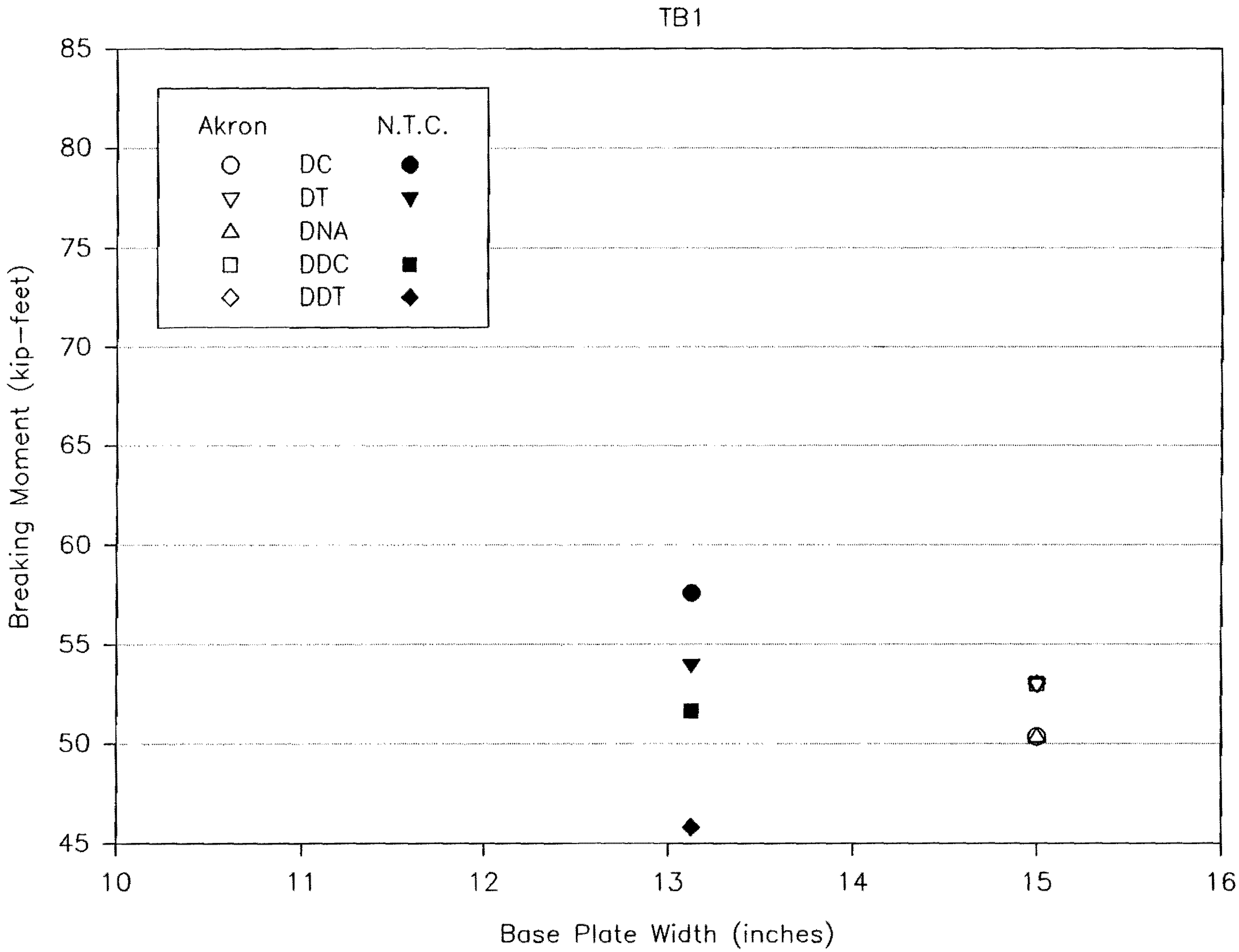

Figure 7. Relationship between Base Plate Width and Base Breaking Moment for Type TB1.

