EVALUATION OF DEFLECTION AND BENDING STRENGTH CHARACTERISTICS OF FIBER-REINFORCED PLASTIC LIGHTNING STANDARDS

95/14

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STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

ENGINEERING SERVICE CENTER,
OFFICE OF MATERIALS ENGINEERING AND TESTING SERVICES

STRUCTURAL MATERIALS BRANCH

EVALUATION OF DEFLECTION AND BENDING STRENGTH CHARACTERISTICS OF FIBER-REINFORCED PLASTIC LIGHTING STANDARDS

FINAL REPORT # FHWA/CA/TL-95/14

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16. Abstract

The results of tests performed on six different models of fiberglass-reinforced plastic (FRP) lighting standards are presented. Four parameters, including deflection of the pole tip under a specified bending load, ultimate bend strength, degradation of coating after 2,500 hours of accelerated weathering, and coating thickness, were evaluated. Results are compared to requirements in the California Department of Transportation 1992 Standard Special Provision 86.08.5 "Fiberglass Lighting Standards." Three different styles of FRP poles, some with breakaway anchor bases, direct burial breakaway joints, and non-breakaway anchor bases, (each style in lengths of 9,140. mm and 10,700. mm), were obtained from two manufacturers of FRP lighting standards.

From tests performed, it was determined that many of the breakaway poles failed to meet many of the Caltrans SSP requirements. A total of three anchor base breakaway poles tested did not meet maximum deflection criteria. A total of eight breakaway poles tested did not meet the minimum ultimate bending load. From exterior protection tests, it was determined that poles from one of the two manufacturers tested did not meet the minimum 3-mil dry finish thickness requirement and a significant change in color occurred in the paint coating after 2,500 hours of accelerated weathering tests. Because of the lack of compliance with Caltrans specifications, all of the breakaway FRP poles tested except one are not permitted to be used on Caltrans contracts until problems have been corrected. All non-breakaway FRP poles tested in this project met Caltrans specifications and are allowed for use in areas where breakaway poles are not required.

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Neither the State of California nor the United States Government endorse products or manufacturers. Trade or manufacturers' names appear herein only because they are considered essential in establishing the completeness and accuracy of this document.

Conversion Factors

SI to English Measurements

Quantity	SI Unit	Divide By	To Get Equivalent English Unit
Length	millimeters (mm)	$2.54 \times 1\ 10^{1}$	inches
	meters (m)	2.54×10^{-2}	inches
	meters (m)	3.048×10^{-1}	feet
	kilometers (km)	1.609	miles
Area	square meters (m^2)	6.452×10^{-4}	square inches (in^2)
	square meters (m^2)	9.29×10^{-2}	square feet (ft^2)
Volume	liters (l)	3.785	U.S. gallon (gal)
	cubic meters (m^3)	2.832×10^{-2}	cubic feet (ft^3)
	cubic meters (m^3)	7.646×10^{-1}	cubic yard (yd^3)
Mass	kilograms (kg)	4.536×10^{-1}	pounds (lbm)
Density	kilograms per cubic meter (kg/m^3)	1.602×10^{1}	(lb/ft^3)
Force	newton (N)	4.448	pounds (lb)
	newton (N)	4.448×10^{3}	kips (1000 lb)
Bending Moment or Torque	newton-meters (Nm)	1.130×10^{-1}	inch-pounds (in-lb)
	newton-meters (Nm)	1.356	foot-pounds (ft-lb)
Pressure	pascal (Pa)	6.895×10^{3}	pounds per square inch (psi)
	pascal (Pa)	4.788×10^{1}	pounds per square foot (psf)

Temperature	degrees Celsius (°C)	°C * 1.8 + 32 = °F	degrees Fahrenheit (°F)

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EVALUATION OF DEFLECTION AND BENDING STRENGTH CHARACTERISTICS OF FIBER-REINFORCED PLASTIC LIGHTING STANDARDS

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EVALUATION OF DEFLECTION AND BENDING STRENGTH CHARACTERISTICS OF FIBER-REINFORCED PLASTIC LIGHTING STANDARDS

1. INTRODUCTION

1.1 Problem

Recently Caltrans has approved the use of certain sizes of fiber-reinforced plastic (FRP) lighting poles as alternatives to galvanized steel lighting poles which have long been the sole system approved for use in California. A new Caltrans Standard Special Provision (SSP) 86.08.5 regulating these FRP lighting poles has been developed, however no FRP poles have been tested by Caltrans to verify compliance for: 1) maximum pole deflection under a specified bending load, 2) minimum ultimate bending strength, and 3) requirements for thickness, type, and durability of the exterior coating.

1.2 Objectives

The objectives of this project were to (1) verify that FRP lighting poles (obtained from two manufacturers) meet two critical criteria in the Caltrans Standard Special Provision - maximum pole deflection under a specified bending load and minimum ultimate bending strength, (2) evaluate the exterior protection of the test poles for compliance to the SSP, and 3) develop a Caltrans test procedure that can be used to evaluate these criteria when quality assurance testing needs to be performed in the future.

1.3 Background

Fiberglass-reinforced plastic (FRP) lighting poles have been successfully used since the early 1970's by a number of cities, counties and DOT's across the United States. Based on satisfactory performance of FRP light poles nationwide and on the manufacturers test data, Caltrans approved the use of certain types of FRP lighting poles in early 1990. Until this research project was initiated, Caltrans had not done any independent testing to confirm that FRP poles being supplied met Caltrans' specifications.

When cost effective or aesthetically desirable, FRP lighting poles are specified in Caltrans contracts as alternates to either Caltrans Types 15 or 21 galvanized steel lighting poles. FRP lighting poles are fitted with aluminum mast arms and luminaires, and are typically installed along freeways and in roadside rest areas.

FRP lighting poles offer a number of advantages over galvanized steel poles: these include 1) economy (based on lower life cycle costs), 2) lighter weight, 3) non-corrosive, 4) non-conductive, and 5) aesthetically pleasing (may be painted any color). Known disadvantages include: 1) damage easily when impacted by an auto 2) may exhibit high deflection under a maximum design bending load, 3) may have potentially short service life of exterior painted surface, 4) difficulty in determining basic strength and deflection properties accurately without doing full scale destructive testing, 5) potentially have a short fatigue life of connections and mast arm, 6) inability to reliably determine severity of damage following an accident which may have caused bruising or fracture of internal glass reinforcing fibers, and 7) length of single-tube aluminum mast arms are limited to about 3.7 meters unless larger trussed arms are used.

The vertical poles on FRP lighting standards are round, hollow, and tapered and support aluminum mast arms or top mounted luminaries. The most common type of FRP vertical pole shaft is composed of a matrix of thermal-setting resin reinforced with continuous spirally wrapped fiberglass filaments laid down in two separate layers. The first filament layer is wrapped at a higher angle than the second, and each layer has a selected number of filaments which alternately cross, providing the axial and compressive strength to the pole (see Figure 1). Caltrans requires that the outer resin surface of the pole may be sanded to provide a smooth finish. Caltrans also requires that the exterior surface be painted with an aliphatic-type acrylic polyurethane, and that the standard finish coating is semi-gloss, pigmented, and typically light grey. It must have a minimum dry film thickness of 3-mils, be smooth and uniform over the entire body of the pole, and be weather and ultraviolet resistant.

FRP poles tested in this project were all constructed using a method where fiberglass filaments, coated with a polyester resin, are continuously wound with alternate layers crossing one another in opposite directions.

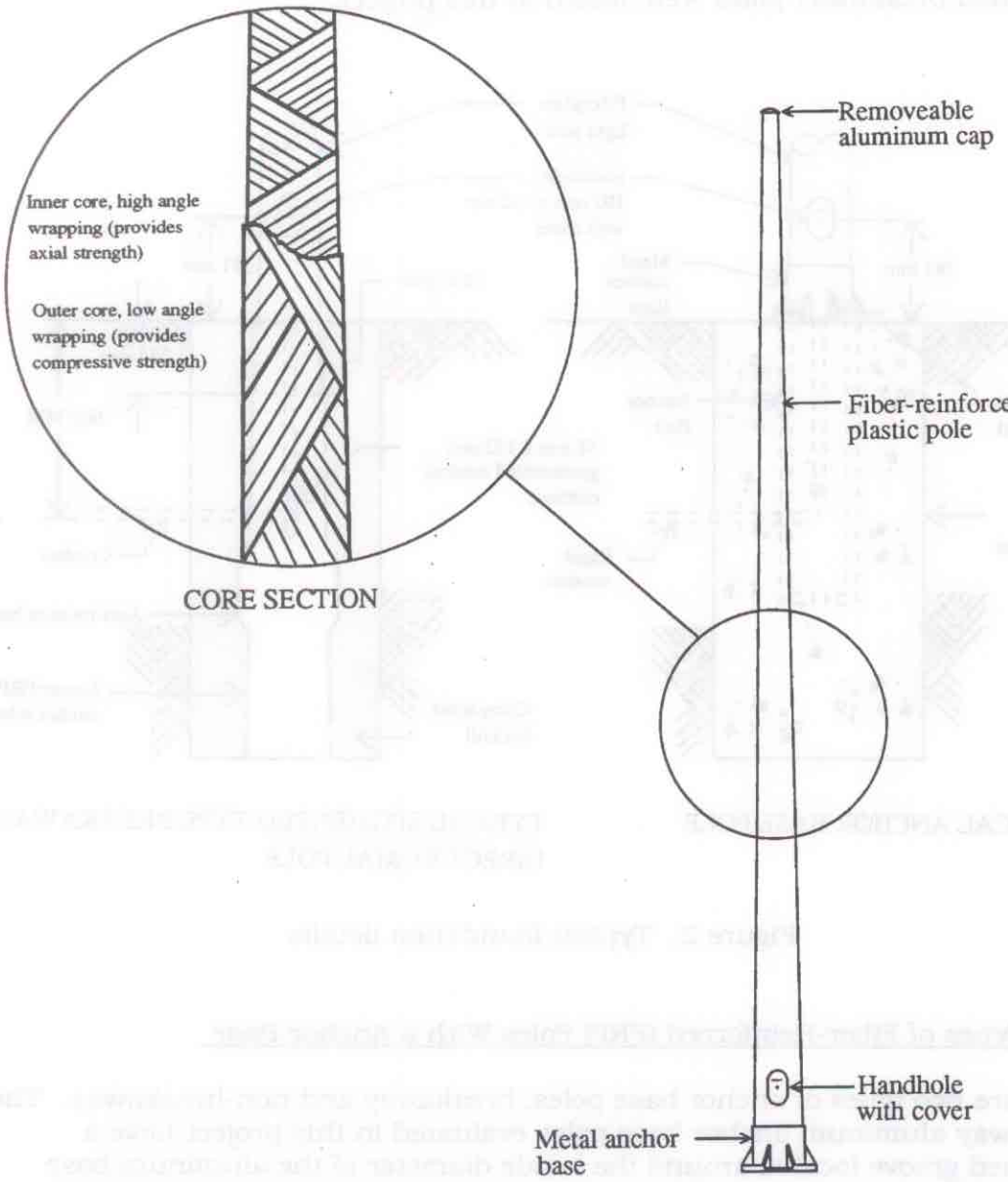
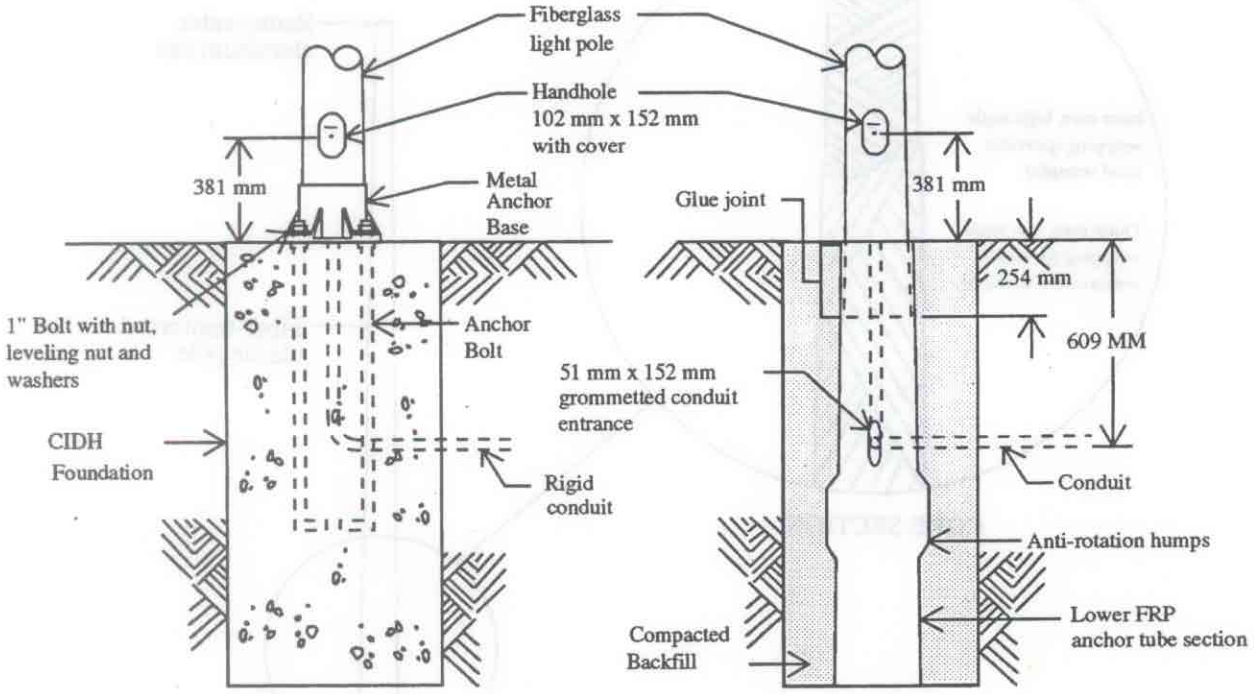


Figure 1. Fiber-reinforced plastic light pole construction

FRP lighting poles are designed to be either mechanically fastened to a concrete foundation via anchor bolts and a metal flanged anchor base (either aluminum or galvanized steel) bonded to the pole, or directly buried in augered holes in the ground (see Figure 2). Anchor base poles can be equipped with either a breakaway aluminum anchor base (such as with an FHWA-approved internal grooved), or a non-breakaway base. Direct burial poles can be either the segmented breakaway type or the one-piece breakaway type, although only the segmented breakaway poles were tested in this project.



TYPICAL ANCHOR BASE POLE

TYPICAL SEGMENTED-TYPE BREAKAWAY DIRECT BURIAL POLE

Figure 2. Typical foundation details

1.3.1 Types of Fiber-Reinforced (FRP) Poles With a Anchor Base

There are two types of anchor base poles: breakaway and non-breakaway. The breakaway aluminum anchor base poles evaluated in this project have a machined groove located around the inside diameter of the aluminum base casting. The aluminum casting is designed to break along the groove in the event of a collision creating a high shear force (see Figure 3). If light poles are protected from impact, such as when located behind barrier rails or sound walls, non-breakaway poles having a flanged anchor base (either galvanized steel or aluminum) may be used.

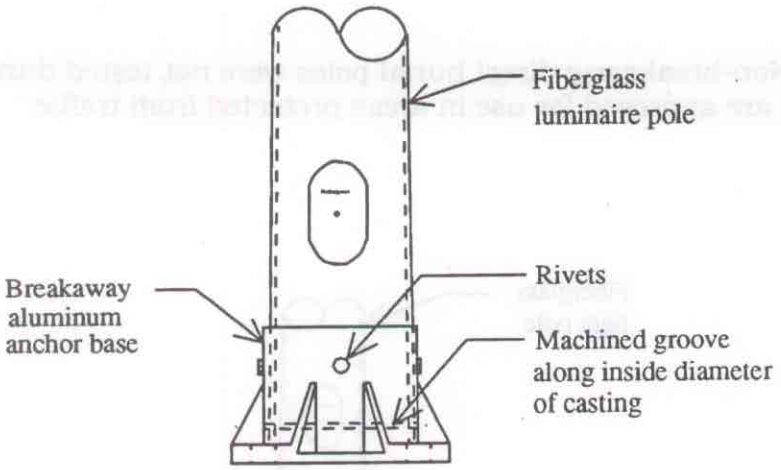


Figure 3. Shakespeare's breakaway anchor base

Both types of flanged base poles consist of a FRP pole shaft bonded with epoxy and bolted or riveted to a metal flanged anchor base of either aluminum or steel. The flanged anchor base is designed to be mechanically fastened to a cast in drilled hole concrete foundation via four cast-in-place anchor bolts with nuts, leveling nuts and washers. To accommodate anchor bolts, the square flange on the metal anchor base has four 31.75 x 44.45 mm radial slots (one at each corner) spaced at 90 degrees with a bolt circle diameter of 292.1 mm. A 101.6 mm x 152.4 mm oval wiring access handhole and handhole cover bearing the name of the manufacturer is required and located 381 mm from the bottom of the anchor base to the centerline of the handhole. Unless otherwise specified by the designer, it is located on the downstream traffic side of the pole so that oncoming traffic can be seen by an electrical worker doing maintenance on the pole. These FRP poles can be fitted with either top or mast arm-mounted luminaires.