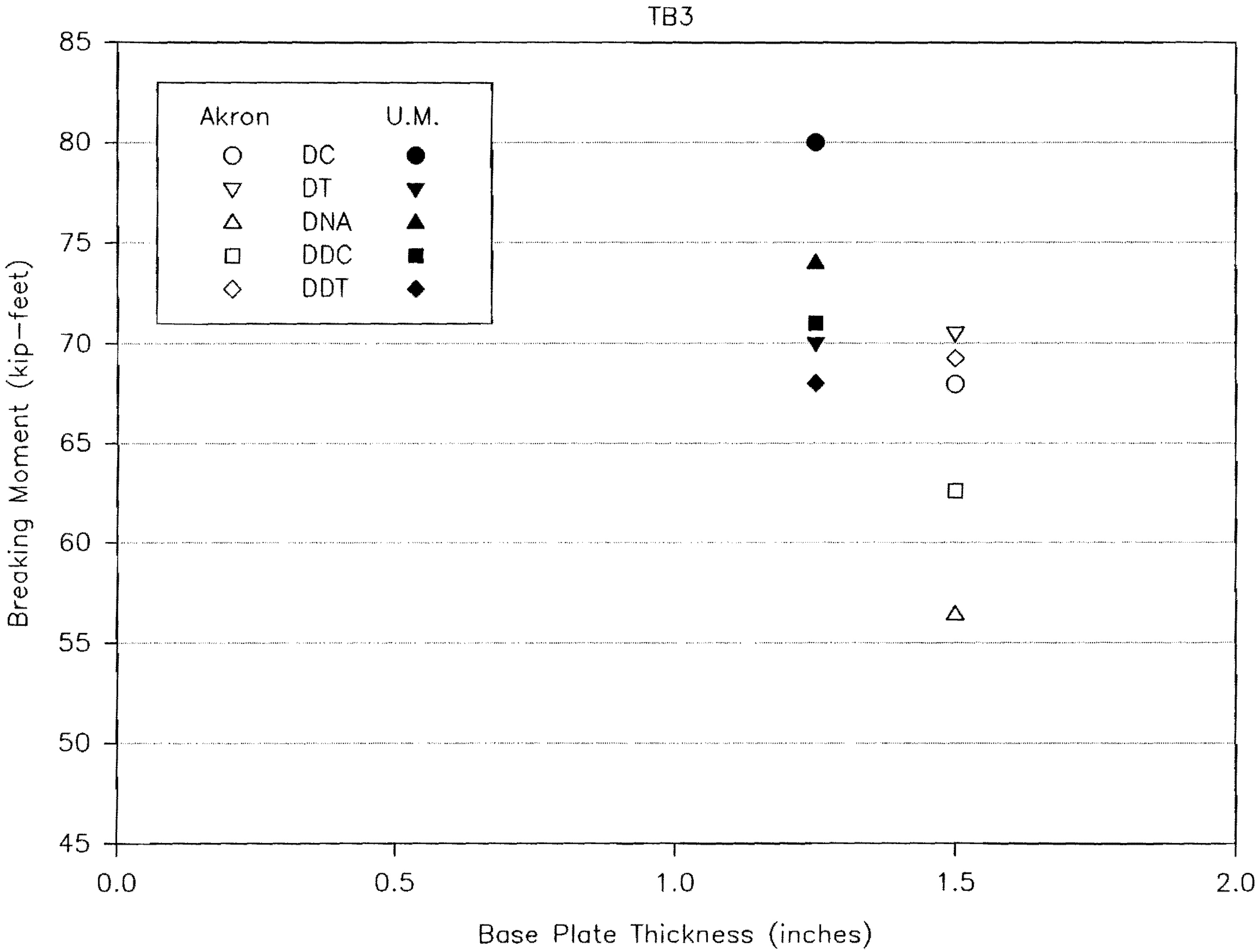

Figure 8. Relationship between Base Plate Thickness and Base Breaking Moment for Type TB3.