Two types of FRP anchor base poles which may be substituted for galvanized steel lighting poles are: 1) the breakaway (internal grooved) aluminum anchor base types [Caltrans Types 15F B (9144 mm long) and 21F B (10 700 mm long)], and 2) the non-breakaway with either a cast aluminum or galvanized steel flanged anchor base [Caltrans types 15F (9144 mm long) and 21F (10 700 mm long)].

1.3.2 Direct Burial FRP Poles

There are two types of direct burial FRP poles, breakaway and non-breakaway. Breakaway direct burial FRP poles evaluated in this project have an external breakaway joint where the above-ground tube section and the buried anti-rotation tube sleeve section are epoxy bonded together. When installed, the top of the breakaway joint is level with the finished grade and the upper tube section is designed to slip out of the lower tube when impacted by an auto (see

Figure 4). Non-breakaway direct burial poles were not tested during this project, but are approved for use in areas protected from traffic.

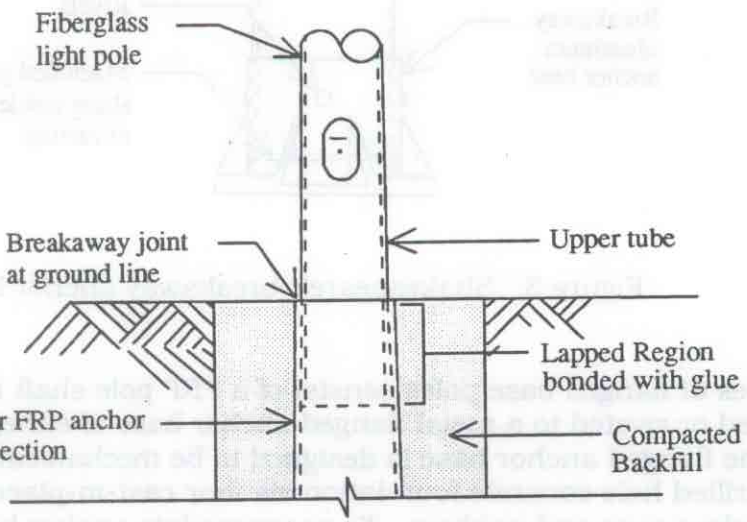


Figure 4. Shakespeare's direct burial poles breakaway joint

Breakaway direct burial FRP poles are made up from two telescoping fiberglass sections, an above-ground FRP pole tube section (shaft) slipped inside and epoxy bonded to an anchor tube sleeve section which is buried in the ground. The anchor tube sleeve section which is buried in the ground is fabricated with two flared humps near it's base that provide rotational resistance. Direct Burial poles are installed by setting the anchor tube section of the pole into the center of an augered hole with it's grommetted conduit access hole toward the pull box, trenching from the conduit access hole in the pole base to the pull box, hooking up the electrical conduit, and then back-filling and compacting with soil. Direct Burial poles are also equipped with a handhole and handhole cover, and can be fitted with either top or mast mounted luminaires.

Two sizes of FRP direct burial poles, having above-ground lengths of either 9144 mm or 10 700 mm, are available. These include: 1) the Caltrans type 15F B, breakaway direct burial, and 2) the Caltrans type 21F B, breakaway direct burial poles.

1.3.3 Design Criteria

In 1992 the position of the handhole, a small wiring access opening near the bottom of the poles, was changed so that electrical maintenance personnel

working on wiring at the pole base would have a better view of oncoming traffic. It is now located on the downstream side of the pole rather than beneath the mast arm. This location can be subjected to extreme tension or compression during severe wind loading perpendicular to the mast arm. Caltrans design wind velocity for FRP lighting poles is 128.7 km/h. When the lighting standard is subjected to bending stresses experienced during heavy wind loading, the handhole area, even though provided with additional fiberglass reinforcement, is weakened from cutting of fiberglass strands and is a natural location for bending failure.

The principle reasons for determining deflection and ultimate bending strength of FRP lighting poles are: 1) to verify that they meet Caltrans specifications, and 2) to insure that bending failure does not result at a substandard stress level due to the new handhole location.

In order for FRP lighting poles to be used on California's highways, they must 1) meet all requirements in the Caltrans Standard Special Provision 86.08.5, "Fiberglass Lighting Standards", and 2) comply with a Caltrans policy which requires highway safety appurtenances pass an impact performance evaluation (April 1993). Lighting poles with breakaway supports must be crash tested in accordance with requirements of test level 3 in National Cooperative Highway Research Program Report No. 350, "Recommended Procedures for the Safety Performance Evaluation of Highway Features" and meet specified evaluation criteria.

1.3.4 Manufacturers

FRP lighting poles for this project were purchased from two manufacturers, Shakespeare and Whatley. Both companies use a similar manufacturing process. Only one of the manufacturer, Shakespeare, has crash tested their FRP lighting standards according to NCHRP 350 requirements and many of their poles are presently approved for crashworthiness by FHWA and Caltrans. Whatley has not crash tested their fiberglass pole products, and offer only non-breakaway FRP light poles. Although these two companies manufacture a number of different styles and sizes of FRP lighting poles, only the anchor base and direct burial types of lighting poles were selected for quality assurance testing in this project. Anchor base poles selected for testing have an anchor bolt pattern and bolt sizes which match those of similar types of current Caltrans galvanized steel light poles.

In Table 1, the Caltrans FRP pole type and quantity which was evaluated and the corresponding manufacturer and pole model number is listed.

Table 1. Summary of FRP poles tested.

Caltrans FRP Pole Type and Quantity to be Tested	Manufacturer/Model
Caltrans Type 15F B, Breakaway Aluminum Anchor Base, Internal Grooved, 9144 mm (3 each)	Shakespeare AHW30-00S2CZ
Caltrans Type 21F B, Breakaway Aluminum Anchor Base, Internal Grooved, 10 700 mm (3 each)	Shakespeare AHW35-00S2CZ
Caltrans Type 15F, (Non-Breakaway) Flanged Galvanized Steel Anchor Base, 9144 mm (3 each)	Whatley A4330-03-65 N4,6
Caltrans Type 21F, (Non-Breakaway) Flanged Galvanized Steel Anchor Base, 10 700 mm (3 each)	Whatley A4335-03-65 N4,6
Caltrans Type 15F B, Breakaway Direct Burial, 9144 mm (3 each)	Shakespeare BBW35-00S2CZ01
Caltrans Type 21F B, Breakaway Direct Burial, 10 700 mm (3 each)	Shakespeare BBW41-00S2CZ01

1.3.5 Minimum Bending Strength and Maximum Deflection

Caltrans has specified two test loads for each style and size of FRP pole: 1) the deflection test load, and 2) the bending strength test load. The deflection test load is the amount of force applied to the tip of the pole at which the measured pole deflection cannot exceed 13% of the height of the pole which projects above the ground line.

The bending strength test load is the minimum amount of force applied near the tip of the pole and perpendicular to the pole axis which the pole must withstand before it fails in bending.

In Table 2, the deflection and bending strength test loads are listed for the various Caltrans types of approved FRP poles.

Table 2. Magnitude of required deflection and bending strength test loads

Caltrans Pole Type	Deflection Test Load	Bending Strength Test Load
Type 15F B, Breakaway Anchor Base	1606 N (361 lbs)	2406 N (541 Lbs)
Type 21F B, Breakaway Anchor Base	1708 N (384 lbs)	2562 N (576 lbs)
Type 15F, Non-Breakaway Anchor Base	1606 N (361 lbs)	2406 N (541 lbs)
Type 21F, Non-Breakaway Anchor Base	1708 N (384 lbs)	2562 N (576 lbs)
Type 15F B, Breakaway Direct Burial	1606 N (361 lbs)	2406 N (541 lbs)
Type 21F B, Breakaway Direct Burial	1708 N (384 lbs)	2562 N (576 lbs)

1.3.6 Literature Search

A literature search was performed to determine if any previous independent evaluations or testing had been done to determine deflections under design bending loads or ultimate bending strength of FRP lighting poles. Using DIALOG Information Services, the NTIS database was searched for information relating to FRP lighting poles. No relevant reports concerning bend testing of FRP lighting poles were found.

2. TECHNICAL DISCUSSION

2.1 Test Conditions and Pole Orientation

Deflection and bending strength testing for each model of FRP lighting pole tested were done according to the following format: 1) The first test pole of each model was oriented so that its handhole was on the extreme compression side of the bent pole, 2) the second test pole of each model was oriented so that the handhole was on the extreme tension side of the bent pole, and 3) the third test pole of each model was oriented so that handhole was in the position which resulted in the greater deflection or lower ultimate bending strength as

determined from the first two tests. All poles were first subjected to the required deflection load and then were loaded to their ultimate bending strength.

Evaluation of the exterior coatings was conducted by first: 1) randomly selecting three poles from each manufacturer, measuring the coating thickness at three places on each pole (top, center, and base) with a Tooke gauge, and 2) cutting three 76 x 127 mm sample pieces, one from each manufacturer's poles, and subjecting them to 2,500 hours of accelerated weathering testing according to the procedure outlined in Caltrans SSP 86.08.5 (Appendix A).

2.1.1 Test Facilities

All testing was conducted at Caltrans' Office of Materials Engineering and Testing Services (METS), Structural Materials Branch, 5900 Folsom Blvd. Sacramento California.
Bending tests were performed outdoors when air temperatures were between 18°C and 32°C.

2.2 Materials - Test Specimens

Pole samples were ordered from two common fiberglass lighting pole manufactures, Shakespeare and Whatley. Two common sizes of lighting poles were ordered, Caltrans Type 15F and Type 21F in both the breakaway (both grooved anchor base and direct burial) and fixed anchor base styles.

2.2.1 Selection of Fiber-Reinforced Plastic (FRP) Poles

FRP test specimens were chosen based on manufacturer's assurance that requirements of Caltrans Standard Special Provision 86.08.5, "Fiberglass Lighting Standards" (Appendix A), and Caltrans Standard Plans for "Fiberglass Lighting Standards" (Appendix B) were met. In Tables 3, 4, and 5 of this report, properties of FRP poles, as advertised from Shakespeare and Whatley, have been compared to Caltrans requirements.

Table 3. Comparison of advertised and required properties of breakaway FRP anchor base poles

Properties	Caltrans Pole Type 15F B Breakaway Aluminum Anchor Base (Internal Grooved)		Caltrans Pole Type 21F B Breakaway Aluminum Anchor Base (Internal Grooved)	
	Shakespeare AHW30 Specifications	Caltrans Requirements	Shakespeare AHW35 Specifications	Caltrans Requirements
Overall Shaft Length	9144 mm	9144 mm	10 700 mm	10 700 mm
Diameter of Shaft Top	124.5 mm	121.9 mm	124.5 mm	121.9 mm
Diameter of Shaft Base	215.9 mm	215.9 mm	215.9 mm	215.9 mm
Wall Thickness	7.6 mm	N/A	6.3 mm	N/A
Minimum Bending Strength	2670 N	2406 N	2562 N	2562 N
Deflection Limits	11.46% of length above ground at a bending load of 1780 N.	Maximum deflection shall not exceed 13% of length of the pole above ground at a bending load of 1606 N.	10.9% of length above ground at a bending load of 1780 N.	Maximum deflection shall not exceed 13% of length of the pole above ground at a bending load of 1708 N.
Anchor Bolt Circle Diameter	292.1 mm bolt circle for use with 4-25.4 mm anchor bolts.	292.1 mm bolt circle for use with 4-25.4 mm anchor bolts.	292.1 mm bolt circle for use with 4-25.4 mm anchor bolts.	292.1 mm bolt circle for use with 4-25.4 mm anchor bolts.
Handhole Size & Location	101.6 mm X 152.4 mm oval, 381 mm from the bottom of the anchor base to the centerline of the handhole.	101.6 mm X 152.4 oval, 381 mm from the bottom of the anchor base to the centerline of the handhole.	101.6 X 152.4 mm oval, 381 mm from the bottom of the anchor base to the centerline of the handhole.	101.6 mm X 152.4 mm oval, 381 mm from the bottom of the anchor base to the centerline of the handhole.

Table 4. Comparison of advertised and required properties of non-breakaway FRP anchor base poles

Properties	Caltrans Pole Type 15F (Non-breakaway) Flanged Galvanized Steel Anchor Base		Caltrans Pole Type 21F (Non-breakaway) Flanged Galvanized Steel Anchor Base	
	Whatley A4330 Specifications	Caltrans Requirements	Whatley A4335 Specifications	Caltrans Requirements
Overall Shaft Length	9144 mm	9144 mm	10 700 mm	10 700 mm
Diameter of Shaft Top	132.1 mm	121.9 mm	132.1 mm	121.9 mm
Diameter of Shaft Base	236.2 mm	215.9 mm	256.5 mm	215.9 mm
Wall Thickness	5.56 mm min.	N/A	5.56 mm min.	N/A
Minimum Bending Strength	5340 N	2406 N	5340 N	2562 N
Deflection Limits	The pole shall deflect no more than 4.5% of the length above ground with 890 N of lateral top load.	Maximum deflection shall not exceed 13% of length of the pole above ground at a bending load of 1606 N.	The pole shall deflect no more than 4.5% of the length above ground with 890 N of lateral top load.	Maximum deflection shall not exceed 13% of length of the pole above ground at a bending load of 1708 N.
Anchor Bolt Circle Diameter	292.1 mm bolt circle for use with 4-25.4 mm anchor bolts.	292.1 mm bolt circle for use with 4-25.4 mm anchor bolts.	292.1 mm bolt circle for use with 4-25.4 mm anchor bolts.	292.1 mm bolt circle for use with 4-25.4 mm anchor bolts.
Handhole Size & Location	101.6 mm X 152.4 mm oval 381 mm from the bottom of the anchor base to the centerline of the handhole.	101.6 mm X 152.4 mm oval, 381 mm from the bottom of the anchor base to the centerline of the handhole.	101.6 mm X 152.4 mm oval, 381 mm from the bottom of the anchor base to the centerline of the handhole.	101.6 X 152.4 mm oval, 381 mm from the bottom of the anchor base to the centerline of the handhole.

Table 5. Comparison of advertised and required properties of breakaway FRP direct burial poles

Properties	Caltrans Pole Type 15F B Breakaway Direct Burial		Caltrans Pole Type 21F B Breakaway Direct Burial	
	Shakespeare BBW35 Specifications	Caltrans Requirements	Shakespeare BCW41 Specifications	Caltrans Requirements
Overall Shaft Length	10 700 mm	N/A	12 500 mm	N/A
Diameter of Shaft Top	162.6 mm	161.9 mm	167.6 mm	168.3 mm
Diameter of Shaft Base	292.1 mm	260.4 mm	302.3 mm	282.6 mm
Wall Thickness	6.35 mm	N/A	7.62 mm	N/A
Ultimate Bending Strength	4005 N	2406 N	3393.75 N	2562 N
Deflection Limits	5.97% of length above ground at 1780 N.	Maximum deflection shall not exceed 13% of length of pole above ground at a bending load of 1606 N.	7.2% of length above ground at 1780 N.	Maximum deflection shall not exceed 13% of length of pole above ground at a bending load of 1708 N.
Anchor Bolt Circle Diameter	N\A	N/A	N/A	N/A
Handhole Size & Location	101.6 mm X 152.4 mm oval, 381 mm from finished grade to the centerline of the handhole.	101.6 mm X 152.4 mm oval, 381 mm from finished grade to the centerline of the handhole.	101.6 mm X 152.4 mm oval, 381 mm from finished grade to the centerline of the handhole.	101.6 mm X 152.4 mm oval, 381 mm from finished grade to the centerline of the handhole.

All Shakespeare FRP poles used for testing were breakaway types. Shakespeare has successfully crash tested many of their breakaway poles and gained FHWA approval. Whatley FRP poles evaluated were non-breakaway, have not been crash tested, and can only be used in locations where they are protected from being hit by errant vehicles.

Special attention to certain dimensions, such as anchor bolt circle diameters and handhole size and location, was required when ordering the poles. The size and location of the handhole make a difference in the ultimate strength of a pole. In conducting this research, Caltrans specifications required that, 1) handholes be 101.6 mm x 152.4 mm oval, oriented on the downstream traffic side of the pole, and centered 381 mm from the bottom of the base plate or ground line, and 2) the anchor bolt circle be 292 mm in diameter. In order for Whatley poles to meet the Caltrans handhole specifications they had to modify their standard anchor base module by cutting out a portion of the steel sleeve section of the anchor base to reduce their normal handhole height to 381 mm (see Figure 5).

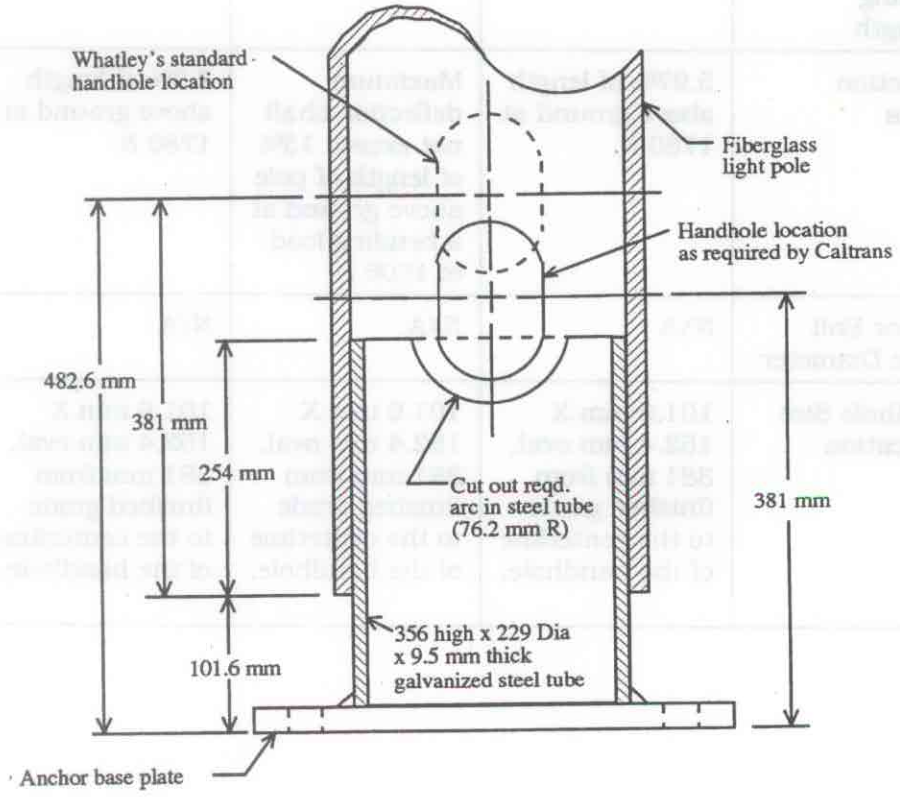


Figure 5. Modifications by Whatley of their standard anchor base and handhole location.

2.3 Test Fixture Used For Deflection and Bending Strength Tests

2.3.1 Design of Test Fixture

A test fixture shown in ASTM's "Standard Specification for Reinforced Thermosetting Plastic Poles", Designation D 4923 - 92 (see Appendix D) was designed and built to test pole shafts in bending. This fixture provided a practical way to test both anchor base and direct burial light poles. A detailed as-built drawing of the two-part fixture is shown in Appendix E.

2.3.2 Fabrication of Test Fixture

The two fixtures shown in Figure 6 are fabricated from ASTM A-36 and A-500 steel and were mounted on a 203 mm thick concrete slab. The tall fixture used to test poles with flanged base plates is capable of handling 56.4 kN·m of base bending moment, the equivalent to a 10 700 mm high anchor base FRP pole being loaded at it's tip with a load of 5.34 kN.

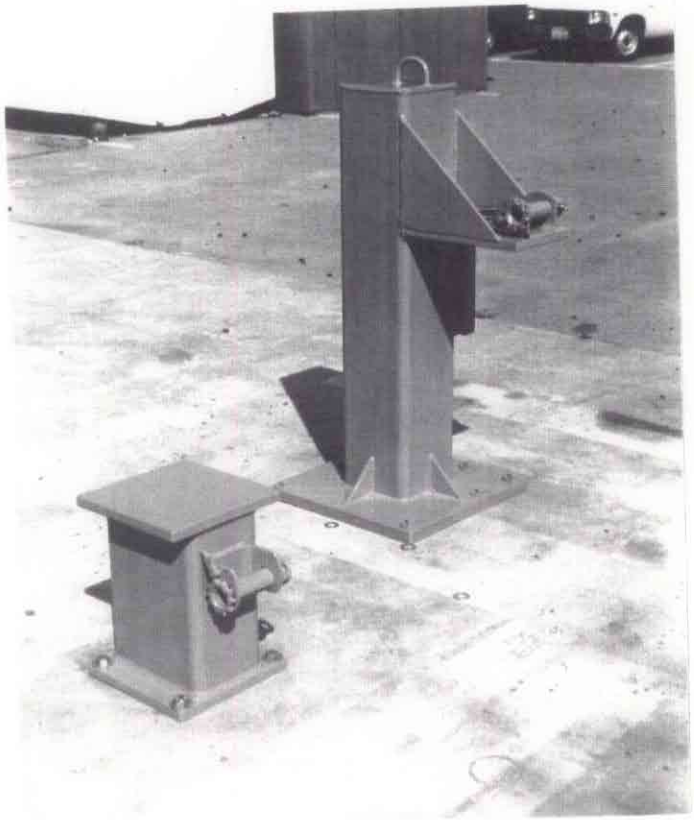


Figure 6. Caltrans ground line and pole butt support fixtures for conducting bending/deflection tests.

2.4 Preparation for Deflection and Bending Strength Testing

2.4.1 FRP Lighting Pole Measurements

Each light pole was weighed and measured prior to testing. Pole weights were determined using a load cell and strain indicator while suspending the pole from a forklift tine. Top and bottom pole diameters were measured with calipers and a scale; the wall thickness of the pole was determined by coring a plug and measuring it's thickness with a micrometer.

2.4.2 Mounting Procedure for Anchor Base Poles

A typical test setup for mounting poles with flanged anchor bases is shown in Figure 7.

Figure 7. Anchor base test pole mounted to ground line support fixture.

Only the tall ground line support fixture was used to test flanged anchor base poles. The short pole butt support fixture was used only to support the bottom tube section of direct burial poles. The poles base plate was securely bolted to the plate on the ground line support fixture so that the pole shaft hung in a cantilevered horizontal position. Anchor base poles were positioned so handholes were facing up for compression tests or down for tension tests. A forklift was used to hold the pole in a horizontal position (prevent the tip from

sagging) while aligning the four radial slots (292 mm bolt circle) in the anchor base with the four bolt holes in the fixture base. Once the anchor base assembly was aligned, the mounting bolts, washers, and nuts were installed. The handhole was located in the desired quadrant, and each of the 25.4 mm diameter anchor bolts on the pole base was torqued to 271 N·m. A car jack was positioned near the top of the pole and adjusted to support the tip so that the initial position of the pole was horizontal. The forklift was then removed.

2.4.3 Mounting Procedure for Direct Burial Poles

A typical mounting setup for direct burial poles is shown in Figure 8.

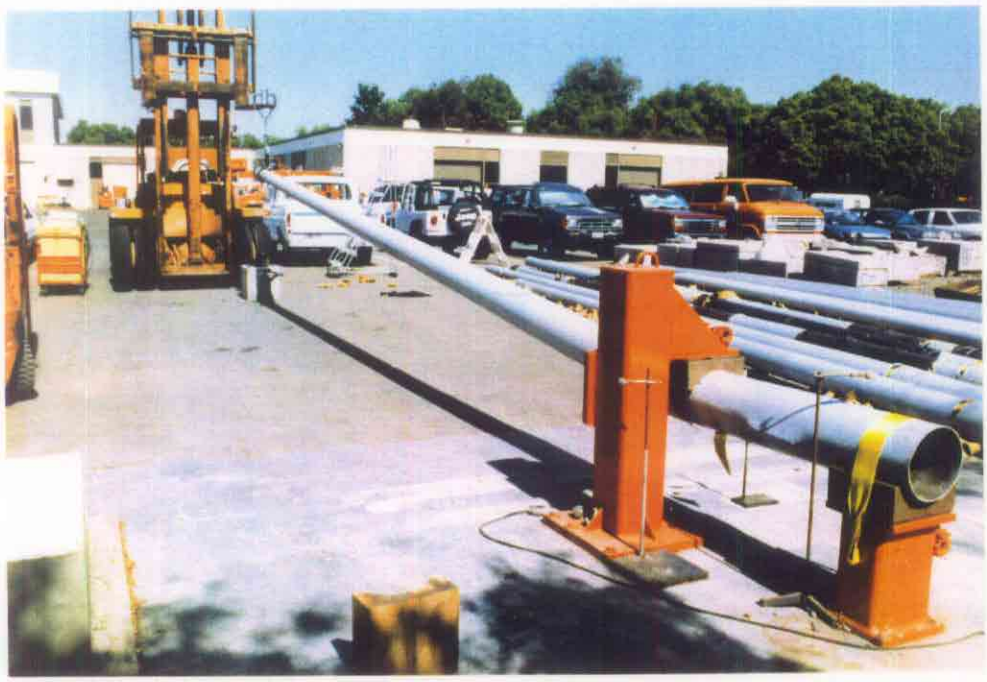


Figure 8. Direct burial test pole mounted to combination pole butt/ground line support fixture.

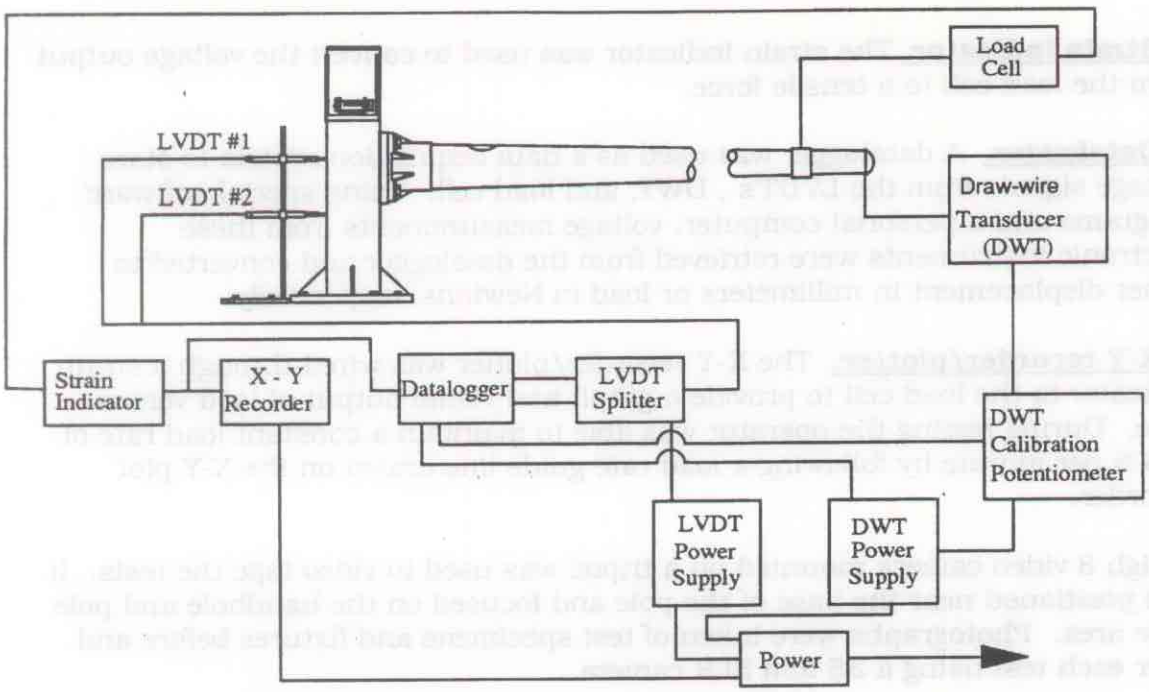
Direct burial light poles were positioned with their handhole oriented for either compression or tension tests. Poles were lifted into position using a forklift. The lower pole tube section which is normally buried below ground was securely held by two wooden support saddle blocks positioned to resist the applied moment, with one block attached to each section of the two-part test fixture. The handhole location was carefully adjusted and the base was then cinched down securely with two winch binders and 101.1 mm-wide web straps. The forklift was then removed.

After mounting the poles to the test fixture and leveling in a cantilevered horizontal position, a pole centerline was established and marked on the longitudinal axis of the horizontal light pole. Using a leveling transit, the pole tip was adjusted up or down with the car jack positioned near the top of the pole until the pole centerline was leveled (see Figure 9). The linear variable differential transformer (LVDT) used to monitor deflection of the pole was zeroed.

Figure 9. Leveling poles

2.5 Data Acquisition System Used to Monitor Load at 13% Deflection and Ultimate Bending Strength

Loads applied to the pole tip and tip displacement were recorded by electronic instrumentation. A video camera, and 35 mm camera were also used to document testing. The schematic of the data acquisition equipment is shown in Figure 10.



Note: LVDT = linear variable differential transformer

Figure 10. Schematic of data acquisition equipment

Electronic equipment used to gather data included:

1) **Two linear variable differential transformers (LVDTs).** LVDTs were used to measure displacement of the test fixture and the pole base as the pole was being loaded. These displacement measurements were necessary to calculate the amount of correction to apply to the tip caused by the rotation of the test fixture and light pole base. The LVDTs were mounted on a stand bolted to a concrete slab and positioned against the test fixture while testing anchor base poles, and to the lower pole tube while testing direct burial light poles.

2) **One draw-wire transducer (DWT).** The DWT was used to measure the deflection of the pole tip. The body of the DWT was anchored to a stationary base and the spring-loaded draw-wire was attached to a chain loop which was taped securely to the tip of the pole at the end cap. As the pole tip deflected when a vertical load was applied, the wire was pulled from the transducer base unit and a electrical signal proportional to the movement of the pole tip was recorded. These signals were converted from DC voltage to lengths which were the actual deflection of the pole tip.

3) **Load cell.** A calibrated load cell (11 kN capacity) was used to measure the bending load applied to the pole tip during testing. The load cell was attached between the strap at the pole tip and the hoist chain on the forklift.

4) **Strain indicator.** The strain indicator was used to convert the voltage output from the load cell to a tensile force.

5) **Datalogger.** A datalogger was used as a data acquisition system to store voltage signals from the LVDT's , DWT, and load cell. Using special software programs and a personal computer, voltage measurements from these electronic instruments were retrieved from the datalogger and converted to either displacement in millimeters or load in Newtons, respectively.

6) **X-Y recorder/plotter.** The X-Y recorder/plotter was wired through a strain indicator to the load cell to provide a graph and visual output of load versus time. During testing the operator was able to maintain a constant load rate of 445 N per minute by following a load rate guide line drawn on the X-Y plot recorder.

A high 8 video camera mounted on a tripod was used to video tape the tests. It was positioned near the base of the pole and focused on the handhole and pole base area. Photographs were taken of test specimens and fixtures before and after each test using a 35 mm SLR camera.

2.6 Deflection and Bending Strength Test Procedures

2.6.1 Test Setup

A typical setup for deflection and bending strength tests is shown in Figures 11 and 12.