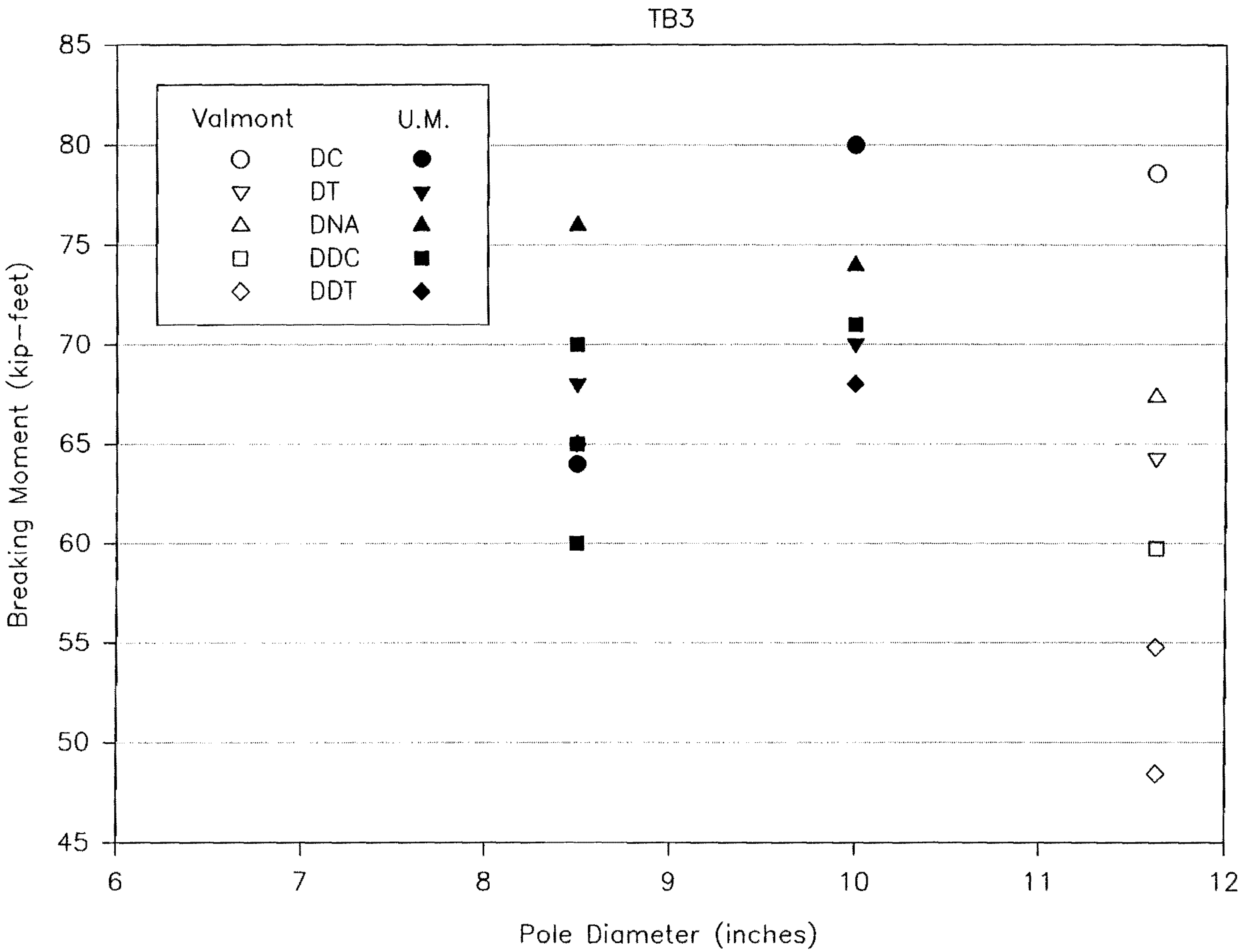

Figure 9. Relationship between Pole Diameter and Base Breaking Moment for Type TB3.