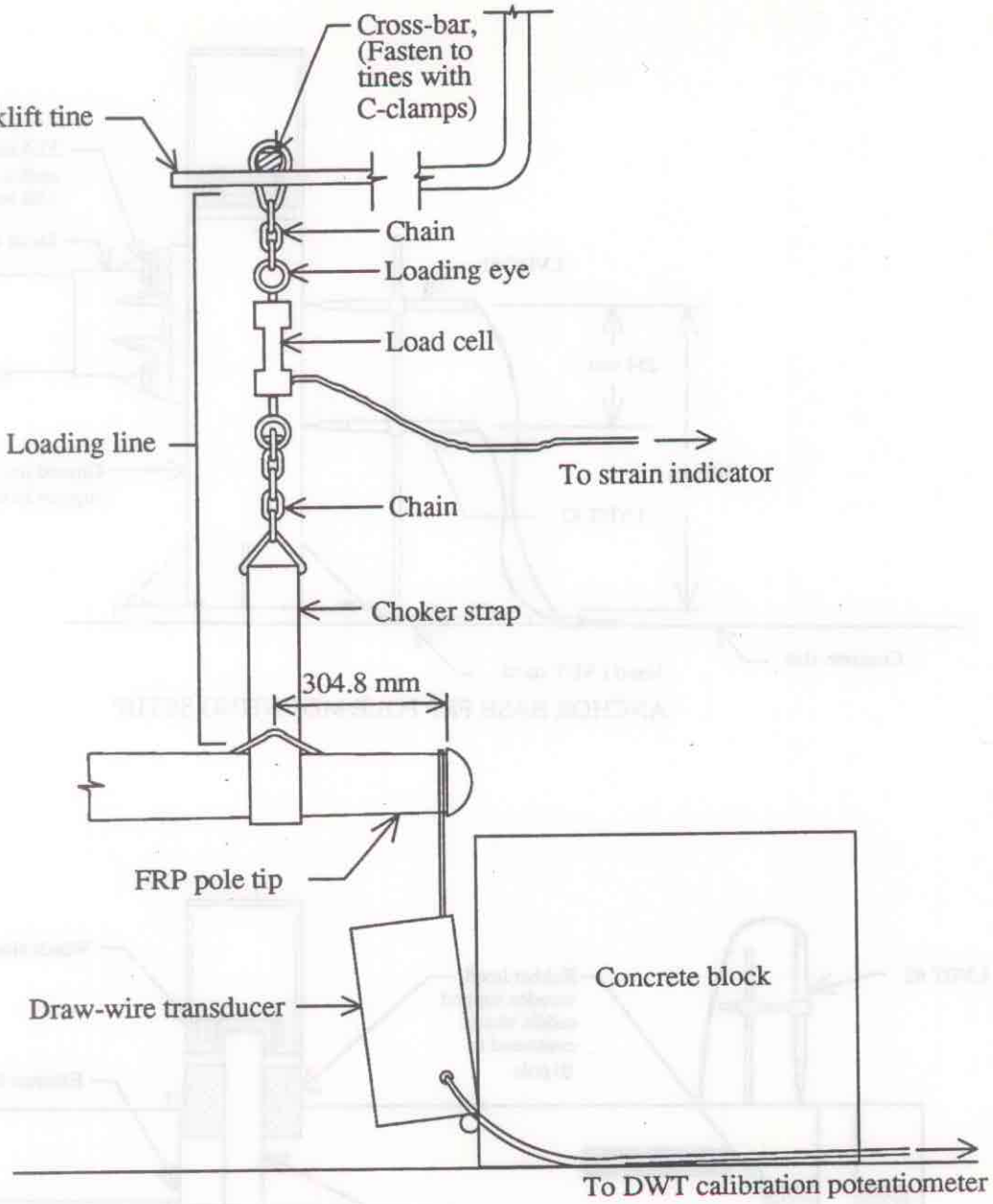
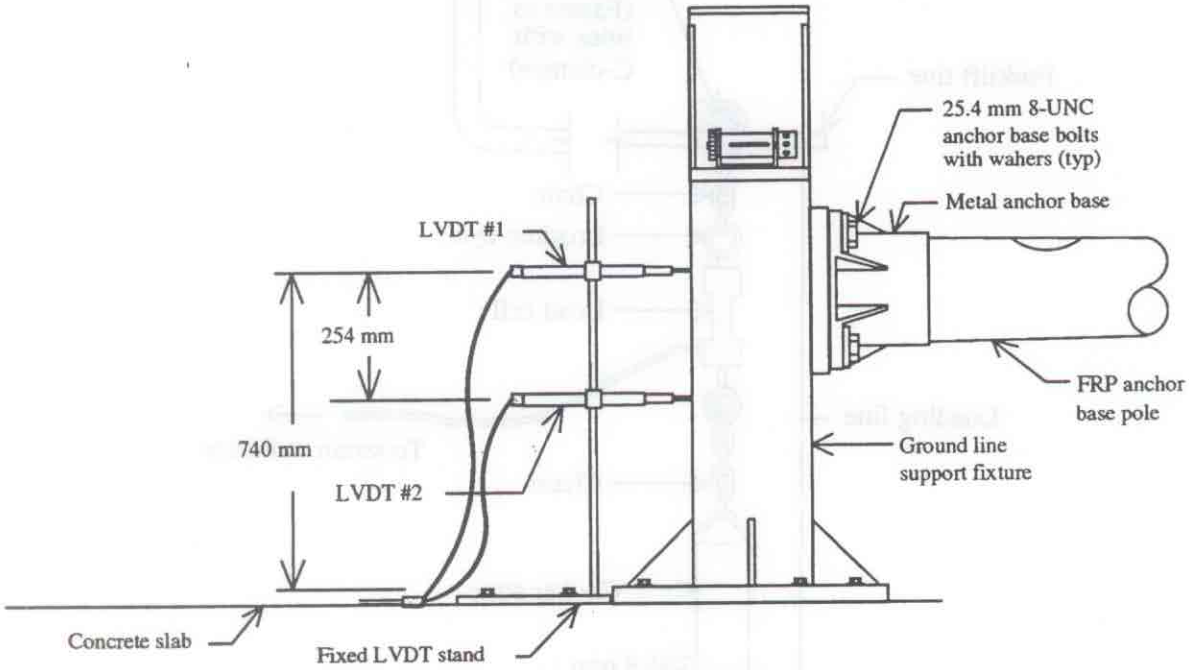
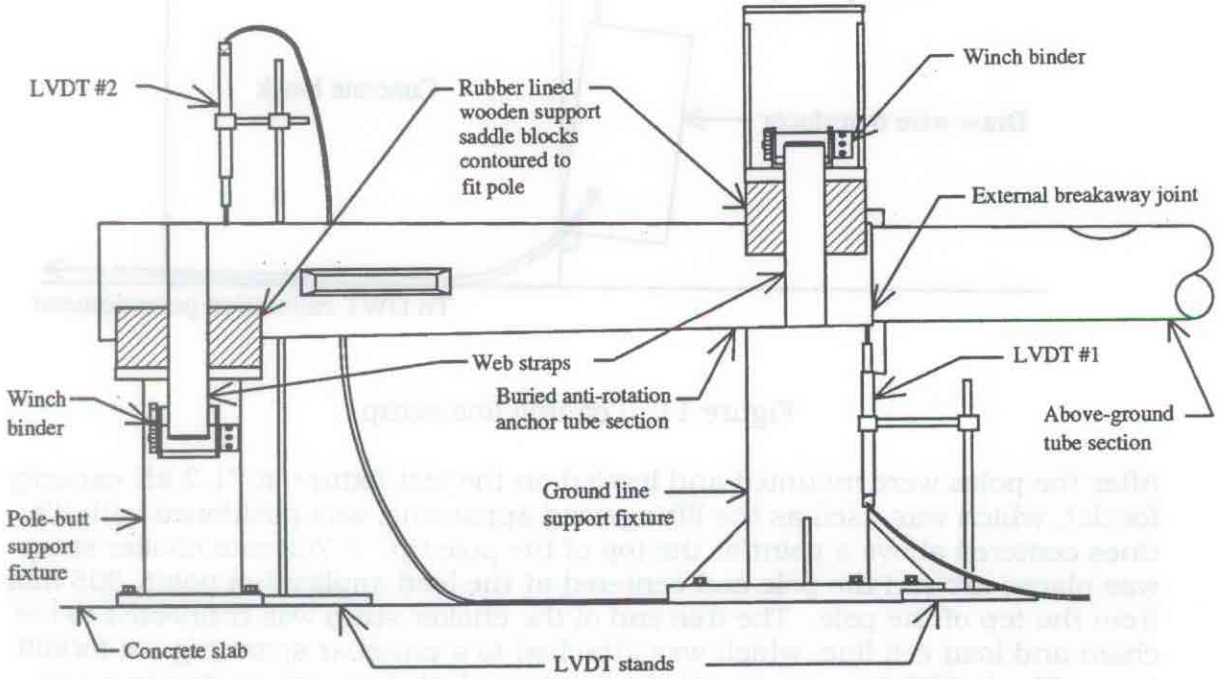


Figure 11. Loading line setup

After the poles were mounted and leveled on the test fixture, a 71.2 kN capacity forklift, which was used as the lifting/load apparatus, was positioned with it's tines centered above a point at the top of the pole tip. A 762 mm choker strap was placed around the pole and centered at the load application point, 305 mm from the top of the pole. The free end of the choker strap was connected to the chain and load cell line, which was attached to a crossbar spanning the forklift tines. The forklift tines were raised to remove slack from the loading line and positioned so the loading line was perpendicular to the axis of lighting pole. The loading line was maintained within ±5° of vertical while applying the



ANCHOR BASE FRP POLE MOUNTING SETUP



DIRECT BURIAL FRP POLE MOUNTING SETUP

Figure 12. Test fixtures and mounting setup

increasing test load. Once the loading line was correctly positioned, the reading on the load cell was zeroed.

Deflection of the FRP poles was measured with a draw-wire transducer (DWT). The DWT was anchored to a large concrete block which was located near the tip of the pole and was positioned so the draw-wire was centered on the tip of the pole. The draw-wire was attached to the tip of the light pole, the electrical wires were connected to the datalogger, and the signal was zeroed.

Two LVDTs used to measure displacement at the pole base were positioned against either the test fixture or the lower wall of the pole depending on whether an anchor base or direct burial pole was being tested. During testing of poles having an anchor base, LVDT #1 was centered on the backside of the test fixture support column, 740 mm above the top of the fixture base plate. LVDT #2 was placed 254 mm directly below LVDT #1. For testing of direct burial light poles, LVDT #1 was centered on the underside of the pole 25.4 mm below the ground line on the light pole. LVDT #2 was centered on the topside of the light pole above the wooden support on the rear pole butt support fixture. For both anchor base and direct burial tests, the LVDTs were wired to the datalogger and the output voltage readings were set at zero.

The electronic equipment used to gather data was programmed to read and store output data at 1/4-second intervals. The X-Y recorder was prepared with a load/time graph line whose slope could be followed by the forklift operator to control the rate of loading.

2.6.2 Test Procedure

For all tests, the datalogger and the X-Y plotter and video camera were used to record measurements. Vertical load was applied to the pole tip by use of a forklift. A constant load rate of 445 N per minute was maintained by visually following a guide line drawn on the load versus time output plot from the X-Y recorder. As the vertical load was applied, the forklift was moved forward to maintain a vertical pull (±5°) on the pole tip. Load cell readings were visually monitored using a digital strain indicator and noted at 223-N increments, and at the specified deflection value and minimum bending strength. Load was applied at a uniform rate until the light pole failed (see Figure 13).

Figure 13. Deflection and bending strength test

2.7 Data Reduction for Test Results

The deflection and loads recorded on the datalogger were downloaded to a computer using special software programs. This data was imported into Lotus 123 software for conversion to engineering units. Lotus 123 software was used to generate graphs detailing load versus deflection.

2.8 Results of Deflection and Bending Strength Tests

2.8.1 Pass/Fail Criteria of Deflection and Bending Strength Tests

When tested as described in this report, deflection at the pole tip was not to exceed a value equal to 13 percent of the length of the pole which projects above the ground line (or anchor base) when subjected to the specified deflection test load.

For bending strength tests to pass, ultimate bending failure of the pole could not occur prior to reaching the applied bending strength test load. Also the test was deemed a failure if the pole showed significant sudden movement due to breaking or separation of the epoxy bond. Typical failure modes at the ultimate bending load are shown in Figures 14 through 17 .

Figure 14. Typical bending failure mode - handhole in compression.

Figure 15. Bond failure of epoxy and slip between anchor base and pole shaft.

Figure 16. Epoxy bond failure between upper/lower tube sections of direct burial pole during bending test.

Figure 17. Failure at bottom of upper pole tube near joint line of direct burial pole.

2.8.2 Summary of Test Results

All tests done in this project were labeled using the same coding system. The pole height designation (in feet) is the distance from either the bottom of the anchor base to the pole tip for anchor base poles or from the ground line to pole tip of the direct burial poles. Figure 18 shows the coding system format.

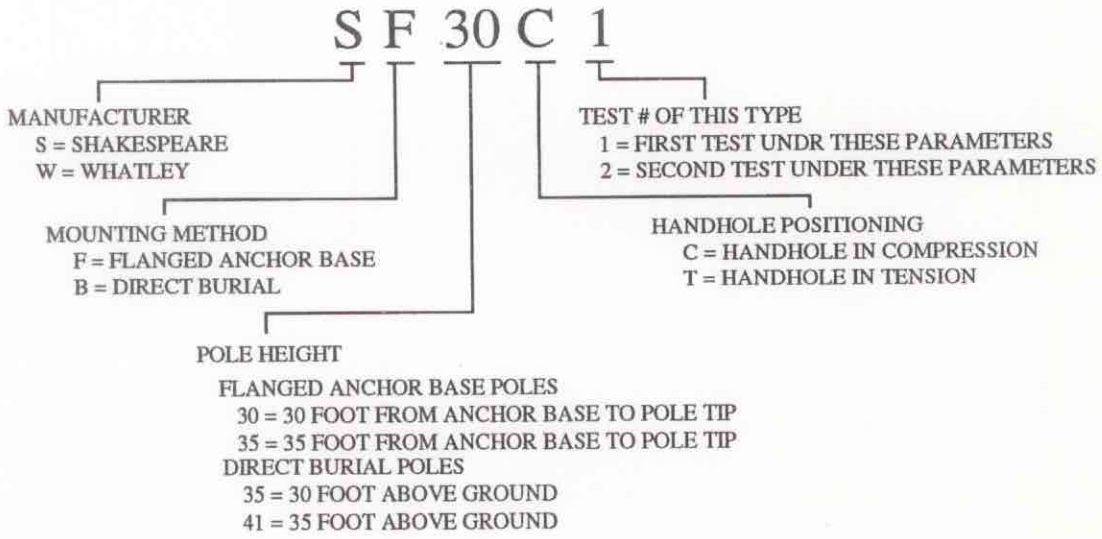


Figure 18. Explanation of coding system format.

The results of 18 tests developed for evaluating FRP lighting standards for a limit on pole deflection under a specified bending load and minimum ultimate bending strength are summarized in Table 6. Discussion of individual test results and load versus deflection graphs for all tests are presented in Appendix F of this report.

TABLE 6. Summary of Test Results

6A. Poles That Passed

Caltrans Pole Type	Anchor Base or Direct Burial	Breakaway or Non-Breakaway	Manufacturer/ Model No.	Test No.	Handhole Orientation	Deflection Test					Bending Strength Test			
						Test Load, N		Deflection, mm		Pass or Fail	Specified Bending Test load, N	Actual Ultimate Bending Strength, N	Failure Mode	Pass or Fail
						Specified	Actual	Allowed	Actual					
15F B	Anchor Base	Breakaway	Shakespeare/AHW30	SF30C1	Compression	1606	1606.6	1188.7	631.5	P	2406	3002	Epoxy bond broke	P
15F B	Anchor Base	Breakaway	Shakespeare/AHW30	SF30T1	Tension	1606	1605.9	1188.7	663	P	2406	2767	Epoxy bond broke	P
15F B	Anchor Base	Breakaway	Shakespeare/AHW30	SF30C2	Compression	1606	1608.3	1188.7	526	P	2406	2953	Epoxy bond broke	P
15F	Anchor Base	Non-Breakaway	Whatley/A4330	WF30C1	Compression	1606	1605.5	1188.7	729.6	P	2406	3011	Broke @ handhole	P
15F	Anchor Base	Non-Breakaway	Whatley/A4330	WF30T1	Tension	1606	1607.5	1188.7	619.6	P	2406	4996	Broke @ handhole	P
15F	Anchor Base	Non-Breakaway	Whatley/A4330	WF30C2	Compression	1606	1607.7	1188.7	592.4	P	2406	3964	Broke @ handhole	P
21F	Anchor Base	Non-Breakaway	Whatley/A4335	WF35C1	Compression	1708	1711.7	1386.8	780.8	P	2562	4207	Broke @ handhole	P
21F	Anchor Base	Non-Breakaway	Whatley/A4335	WF35T1	Tension	1708	1709.7	1386.8	912.9	P	2562	5016	Broke @ handhole	P
21F	Anchor Base	Non-Breakaway	Whatley/A4335	WF35C2	Compression	1708	1710	1386.8	862.9	P	2562	4931	Broke @ handhole	P
15F B	Direct Burial	Breakaway	Shakespeare/BCW41	SB35T1	Tension	1606	1611	1188.7	420.6	P	2406	2973	Broke @ jointline	P

6B. Poles That Failed

Caltrans Pole Type	Anchor Base or Direct Burial	Breakaway or Non-Breakaway	Manufacturer/ Model No.	Test No.	Handhole Orientation	Deflection Test					Bending Strength Test			
						Test Load, N		Deflection, mm		Pass or Fail	Specified Bending Test load, N	Actual Ultimate Bending Strength, N	Failure Mode	Pass or Fail
						Specified	Actual	Allowed	Actual					
21F B	Anchor Base	Breakaway	Shakespeare/AHW35	SF35C1	Compression	1708	1715.5	1386.8	1716	F	2562	1900	Broke @ hanhole	F
21F B	Anchor Base	Breakaway	Shakespeare/AHW35	SF35T1	Tension	1708	1709.2	1386.8	1609	F	2562	2410	Epoxy bond broke	F
21F B	Anchor Base	Breakaway	Shakespeare/AHW35	SF35C2	Compression	1708	1720.5	1386.8	1467	F	2562	2201	Broke @ handhole	F
15F B	Direct Burial	Breakaway	Shakespeare/BBW35	SB35C1	Compression	1606	1607.9	1188.7	282.6	P	2406	2176	Epoxy bond broke	F
15F B	Direct Burial	Breakaway	Shakespeare/BBW35	SB35C2	Compression	1606	1608.1	1188.7	383.8	P	2406	2299	Epoxy bond broke	F
15F B	Direct Burial	Breakaway	Shakespeare/BBW35	SB41C1	Compression	1708	1708.2	1386.8	737.7	P	2562	2437	Epoxy bond broke	F
21F B	Direct Burial	Breakaway	Shakespeare/BCW41	SB41T1	Tension	1708	1711.8	1386.8	686.3	P	2562	2474	Epoxy bond broke	F
21F B	Direct Burial	Breakaway	Shakespeare/BCW41	SB41C2	Compression	1708	1709.4	1386.8	613	P	2562	2352	Broke @ handhole	F

2.8.3 Overview of Deflection and Bending Strength Evaluation Method

Results of testing were evaluated by visual observation and with the data acquisition output. Copies of the load/time graphs generated by the X-Y plotter are included in Appendix G. Video tapes and many photos of tests will be kept with the project file.

2.8.4 Discussion of Test Results

2.8.4.1 Discussion of Test Results of Caltrans Type 15F B Breakaway Aluminum Anchor Base FRP Poles

Shakespeare Model AHW30, 9144 mm Long (30 ft) Breakaway Anchor Base Light Poles

Test #1 (SF30C1); handhole in compression: Deflection did not exceed the limit listed in the SSP, nor did the pole fail prior to reaching the specified minimum ultimate bending strength. There was no visible damage to the pole at the specified loads, however some audible cracking was heard just prior to attaining the deflection and ultimate strength test loads. The epoxy bond connecting the anchor base to the pole shaft separated at a load of 3002 N applied at the pole tip. Ultimate bending failure occurred when the pole buckled at the handhole at 3355 N. Test pole SF30C1 passed both the specified bending load and bending strength criteria.

Test #2 (SF30T1); handhole in tension: Deflection did not exceed the limit listed in the SSP, nor did the pole fail prior to reaching the specified minimum ultimate bending strength. There was no visible damage to the pole at the specified loads, although there was some cracking noises heard prior to reaching the deflection and ultimate strength test loads. The epoxy bond connecting the anchor base to the pole shaft separated at a load of 2767 N applied at the pole tip. Ultimate bending failure occurred when the pole snapped at the handhole at 5,486 N. Test pole SF30T1 passed both the specified deflection and bending strength criteria.

Because some epoxy bond failure was exhibited at a low load in compression test #1 (SF30C1), a replicate compression test, test #3 (SF30C2) was performed.

Test #3 (SF30C2); handhole in compression: Deflection did not exceed the limit listed in the SSP, nor did the pole fail prior to reaching the specified ultimate minimum bending strength. There was no visible damage to the pole at the specified deflection test load, although some cracking noises were heard prior to reaching both the specified deflection and ultimate strength test loads. The epoxy bond connecting the anchor base to the pole shaft began to separate at an applied load of 2,953 N. Ultimate bending failure occurred when the pole buckled at the handhole at a load of 3328 N applied at the pole tip. Test pole SF30C2 passed both the specified deflection and bending strength criteria.

2.8.4.2 Discussion of Test Results of Caltrans Type 21F B Breakaway Aluminum Anchor Base FRP Poles

Shakespeare Model AHW35, 10 700 mm Long (35 ft) Breakaway Anchor Base Light Poles:
Test #1 (SF35C1); handhole in compression: Deflection exceeded the limit listed in the SSP and the pole failed prior to reaching the specified minimum ultimate bending strength. There was no visible damage to the pole at the specified deflection test load or prior to failure, however there was a large amount of audible cracking heard before reaching the deflection test load and ultimate bending strength. Ultimate bending failure occurred at the handhole at a load of 1900 N applied at the pole tip. Test pole SF35C1 failed both the specified deflection and bending strength criteria.

Test #2 (SF35T1); handhole in tension: Deflection exceeded the limit listed in the SSP and the pole failed prior to reaching the specified minimum ultimate bending strength. There was no visible damage to the pole at the specified deflection test load or prior to failure, however there was cracking noises heard prior to attaining the deflection test load and ultimate bending strength. Ultimate bending failure occurred at a load of 2410 N applied at the pole tip when the epoxy bond between the pole shaft and anchor base completely separated and the shaft pulled up and away from the anchor base. Additional loading caused the shaft to pull farther away from the anchor base. Test pole SF35T1 failed both the specified deflection and bending strength criteria.

Because compression test #1 (SF35C1) had a greater deflection and lower ultimate bending strength than tension test #2 (SF35T1), a replicate test, test #3 (SF35C2), was run.

Test #3 (SF35C2); handhole in compression: Deflection exceeded the maximum allowed in the SSP and the pole failed in bending prior to reaching the minimum specified ultimate bending strength. There was no visible damage to the pole at the specified deflection test load or prior to failure, however a loud crack was heard prior to reaching the specified deflection test load followed by additional cracking noises up until bending failure. Ultimate bending failure occurred at the handhole at a load of 2201 N applied at the pole tip. Test pole SF35C2 failed both the specified deflection and bending strength criteria.

2.8.4.3 Discussion of Test Results of Caltrans Pole 15F Non-Breakaway Anchor Base FRP Poles

Whatley Model A4330, 9144 mm Long (30 ft) Non-Breakaway Anchor Base Light Poles:
Test #1 WF30C1; handhole in compression: Deflection did not exceed the limit listed in the SSP, nor did the pole fail prior to reaching the minimum specified

ultimate bending strength. There was no visible damage to the pole prior to reaching the specified test loads. Ultimate bending failure occurred at the handhole location at a load of 3011 N applied to the pole tip. Test pole WF30C1 passed both the specified deflection and bending strength criteria.

Test #2 WF30T1; handhole in tension: Deflection did not exceed the limit listed in the SSP, nor did the pole fail prior to reaching the minimum specified ultimate bending strength. There was no visible damage to the pole prior to reaching the specified test loads. Ultimate bending failure was at the handhole location at a load of 4996 N applied to the pole tip. Test pole WF30T1 passed both the specified deflection and bending strength criteria.

Compression test #1 (WF30C1) had a higher deflection at the deflection test load and lower ultimate bending strength than tension test #2 (WF30T1), thus a replicate compression test, test #3 (WF30C2), was run.

Test #3 WF30C2; handhole in compression: Deflection did not exceed the limit listed in the SSP, nor did the pole fail prior to reaching the minimum specified ultimate bending strength. There was no visible damage to the pole prior to reaching the specified test loads. Ultimate bending failure occurred at the handhole location at a load of 3964 N applied to the pole tip. Test pole WF30C2 passed both the specified deflection and bending strength criteria.

2.8.4.4 Discussion of Test Results of Caltrans Pole 21F Non-Breakaway Anchor Base FRP Poles

Whatley Model A4335, 10 700 mm (35 ft) Non-Breakaway Anchor Base Light Poles:

Test #1 WF35C1; handhole in compression: Deflection did not exceed the limit listed in the SSP, nor did the pole fail prior to reaching the minimum specified ultimate bending strength. There was no visible damage to the pole prior to reaching the specified test loads. Ultimate bending failure was at the handhole location at a load of 4207 Newton applied to the pole tip. Test pole WF35C1 passed both the specified deflection and bending strength criteria.

Test #2 WF35T1; handhole in tension: Deflection did not exceed the limit listed in the SSP, nor did the pole fail prior to reaching the minimum specified ultimate bending strength. There was no visible damage to the pole prior to reaching the specified test loads. Ultimate bending failure was at the handhole location at a load of 5016 N applied to the pole tip. Test pole WF35T1 passed both the specified deflection and bending strength criteria.

Compression test #1 (WF35C1) had a higher deflection and lower ultimate bending strength than tension test #2 (WF35T1), thus a replicate compression test, test #3 (WF35C2), was run.

Test #3 WF35C2; handhole in compression: Deflection did not exceed the limit listed in the SSP, nor did the pole fail prior to reaching the specified minimum ultimate bending strength. There was no visible damage to the pole prior to reaching the specified test loads. Ultimate bending failure was at the handhole location at a load of 4931 N applied to the pole tip. Test pole WF35C2 passed both the specified deflection and bending strength criteria.

2.8.4.5 Discussion of Test Results of Caltrans Type 15F B Breakaway Direct Burial FRP Poles

Shakespeare Model BBW35, 9144 mm (30 ft) Breakaway Direct Burial Light Poles:

Test #1 (SB35C1); handhole in compression: The poles deflection did not exceed the limit listed in the SSP but the pole did fail prior to reaching the specified minimum ultimate bending strength. There was no visible damage to the pole at the specified deflection test load or prior to ultimate bending failure, however some audible cracking was heard before reaching the deflection test load and ultimate bending strength. Ultimate bending failure occurred at a load of 2176 N applied to the pole tip when the epoxy bond between the above-ground pole tube section and the lower anchor tube section failed and the pole shaft pulled away from the base. Additional loading caused the pole tube to pull farther away from the anchor tube. Test pole SB35C1 passed the specified deflection test load criteria but failed prior to reaching the specified bending strength test load.

Test #2 (SB35T1), with the handhole in tension: Deflection did not exceed the limit listed in the SSP, nor did the pole fail prior to reaching the specified minimum ultimate bending strength. There was no visible damage to the pole at the specified loads, but there was some cracking noises heard prior to reaching the deflection and ultimate bending strength test loads. Ultimate bending failure occurred at a load of 2973 N applied to the pole tip when the above-ground pole tube section broke at the joint line with the lower anchor tube section. Test pole SB35T1 passed both the specified deflection and bending strength criteria.

Compression Test #1 (SB35C1) exhibited epoxy bond failure so test #3 (SB35C2) was performed as a replicate compression test.

Test #3 (SB35C2); handhole in compression: The poles deflection did not exceed the limit listed in the SSP but the pole did fail prior to reaching the minimum specified ultimate bending strength. There was no visible damage to the pole at the specified deflection test load or prior to ultimate bending failure, however some audible cracking was heard before reaching the deflection test load and ultimate bending strength. Ultimate bending failure occurred at a load of 2299 N applied to the pole tip when the epoxy bond between the above-ground pole tube section and the lower anchor tube section failed and the pole shaft pulled away from the base. Additional loading caused the pole shaft to

pull farther away from the base. Test pole SB35C2 passed the specified deflection test load criteria but failed prior to reaching the specified bending strength test load.

2.8.4.6 Discussion of Test Results of Caltrans Pole Type 21F B Breakaway Direct Burial FRP Poles

Shakespeare BBW41, 10 700 mm (35 ft) Breakaway Direct Burial Light Poles:

Test #1 (SB41C1); handhole in compression: The deflection at the pole tip did not exceed the limit listed in the SSP but the pole did fail prior to the specified minimum ultimate bending strength. There was no visible damage to the pole at the specified deflection test load or prior to ultimate bending failure, however some audible cracking was heard before reaching the deflection test load and ultimate bending strength. Ultimate bending failure occurred at a load of 2437 N applied to the pole tip when almost simultaneously the epoxy bond between the above-ground pole tube section and the lower anchor tube section failed and the upper pole tube section broke at the handhole. Test pole SB41C1 passed the specified deflection test load criteria but failed prior to reaching the specified bending strength test load.

Test #2 (SB41T1); with the handhole in tension: The deflection at the pole tip did not exceed the limit listed in the SSP but the pole did fail prior to reaching the specified minimum ultimate bending strength. There was no visible damage to the pole at the specified deflection test load or prior to ultimate bending failure, however some audible cracking was heard before reaching the deflection test load and ultimate bending strength. Ultimate bending failure occurred at a load of 2472 N applied to the pole tip when the epoxy bond between the above-ground pole tube section and the lower anchor tube section failed. Additional loading caused the above-ground pole tube to pull farther away from the lower anchor tube section until it finally broke at the joint line. Test pole SB41T1 passed the specified deflection test load criteria but failed prior to reaching the specified bending strength test load.

Compression test #1 (SB41C1) had a higher deflection and lower ultimate bending strength than tension test #2 (SB415T1), thus a second replicate compression test, test #3 (SB41C2), was run.

Test #3 (SB41C2); handhole in compression: The poles deflection did not exceed the limit listed in the SSP but the pole did fail prior to reaching the specified minimum ultimate bending strength. There was no visible damage to the pole at the specified deflection test load or prior to ultimate bending failure, however some audible cracking was heard before reaching the deflection test load and ultimate bending strength. Ultimate bending failure occurred at a load of 2352 N applied to the pole tip when the pole tube section broke at the handhole. Test pole SB41C2 passed the specified deflection test load criteria but failed prior to reaching the specified bending strength test load.

Plots of load versus deflection for anchor base and direct burial poles can be seen in Appendix F.

2.9 Testing on Exterior Coatings

The specified coating for FRP poles is a aliphatic-type acrylic-modified polyurethane which must have a minimum 3-mil dry film thickness and be capable of withstanding 2,500 hours of accelerated weathering. Testing was done according to requirements in paragraph 21 of Caltrans SSP 86.08.5 (Appendix A).

2.9.1 Procedure to Determine Finish Thickness

Three FRP poles were supplied by each manufacturer as ordered and their finish coating thicknesses were measured with a Tooke gauge (ASTM D 4138). Five coating thickness readings were taken from each pole and averaged (see Figure 19).

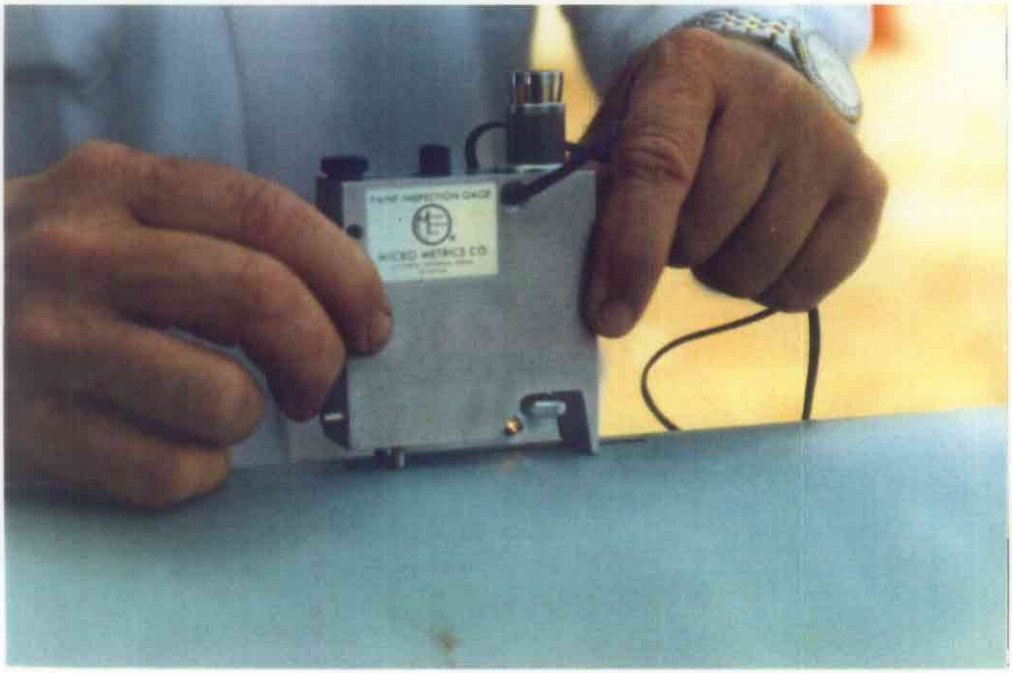


Figure 19. Checking paint thickness with a Tooke gauge.