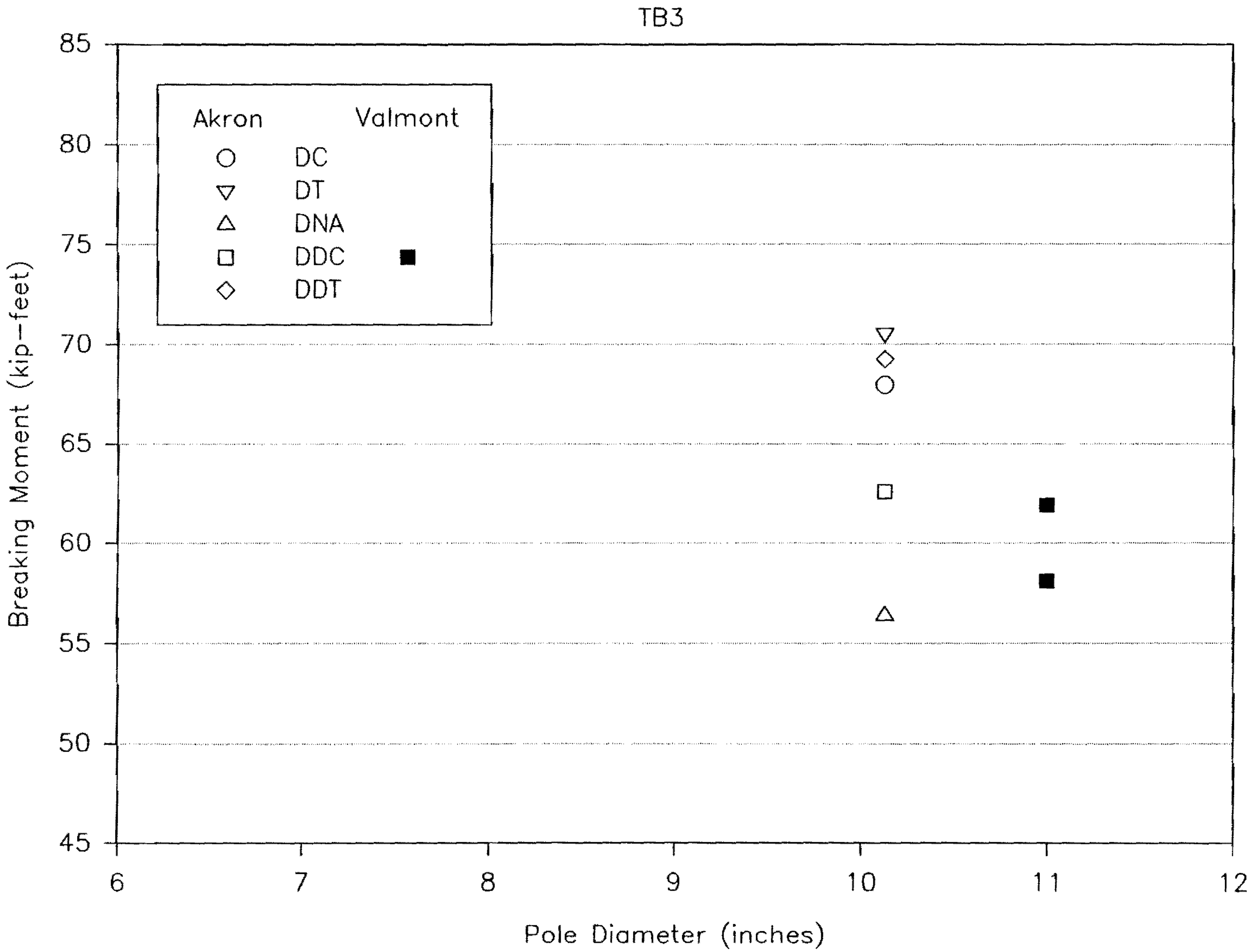

Figure 10. Relationship between Pole Diameter and Base Breaking Moment for Type TB3.

RECOMMENDATIONS

The trends present in the figures containing all of the data (see Figures 1 through 5) indicate the need for a thorough, statistically based series of static tests. The purposes of this series of tests would be the following: to verify the apparent trends in the combined data set, to determine the interaction between the important variables, and to ascertain the sensitivity of these trends to the "normal" variations present in transformer bases including geometric irregularities, variability in material properties, etc. Finally, if the current trends are validated, a set of charts could be constructed which would allow the determination of appropriate transformer base (type TB#?) / pole / base plate combinations. The test matrix would consist of varying pole diameter, base plate thickness, bolt circle (top and bottom), base plate width, and type and size of washers to be used. It would be necessary to limit the scope of such a study to the predominant values existing (or expected) for the given variables. Even if all of the existing t-base data were suitable for incorporation and 2 repetitions were deemed statistically sufficient, it would require approximately 50 static tests to complete any one t-base series. A similar series of tests could be conducted for each t-base type.