2.9.2 Accelerated Weathering Test Procedure

A FRP pole from each manufacturer was selected and a 76 x 127 mm piece of the finished pole was removed and used for the accelerated weathering tests (ASTM designation G 53). The specimens were alternately cycled at 4-hour intervals, first under an ultraviolet light (lamps were UV-B 313 nm wave length) at 60°C and then with condensation at 40°C. The test which simulates effects of rain dew and sunlight deterioration (see Figure 20) was run for 2,500 hours.

Figure 20. 2,500-hour accelerated weathering test

2.9.3 Test Results of Finish Thickness and Accelerated Weathering

The finish coating on Shakespeare and Whatley poles was identified generally as a polyurethane with acrylic additives. The thickness of the Shakespeare coating averaged 2.8 mils, and the Whatley finish averaged 3.25 mils (see Appendix H, Dry Film Thickness Readings of Exterior Paint).

After 2,500 hours of accelerated weathering, the finished surfaces of the Shakespeare and Whatley test specimens showed no signs of fiber exposure,

crazing or checking. The color of the Whatley sample dulled slightly and there was some minor but acceptable chalking. After exposure to UV, the Shakespeare sample showed excessive chalking and changing of color (yellowing), and did not satisfactorily conform to Caltrans requirements (see Figure 21).

Figure 21. Shakespeare test sample from 2,500-hour accelerated weathering test.

3. CONCLUSIONS

A total of 18 FRP poles were evaluated in this project and test results were compared to requirements outlined in the Caltrans Standard Special Provision 86.08.5. Test results are summarized in Table 6, page 29. It was concluded that:

1. The Whatley model A4330 and A4335 poles tested in this research successfully met deflection and minimum ultimate bending strength test criteria for Caltrans type 15F and 21F non-breakaway anchor base poles.

2. The three Shakespeare AHW35 model poles evaluated failed to meet the deflection test criterion for Caltrans Type 21F light poles and are

unsatisfactory for use by Caltrans. Caltrans' maximum deflection limit of 13 percent of the length of the pole above ground was exceeded in all three tests when the poles were subjected to the required 1708 N deflection test load. The same three poles also failed to reach the minimum required ultimate bending strength criterion of 2563 N for Caltrans Type 21F light poles.

3. The three Shakespeare BBW35 model poles tested failed to reach the minimum ultimate bending strength criterion of 2406 N for Caltrans Type 15F B light poles (direct burial) and are unsatisfactory for use by Caltrans.

4. Two of the three Shakespeare BBW41 model poles tested failed to reach the minimum ultimate bending strength criterion of 2562 N for Caltrans Type 21F B light poles (direct burial) and are unsatisfactory for use by Caltrans.

In addition to the above, it was concluded that:

5. The average thickness of the exterior paint on all Shakespeare's models submitted did not meet Caltrans' minimum 3-mils dry film thickness requirement.

6. The paint finish on Shakespeare's models, after 2,500 hours of accelerated weathering, exhibited excessive chalking and changing color (yellowing) when tested in accordance with ASTM Designation: G53 and paragraph 21 of Caltrans Standard Special Provision 86.08.5.

7. Handhole covers and cover inserts on most Shakespeare pole models tested did not fit properly.

8. Handhole covers on Whatley models were not oval nor did they bear the manufacturer's name.

9. Name tags furnished on Shakespeare's models did not conform to Caltrans requirements (required information incomplete and location incorrect).

10. Name tags were not furnished on Whatley models.

4. RECOMMENDATIONS

It is recommended that Caltrans consider Whatley model A4330 and A4335 non-breakaway anchor base poles acceptable for use as Caltrans types 15F and 21F poles respectively, for use in areas where breakaway poles are not required, provided that the deficiencies detailed in items 8 and 10 of the

Conclusions section of this report are corrected.

Because of strength and deflection test failures of various Shakespeare pole models and non-compliance of the paint used on all Shakespeare's lighting poles submitted, Caltrans is not presently accepting Shakespeare's fiberglass light poles on any contracts until all problems previously discussed have been remedied.

It is also recommended that: 1) the current Caltrans Standard Special Provision 86.08.5, be revised according to changes shown in Appendix A, 2) on FRP poles deflection and bending strength be evaluated using the newly developed test procedure "Caltrans Test 683" listed in Appendix C, 3) limited destructive quality assurance testing be periodically performed by the manufacturer (at least once a year) to make sure Caltrans deflection and bending strength requirements are being met, 4) when inspecting FRP light poles, Caltrans personnel should be especially aware of and check at least the following:

- Each pole shall be spirally wrapped in its entirety with weatherproof wrap for protection during shipment and storage prior to shipment from the manufacturer.
- Poles shall be unwrapped and visually inspected for cracking, checking defects, bulges and taper irregularities upon arrival to the job site.
- The top cap of the pole shall be undamaged aluminum or galvanized steel.
- The handhole cover should provide a secure uniform water tight fit, have the manufacturers name, and tamper resistant hardware.
- That each pole identification plate should be located on the anchor base or just above the handhole and be attached with stainless steel screws or rivets. Information on the plates shall include the Caltrans pole type, manufacturers name, part number, year of fabrication, and the word "BREAKAWAY" on internal grooved breakaway flange poles.
- Proper length, pole type, anchor bolt circle diameter, and appropriate hardware.
- One quart of matching paint shall be included with each lot of poles to repair and any scuff marks or damage made by a Tooke gauge when evaluating paint thickness.

and, 5) the Inspection Unit of the Structural Materials Branch obtain, review, approve, and maintain a current copy of the testing and quality control program from each manufacturer selling FRP poles for use on Caltrans contracts, and shall periodically require and witness quality assurance tests and evaluations on FRP lighting poles, base plates, and mast arm samples, as

per Caltrans SSP 86.08.5.

It is further recommended that future studies be conducted to determine: 1) the possibility of mast arm joints and connections of FRP lighting poles failing from excessive fatigue due to wind loading, and 2) the rate of degradation of presently permitted exterior paint coatings due to weathering and eventual exposure of the fiberglass strands.

5. IMPLEMENTATION

- A summary of test results of FRP lighting poles evaluated in this research will be made available by Caltrans Office of Traffic Operations for use by construction personnel.

- A list of recommended items to inspect will be provided to the Inspection unit of the Structural Materials Branch of the Office of Materials Engineering and Testing Services to be used as an inspection guide.

- Recommended revisions to the Standard Special Provision 86.08.5 shall be made by the Office of Office Engineer of the Engineering Service Center.

- The Structural Materials Branch of the Office of Materials Engineering and Testing Services will adopt Caltrans Test 683 (Appendix C) developed to evaluate FRP lighting poles for maximum deflection and minimum bending strength.

APPENDIX A Caltrans Revised Standard Special Provision 86.08.5, "Fiberglass Lighting Standards".

(Use with Fiberglass Lighting Standard details [2 sheets].)
(Use when fiberglass standards are allowed as an option for Types 15, 21, and 30 lighting standards.)
(Furnishing FRP standards must be at the Contractor's option.)

10-3.__ FIBERGLASS LIGHTING STANDARDS{ TC "**10-3.__ FIBERGLASS LIGHTING STANDARDS**"}.--At the option of the Contractor, standards utilizing fiberglass-reinforced thermosetting plastic (FRP) poles may be substituted for steel lighting standards as provided below:

Steel Standard	FRP equivalent
Type 15	Type 15F
Type 15 with Slip Base	Type 15F (Breakaway)
Type 21, Type 30 without Slip Base	Type 21F
Type 30	Type 21F (Breakaway)

2

Fiberglass lighting standards shall consist of round, fiberglass-reinforced thermosetting plastic poles with aluminum mast arms. FRP poles shall be hollow, tapered or with tapered sections, non-conductive and chemically inert.

3

FRP lighting standards shall conform to the details shown on the plans, and shall comply with requirements in the AASHTO manual titled "Standard Specifications for Structural Supports for Signs, Luminaires, and Traffic Signals" **(current edition)** ~~(1985) and ANSI Roadway Lighting Document C136.20, "Fiber Reinforced Plastic (FRP) Lighting Poles,"~~ **except as modified below:**

A. Design wind velocity shall be 80 mph (129 km/h).
B. Design luminaire size shall have an effective projected area (e.p.a.) of 1.6 ft^2 and weigh 60 lb.

4

(Para. 4: Use when anchor base "Breakaway" type standards are required.)

FRP lighting standards specified as "Breakaway" types shall also comply with the requirements in the National Cooperative Highway Research Program Report ~~230~~ **350**, "Recommended Procedures for the Safety Performance Evaluation of Highway ~~Appurtenances~~ **Features" for Test Level 3, and be approved by the Federal Highway Administration and Caltrans. In addition, fiber-reinforced lighting standards shall comply with Caltrans policy for breakaway devices and be crash tested with actual autos or validated bogies**. Design wind velocity for lighting standard systems shall be 80 MPH.

5

(Para. 5: Use when anchor base "Non-Breakaway" type standards are required.)

FRP lighting standards that are not specified as "Breakaway" types shall not have the machined groove inside the anchor base casting as shown in the "Aluminum Anchor Base Elevation" detail shown on the plans **or other breakaway system approved by FHWA and Caltrans**.

6

The pole, with specified luminaire and mast arm installed, shall withstand the bending strength test load shown in the following table. The pole shall withstand this load with the handhole in compression. The pole shall not exceed a maximum deflection of 13 percent of the length of the pole above the ground line when subjected to the deflection test load shown in the following table.

TEST LOAD TABLE

Standard Type	Bending Strength Test Load	Deflection Test Load
Type 15F, Type 15F (Breakaway)	541 lbs.	361 lbs.
Type 21F, Type 21F (Breakaway)	576 lbs.	384 lbs.

7

Deflection and bending strength shall be evaluated according to procedures in California Test 683. ~~Test loads shall be applied according to Section 12, "Pole Deflection Measurements," of ANSI C136.20. Poles shall be loaded 12 inches below the tip.~~

8

FRP standards shall be the anchor base type unless otherwise indicated.

9

The manufacturer shall have a testing and quality control program approved by the Transportation Laboratory and shall submit samples of the base plate and mast arm to the Transportation Laboratory prior to fabricating standards for this contract. Testing and quality control program and base plate and mast arm samples shall be submitted to:

Transportation Laboratory
Structural Materials Branch
5900 Folsom Boulevard
Sacramento, CA 95819-**0128**

10

The Contractor shall provide the Engineer a Certificate of Compliance from the manufacturer in accordance with the provisions of Section 6-1.07, "Certificates of Compliance," of the Standard Specifications. The certificate shall also include a copy of all applicable test reports on the lighting standards. The test reports shall be signed by the manufacturer's management person responsible for the tests. Said certificate shall also certify that the lighting standards comply with the requirements of the specifications and were manufactured in accordance with the approved testing and quality control program.

11

MAST ARMS.--In addition to ~~the~~ **other** requirements stated ~~above~~ **in this SSP**, aluminum mast arms shall comply with requirements in the Aluminum Association's Publication 30,

"Specifications for Aluminum Structures." The aluminum mast arm (connected to the pole and with a State-approved HPS-310 luminaire attached) shall withstand 2 million cycles of vertical cyclic loading (3 "g" level, peak-to-peak) with the ballast removed, and one million cycles of horizontal cyclic loading (1.5 "g" level, peak-to-peak) with the ballast installed, without any sign of distress.

12

CONSTRUCTION.--The pole shall be constructed from ultraviolet-resistant resin which shall be pigmented light grey **, standard color number 26373 of Federal Standard 595B,** and **the resin shall** be of uniform color throughout the entire body of the pole. The finish of the pole shall be smooth. **Each pole shall have a 4" x 6" handhole with a snug-fitting handhole cover, bearing the name of the manufacturer. The handhole cover shall be securely attached to the pole with tamper-resistant A1S1 Grade 304 or 316 stainless steel hardware.**

13

(Para. 13: Use when handhole is to be on side away from mast arm.)

The handhole shall be located on the side **of the pole shaft** ~~away~~ **opposite** from the mast arm **to pole connection.**

14

(Para. 14: Use when handhole is to be on same side as mast arm.)

~~Each pole shall have a handhole and handhole cover, bearing the name of the manufacturer. The handhole cover shall be securely attached to the pole with tamper resistant hardware~~. The handhole shall be located on the same side **of the pole shaft** as the mast arm **to pole connection**.

15

(Para. 15: Use when anchor base poles are required.)

The **anchor** base shall be bonded to the pole with a suitable adhesive, and coated with an aliphatic-type acrylic-modified polyurethane finish. For new installations, adaptor plates shall not be used to attach the standard to the foundation.

16

(Paras. 16 and 17: Use when direct burial poles are allowed.)

The lower anchor tube shall be bonded to the upper pole tube with a suitable abhesive. Direct burial poles shall have a 2" x 6", nominal size, grommetted conduit/conductor entrance located 24 inches (±1 inch) below finished grade after installation. The entrance shall be located directly below the handhole.

17

The butt end of the direct-burial pole shall be flared, or modified by some other acceptable means, to increase the resistance to rotation and pullout and provide additional ground bearing resistance.

18

Each standard shall be provided with a removable aluminum or galvanized steel pole top cap.

19

Each standard shall have **a non-corroding** identification plate conforming to the provisions in the second paragraph of Section 86-2.04,"Standards, Steel Pedestals and Posts," of the

Standard Specifications. The identification plate shall show the **Caltrans** standard type, manufacturer's name, manufacturer's part number and the year of fabrication. If the lighting standard is a breakaway type, the identification plate shall include the word "BREAKAWAY". The plate shall be located either on the anchor base or just above the handhole.

20

EXTERIOR PROTECTION.--An aliphatic-type acrylic-modified polyurethane coating shall cover the exterior of the fiberglass pole. The coating shall be semi-gloss, highly weather resistant and light grey in color **(standard color number 26373 of Federal Standard 595B)** matching the color of the resin and shall have a minimum 3-mil dry film thickness. A one-quart can of the coating to match the **coating on the** poles shall be supplied with each order of poles.

21

The finished surface of the pole shall be capable of withstanding a minimum of 2,500 hours of accelerated weathering when tested in accordance with ASTM Designation: G 53. Lamps shall be UV-B (313 nm wave length). The testing cycle shall be 4 hours UV at 60° C, then 4 hours CON at 40° C.

22

After testing, the finished surface of the pole shall exhibit the following:

Fiber exposure:	None
Crazing:	None
Checking:	None
Chalking:	Very slight
Change in color:	May dull slightly
Paint Adhesion:	**5A scale rating, as per ASTM D3359, method A using Permacel 99 tape or equivalent.**

23

PACKAGING.--Each pole shall be spiral wrapped in its entirety with a weatherproof wrap **by the manufacturer after fabrication and prior to shipment** for protection during shipping and storage.

24

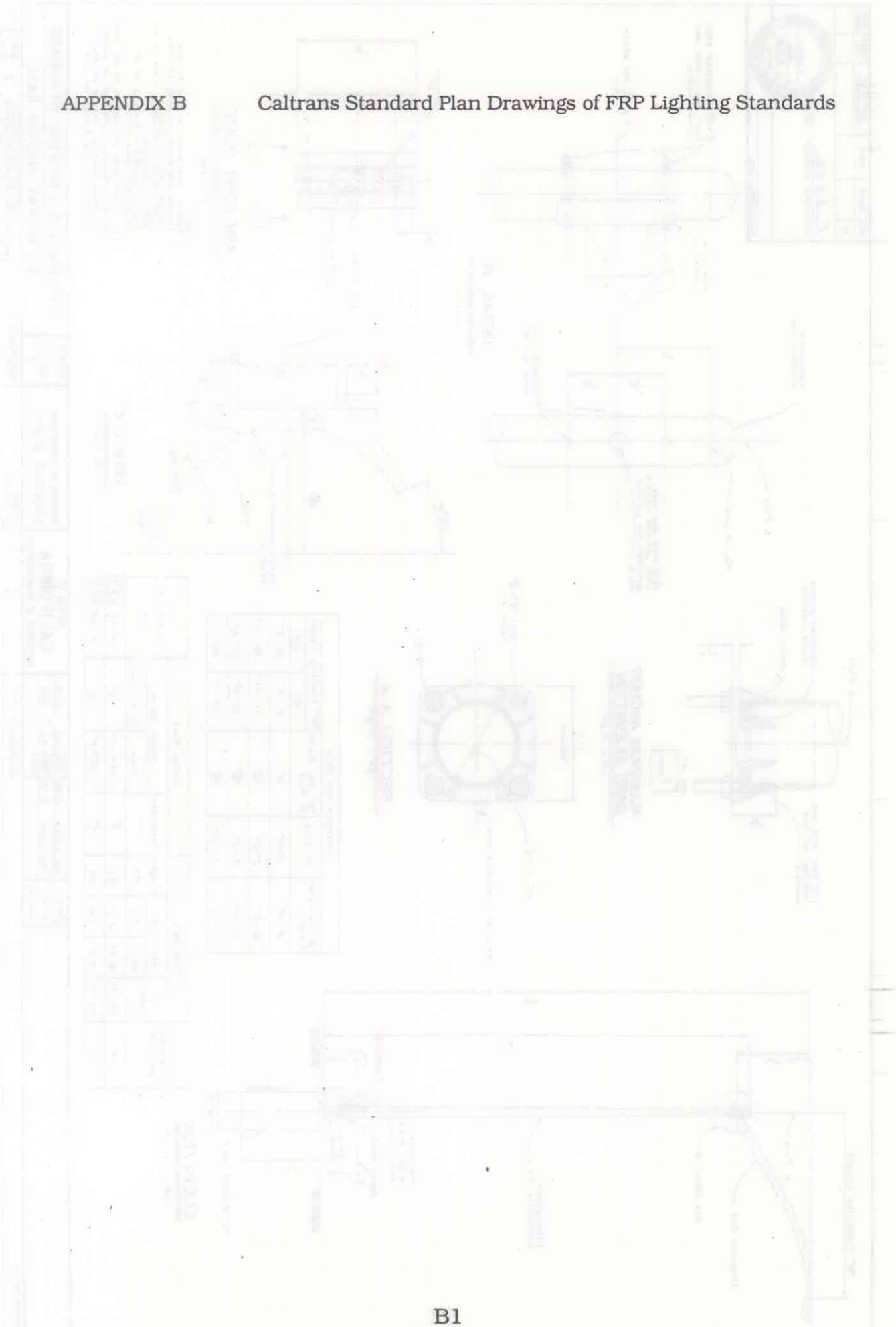
(Para. 24: Use when direct burial poles are allowed.)

INSTALLATION.--Installation and backfilling for direct burial poles shall be as ~~provided~~ **required** for wood poles in Section 86-2.12, "Wood Poles," of the Standard Specifications.

25

BONDING AND GROUNDING.--Each FRP lighting standard shall have its luminaire, mast arm and anchor bolts effectively grounded as provided in Section 86-2.10, "Bonding and Grounding," of the Standard Specifications. A separate bonding connection to the mast arm will not be required provided there is non-insulated contact between the luminaire and the mast arm.

APPENDIX B Caltrans Standard Plan Drawings of FRP Lighting Standards



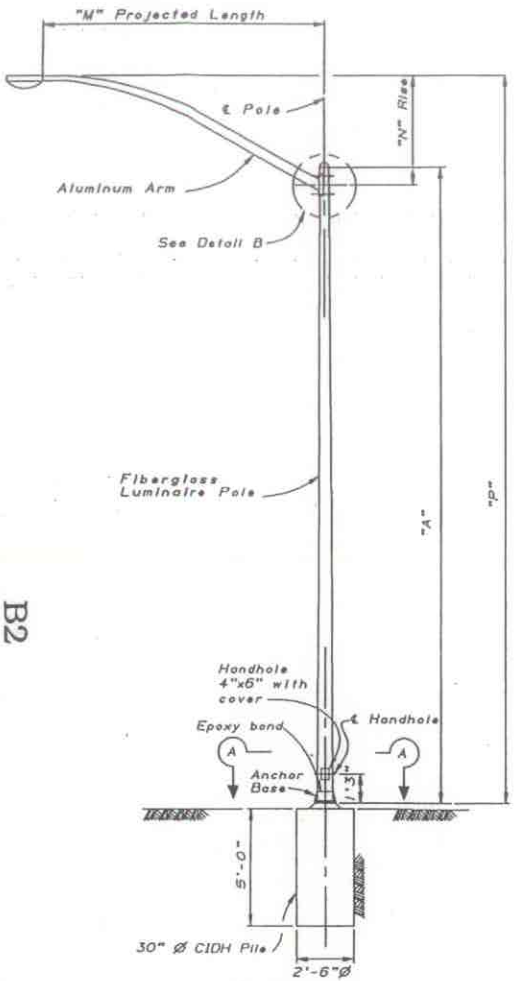
DIST.	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
0					

Earl M Riker
REGISTERED ENGINEER - CIVIL

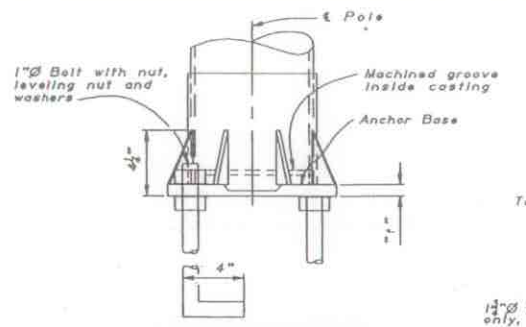
E.M. Riker No. 5204 Exp. 12-31-92 CIVIL — REGISTERED PROFESSIONAL ENGINEER — STATE OF CALIFORNIA

PLANS APPROVAL DATE

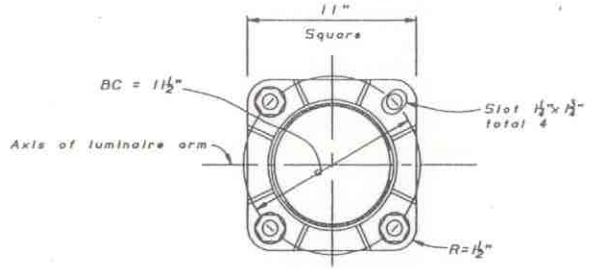
B2



ELEVATION
3/8" = 1'-0"



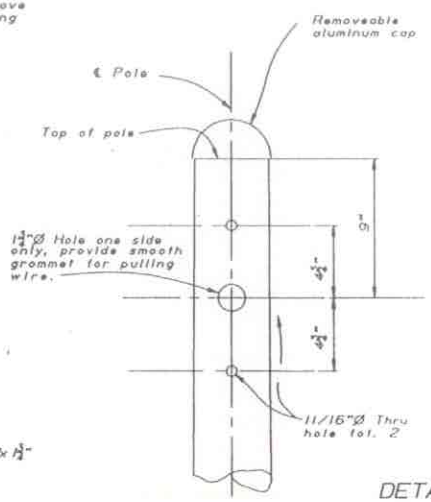
ALUMINUM ANCHOR BASE ELEVATION
3" = 1'-0"



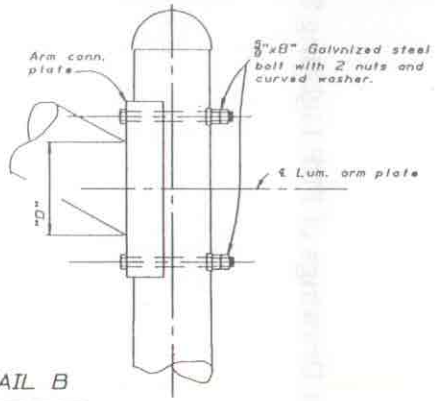
SECTION A-A
3" = 1'-0"

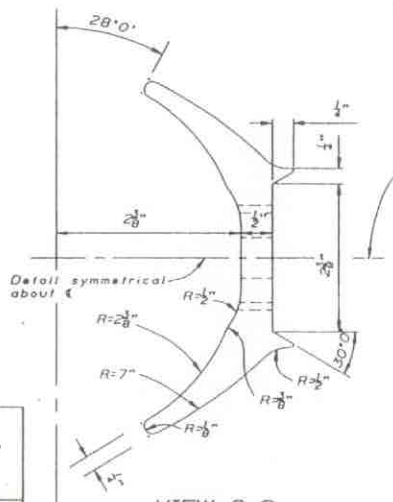
Luminaire Arm Data				
M: Projected Length	N: Rise	"D" Min. Depth At Pole	"P" Mounting Height	
			15F	21F
6'-0"	2'-0"	5"	31'-3"	36'-3"
8'-0"	2'-8"	5⅞"	31'-11"	36'-11"
10'-0"	3'-3"	5⅞"	32'-6"	37'-6"
12'-0"	3'-10"	5⅞"	33'-1"	38'-1"

Fiberglass Pole Type	Pole Data				Anchor Base			Luminaire Arm
	"A" Height	Min. O.D.		Weight lbs.	Thickness "t"	Anchor Bolts		
		Base	Top			Size	Bolt Circle	
15F	30'-0"	8.5"	4.8"	161	¾"	1"x36"x4"	11½"	6'-12' [12']
21F	35'-0"	8.5"	4.8"	186	¾"	1"x36"x4"	11½"	6'-12' [12']



DETAIL B
3"=1'-0"





VIEW C-C
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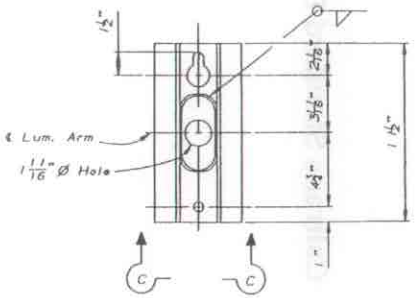


ARM CONN. PLATE
3" = 1'0"

Notes:
1. Torque base bolts to 200 ft./lbs.
2. Torque arm bolts for snug fit then torque lock nut firm.
3. Luminaire Arm connection plate to be 6061-T6 aluminum.
4. Top of foundation must be at or lower than base plate.
5. [ ] Indicates arm length to be used unless otherwise indicated on plans.
6. Handhole shall be located on the traffic downstream side of pole.

DESIGN	BY Earl M. Riker	12-90	CHECKED Kevin Wall	10-92	
DETAILS	BY Ben Matsuo	12-90	CHECKED Kevin Wall	10-92	
QUANTITIES	BY		CHECKED		

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

DIVISION OF STRUCTURES
STRUCTURE DESIGN

CU 59
EA 910076

BRIDGE NO. 0
POST MILE 0

FIBERGLASS LIGHTING STANDARD
BREAKAWAY ANCHOR BASE

ORIGINAL SCALE IN INCHES FOR REDUCED PLANS 0 1 2 3

DISREGARD PRINTS BEARING EARLIER REVISION DATES

REVISION DATES (PRELIMINARY STAGE ONLY)

SHEET OF

tsbgl fiberglass-pole normal-base-pl

DIST.	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
0					

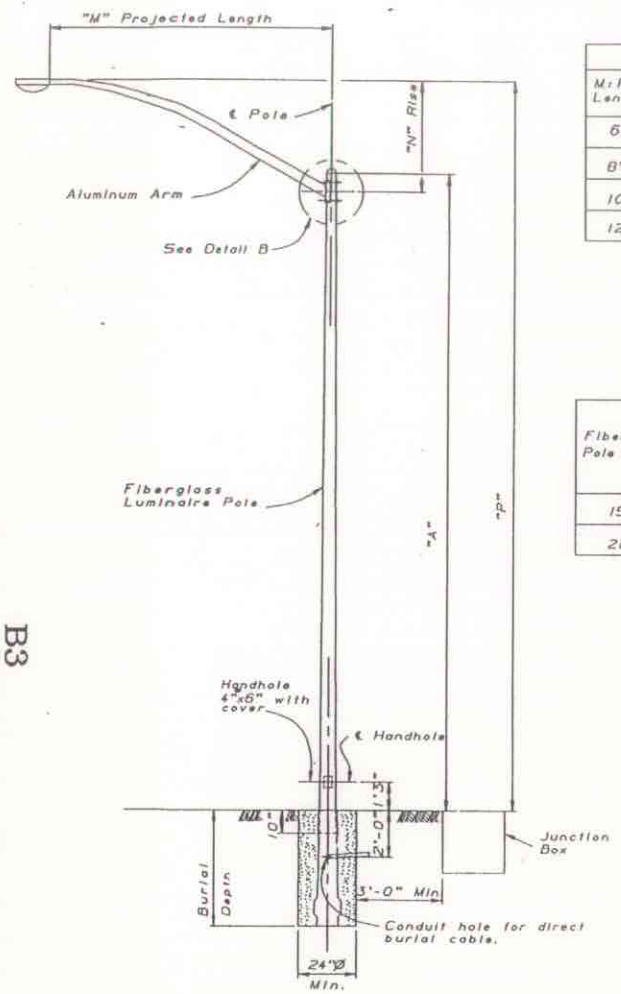
Earl M Riker
REGISTERED ENGINEER - CIVIL

REGISTERED PROFESSIONAL ENGINEER — E.M.Riker No. 9204 Exp. 12-31-92 CIVIL — STATE OF CALIFORNIA

PLANS APPROVAL DATE

B3

tsbgl fiberglass-pole.plb



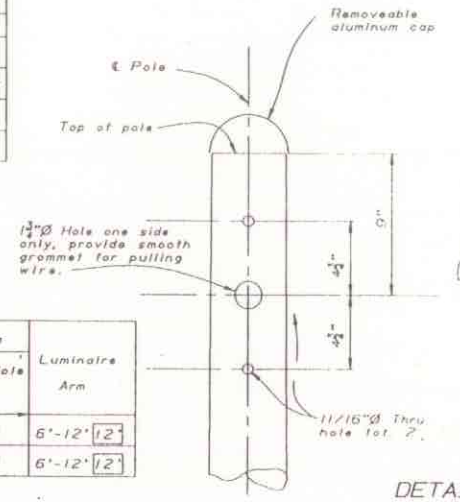
ELEVATION

3/8" = 1'-0"

Notes:
1. Backfill with approved soil that was removed from hole.
2. Foundation design is based on soil equal to a freeway embankment.

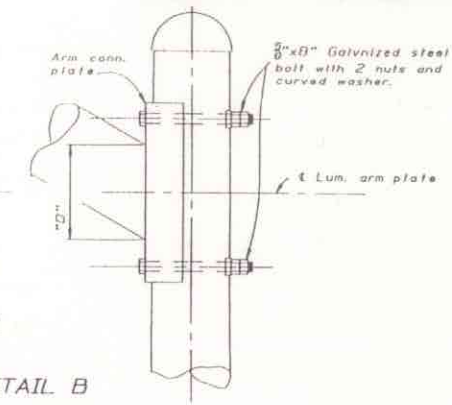
Luminaire Arm Data				
M: Projected Length	N: Rise	"O" Min. Depth At Pole	"P" Mounting Height	
			15F	21F
6'-0"	2'-0"	5"	31'-3"	36'-3"
8'-0"	2'-8"	5 7/8"	31'-11"	36'-11"
10'-0"	3'-3"	5 7/8"	32'-6"	37'-6"
12'-0"	3'-10"	5 7/8"	33'-1"	38'-1"

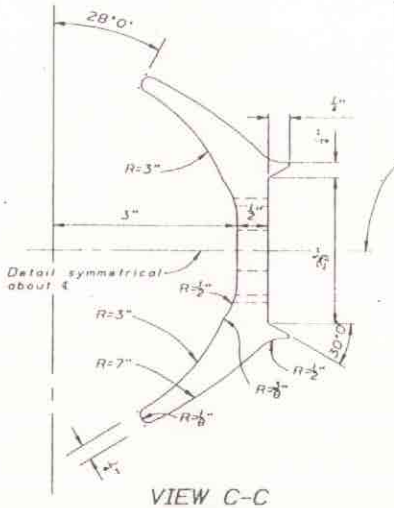
Fiberglass Pole Type	Pole Data				Embedment Data		Luminaire Arm
	"A" Height	Min. O.D.		Weight lbs.	Burial Depth	Min. Hole Dia	
		Base	Top				
15F	30'-0"	10 1/4"	6 1/8"	216	5'-0"	24"Ø	6'-12' 12'
21F	35'-0"	1 1'-0"	6 7/8"	297	6'-0"	24"Ø	6'-12' 12'



DETAIL B

3"=1'-0"





VIEW C-C

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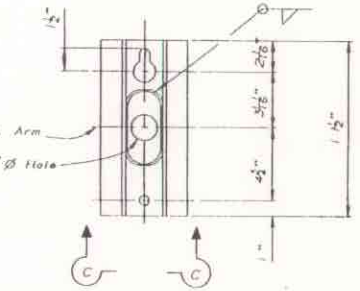


ARM CONN. PLATE

3" = 1'0"

Notes:
1. Torque arm bolts for snug fit then torque lock nut firm.
2. Luminaire Arm connection plate to be 6061-T6 aluminum.
3. ☐ Indicates arm length to be used unless otherwise indicated on plans.
4. Handhole shall be located on the traffic downstream side of pole.