There is insufficient data to determine the suitability of using TB1, TB2, or TB3 17 in. t-bases as substitutes for existing 20 in. high bases. While it is assumed that satisfactory breakaway performance would result from such a substitution, it is not clear that the 17 in. high t-bases have the same static strength as the 20 in. bases. A series of static tests could be conducted to attempt to answer this question. However, it is unclear which pole, baseplate, etc. should be used to determine the adequacy of the new t-bases.

It is recommended that Phase 2 of this study consist of the following tasks:

1. A series of static tests to failure of a single configuration with all variables remaining constant to determine the effect of material and geometric uncertainties;
2. A statistically designed set of tests to determine the correlation of the different variables studied. It is envisioned that some parameters may be assumed dependent on other parameters so as to limit the total number of tests. For example, pole diameter, base plate thickness, and bottom bolt circle might be selected as independent variables, with base plate width and top bolt circle dependent on the pole diameter.

3. A series of tests on strain gaged t-bases which are not taken to failure to determine the critical door orientation (the existing data does not show a consistent trend);

4. A series of tests to failure of the "old" t-bases. If a goal is to replace "old" with "new" in a maintenance operation, then data on the strength of "old" t-bases must be determined.

REFERENCES

Date (2)	From (3)	To (4)	Subject with Remarks (5)
2-1-86	Akron F. Company.	TxDOT	Static test of TB3-20
2-23-89	Karl Mac-chietto (Valmont)	John Panak (TxDOT)	The State of Texas light pole Specification
10-19-89	Jeffrey H. O'Connor (Valmont)	TxDOT	Certification, T-base testing for the State of Texas
5-18-90	Valmont	John Panak	Plastic mom. cal. of 80 & 90 mph for different types of steel poles
5-18-90	Donald F. Stevens (Nebraska T. corp.)	Dennis O'Brian (Valmont)	T-base load test for TxDOT with photos
5-29-90	Redwin Krueger Inc.	Karl Burkett (TxDOT)	P & K aluminum poles
11-8-90	Michael Barker (JEM Engin.& Manuf.)	John Panak	Akron Transformer Base testing
11-16-90	Luis Ybanez (TxDOT)	Michael Barker (JEM E.& M.)	Transformer base testing
11-19-90	Union Metal	John Panak	T-base strength test of two models-20"
12-11-90	D. H. O'Brian (Valmont)	John Panak	Static test results of alum. t-base
3-6-91	Joe Brindlinger (Union Metal)	John Panak	Plastic mom. capacity of TB3-17 as used on Drawing 1408 M-90-D5
3-6-91	Joe Brindlinger (Union Metal)	John Panak	Test of A. F. alum. T-base TB3-17
3-14-91	Gilbert Barr (TxDOT)	Karl Burkett	Transformer bases for luminaires
3-18-91	Earnest Kanak (Union Metal)	Gary K. Trietsch (TxDOT)	T-bases for Luminaires concerning letter #5
5-2-91	James R. Sutphen (JEM Engin.& Manuf.)	John Panak	Chem. comp., temp.-mech.prop. of material, static test of TB3-17; TB1-17
6-10-91	Michael Barker (JEM Engin.& Manuf.)	John Panak	T-base testing info. concerning letter #13
7-16-92	Akron F. Company	Karl Burkett	Mat. test for TB1-17, TB3-20, A2849 by AL-Fe Heat Treating, Inc.
6-4-93	Robert A. Sik (Akron Foundry)	Hayes E. Ross, Jr. (TTI)	TB, Pole, and Static Test Data
6-10-93	Paul Haig (Union Metal)	Hayes E. Ross, Jr. (TTI)	TB, Pole, and Static Test Data
6-10-93	Joe B. Mayer, Jr. (Southwest Res. Inst.)	Hayes E. Ross, Jr. (TTI)	TB, Pole, and Static Test Data
6-11-93	Walt Wolos (P&K Pole Products)	Hayes E. Ross, Jr. (TTI)	TB, Pole, and Static Test Data
6-14-93	D. H. O'Brian (Valmont)	Hayes E. Ross, Jr. (TTI)	TB, Pole, and Static Test Data
6-15-93	Robert A. Sik (Akron Foundry)	James R. Morgan (TTI)	Pole Data