DESIGN	BY Earl M. Riker	1-91	CHECKED Kevin Wall	10-92	STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION	DIVISION OF STRUCTURES STRUCTURE DESIGN	BRIDGE NO. 0
DETAILS	BY Ben Matsuo	1-91	CHECKED Kevin Wall	10-92			POST MILE 0
QUANTITIES	BY		CHECKED			CU 59 EA 910076	

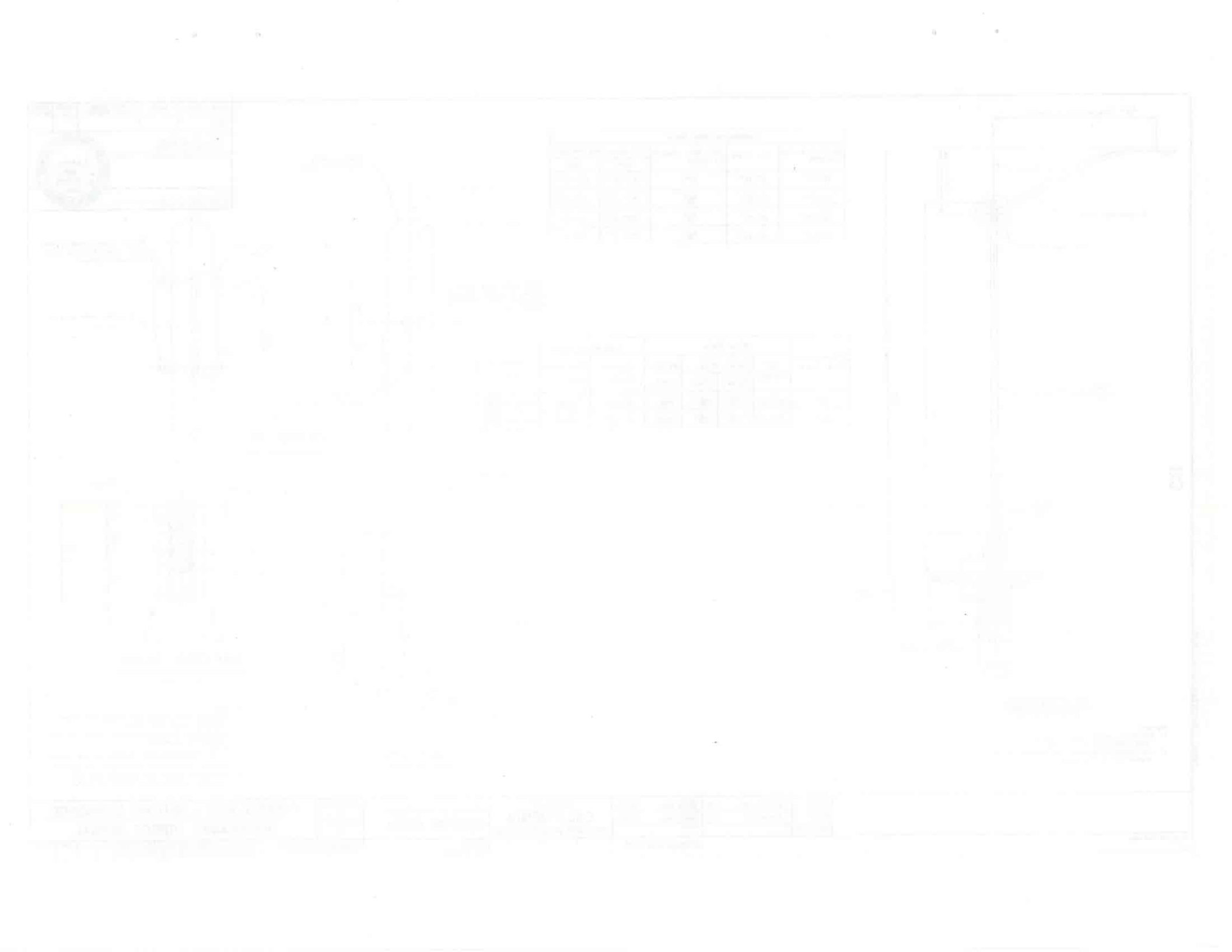
FIBERGLASS LIGHTING STANDARD BREAKAWAY DIRECT BURIAL

ORIGINAL SCALE IN INCHES FOR REDUCED PLANS 0 1 2 3

DISREGARD PRINTS BEARING EARLIER REVISION DATES

REVISION DATES (PRELIMINARY STAGE ONLY)

SHEET OF



APPENDIX C

Proposed California Test 683, "Method for Testing Deflection and Bending Strength of Fiber-Reinforced Plastic Poles".

DEPARTMENT OF TRANSPORTATION
ENGINEERING SERVICE CENTER
Transportation Laboratory
P. O. Box 19128
Sacramento, California 95819

California Test 683
July 1995

METHOD FOR TESTING DEFLECTION AND BENDING STRENGTH OF FIBER-REINFORCED PLASTIC POLES

CAUTION: Prior to handling test materials, performing equipment setups, and/or conducting this method, testers are required to read **"SAFETY AND HEALTH"** in Section C of this method. It is the responsibility of whoever uses this method to consult and use departmental safety and health practices and determine the applicability of regulatory limitations before any testing is performed.

A. SCOPE

This method describes the test procedure to be used for determining 1) deflection under a specified bending load and 2) ultimate bending strength of fiber-reinforced lighting poles.

B. DESCRIPTION OF TERMS

Fiber-reinforced plastic (FRP) lighting pole - a round hollow tapered pole designed to serve as the vertical support for aluminum mast arms or top mounted luminaires. The shaft is composed of a matrix of thermal-setting resin reinforced with continuous spirally-wrapped fiberglass filaments.

Anchor base pole - a FRP pole which has a metal flanged anchor base bonded to the pole base and is mechanically fastened to a concrete foundation via anchor bolts.

Direct burial pole - a FRP pole whose extra length allows it to be directly buried in an augured hole in the ground.

Pole deflection test load - the amount of force applied at the tip of a cantilevered pole at which the measured tip deflection of the pole cannot exceed 13% of the height of the pole which projects above the ground.

Bending strength test load - the minimum amount of force applied at the tip of a cantilevered pole perpendicular to the pole axis which the pole must withstand.

C. SAFETY AND HEALTH

This method may involve the use of hazardous chemicals. Prior to handling or testing of materials, Caltrans personnel are required to obtain, read and follow information in the materials data sheets for any hazardous materials being tested. In addition they are required to read and follow information in pertinent sections of Parts A, B, and C of the Caltrans Laboratory Safety Manual. Requirements for general safety principles, standard operating procedures, protective equipment or apparel and how to handle accidents, spills and emergencies are discussed in the above-noted reference.

Personnel are required to wear appropriate hand and eye protection when handling fiber-reinforced materials or any other potentially hazardous materials.

This method does not purport to address all the safety problems associated with its use. It is the responsibility of whoever uses this method to read, consult, understand, and follow appropriate material safety data sheets and safety manuals, and establish appropriate

safety and health practices and determine the applicability of regulatory limitations prior to use. Users of this method do so at their own risk.

D. TESTING APPARATUS

The following testing apparatus is required to evaluate FRP lighting poles for compliance with maximum pole deflection and minimum ultimate bending strength requirements:

1. Test fixtures, equivalent to those shown in Figure 1 and designed to withstand loads from deflection/bending tests of both anchor base and direct burial style FRP poles.
2. Two linear variable differential transformers (LVDTs) having a minimum 50 mm stroke capable of measuring linear movement to within an accuracy of ±0.03 mm.
3. One draw wire position transducer (DWT) designed to measure movement of the pole tip up to 4800 mm (pre-calibrated),
4. A load cell or similar device (11 kN capacity) capable of monitoring the vertical tension load applied to pole tip to within ±1% of the actual load applied.
5. A data acquisition system which can be programmed prior to testing to receive and store voltage signals/measurements from the LVDTs, a DWT, and a load cell at 1/4-second intervals.
6. A personal computer with appropriate software.
7. An X-Y recorder/plotter which can accept wiring from a load cell and DWT to provide a graph and visual output of load versus time.
8. A DWT calibration potentiometer.
9. A power supply for the LVDTs.
10. A power supply for the DWT.
11. A forklift with adequate capacity.
12. A sling/choker and two lengths of chain with suitable connecting links.
13. Two adjustable LVDT supports.
14. A fixed support on which the DWT can be mounted.
15. A jack to support the pole tip.
16. A level (or transit) and tripod.
17. A strain indicator to convert the voltage output from the load cell to a tensile force.
18. A distribution splitter for LVDTs.
19. A video camera.

E. TEST PROCEDURE

1. Mounting and leveling procedure for poles:
   a. Anchor base poles.
      (1) Using a forklift, mount the anchor base pole to the front support in a cantilevered horizontal position. Locate the electrical access handhole in the desired quadrant (face down to put handhole region in tension, or up to put handhole region in compression).
      (2) Align the four radial slots of the pole's flanged anchor base with the bolt holes in the mounting plate of the front support. Install the mounting bolts, washers, and nuts and torque to the appropriate level.
      (3) Place a jack to provide support beneath the top of the pole, and adjust to lift the pole tip to a horizontal position. Remove the forklift.
   b. Direct burial poles.
      (1) Using a forklift, place the direct burial pole in a cantilevered horizontal position with its electrical access handhole located in the desired quadrant (facing down to load handhole region in

tension or up to load handhole region in compression).

(2) Secure the lower shaft section of the direct burial pole between two rubber-lined wooden support saddle blocks contoured to fit the outer diameter of the lower pole shaft. One block is attached to each section of the two-part steel test fixture.

(3) Position a jack beneath the top of the pole to support the pole.

(4) Using a level to check elevation, adjust the pole tip up or down with the jack until the pole is straight and horizontal. Shim below the front and/or rear saddle blocks as necessary so that a horizontal position of the pole shaft is maintained.

(5) Cinch down web straps with the two winch binders to firmly hold the base of the pole tube. Remove the forklift.

c. After mounting the pole to the test fixture, establish a longitudinal centerline along the outside surfaces of the horizontal pole.

2. Setup of data acquisition system (Figures 2, 3 and 4):

a. Position the data logger and power supplies near the forklift on a wheeled table cart.

b. LVDT placement on anchor base poles.

(1) Utilize an adjustable LVDT stand, as shown in Figure 2a, to position LVDT #1 so it is centered on the backside of the front support of the fixture's main column, 740 mm above the top of the test fixtures base plate. Then position LVDT #2 250 mm directly below LVDT #1. Wire both LVDTs to a distribution splitter and the distribution splitter to the data logger.

c. LVDT placement on direct burial poles:

(1) Use an adjustable LVDT stand to position LVDT #1 on the underside of the lower section of the pole tube 25 mm from the groundline joint toward the pole base, as shown in Figure 2b. A second adjustable LVDT stand is used to center LVDT #2 on the top of the pole above the rear support fixture. Wire both LVDTs to the distribution splitter and then the distribution splitter to the data logger.

d. Position a large concrete block, as shown in Figure 3, beneath the pole tip as an anchorage for the DWT. Fasten the DWT to the block so that the draw wire is aligned with the centerline of the tip of the pole. Pull the spring-loaded draw wire from its casing approximately 50 mm and attach it to the pole tip. Wire the DWT through a calibration potentiometer to the data logger.

e. Position the forklift over, and in line with, the load application point at the top of the pole tip. Center a sling/choker of sufficient strength to load the pole at the load application point 300 mm from the tip of the pole and cinch it down. Connect the free triangular end of the choker strap to the load cell by a loading chain which is attached to the forklift tines. Raise the forklift tines to remove slack from the loading chain and position so that the loading chain is perpendicular to the axis of the lighting pole. The loading chain must be maintained to within ±5° of vertical while applying loads. Correctly position the loading chain, then wire the load cell through the P3500 strain indicator to the X-Y recorder/plotter and the data logger.

f. Prepare the X-Y recorder/plotter with the desired load/time graph line of 445 N per minute so that it can be followed while testing to maintain a steady even load.

g. Focus the video camera on the handhole and pole base area.

3. Testing

a. Connect the power source to the data acquisition system and turn on its components.

b. Adjust the LVDTs, DWT and load cell output readings according to the requirements of the data acquisition program.

c. Start the video camera.
d. Start the data acquisition system.
e. Start the HP X-Y plotter.
f. Following the slope of the desired load/time graph line, apply the vertical load to the pole tip by raising the forklift tines.
   (1) As the vertical load is applied, maintain a vertical pull (within ±5°) on the tip of the pole by adjusting the position of the forklift.
   (2) Monitor load cell readings using the strain indicator and make any appropriate special notes at 223 N increments, at the specified deflection value, and at the minimum bending strength of the pole.
   (3) Continue to increase the load at a uniform rate until the pole fails.
g. Photograph failure mode.
h. Record test observations on the X-Y plotter/recorder graph sheet.

F. REPORTING OF TEST RESULTS

Results of all deflection and bending strength tests performed must be reported. The report of test results shall include the following minimum information.

1. Test sponsor and test agency.

2. Dates of testing and report preparation.

3. Identification of the pole type including Caltrans pole type, manufacturer, manufacturer's model number, pole length, and pole diameters at the tip and ground line.

4. Size of handhole and position during bend test, i.e., in tension, compression, or at the neutral axis.

5. Dimensions of the pole shaft, including diameter and wall thickness at tip, mid-height, and groundline, length of pole from tip to groundline , and length below groundline, if a direct burrial pole.

6. Weight of pole shaft.

7. The Caltrans deflection and bending strength specifications and test loads.

8. Amount of tip deflection at the specified deflection test load.

9. Test results at the specified bending test load.

10. Mode/description of any failure (if it occurs).

11. Photographs of pole at groundline and handhole at specified bending test load.

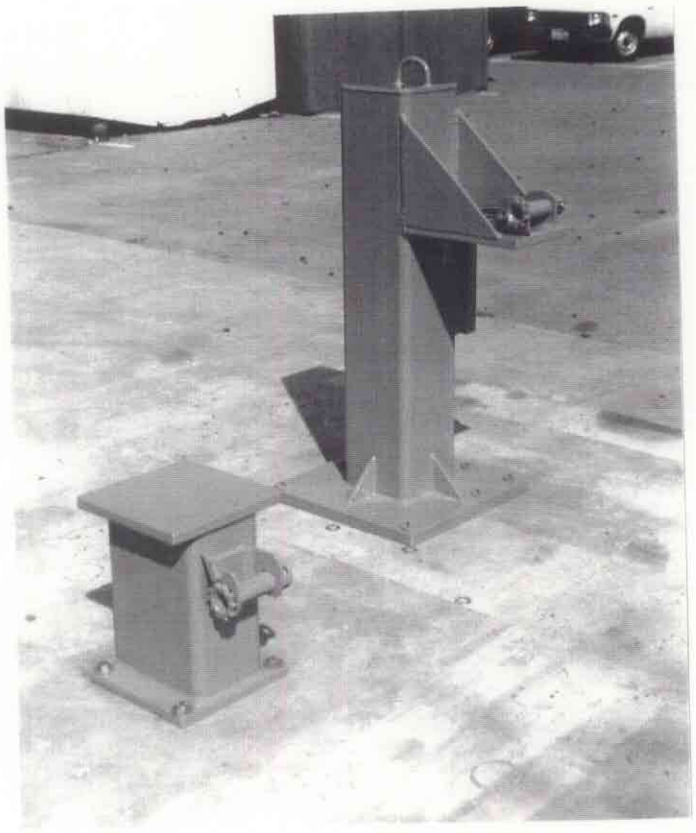
12. Discussion of test results.

13. Copy of X-Y recorder graph.

14. Copy of computer-generated graph from data acquisition system.

15. The test number and the number of poles tested under the same parameters.

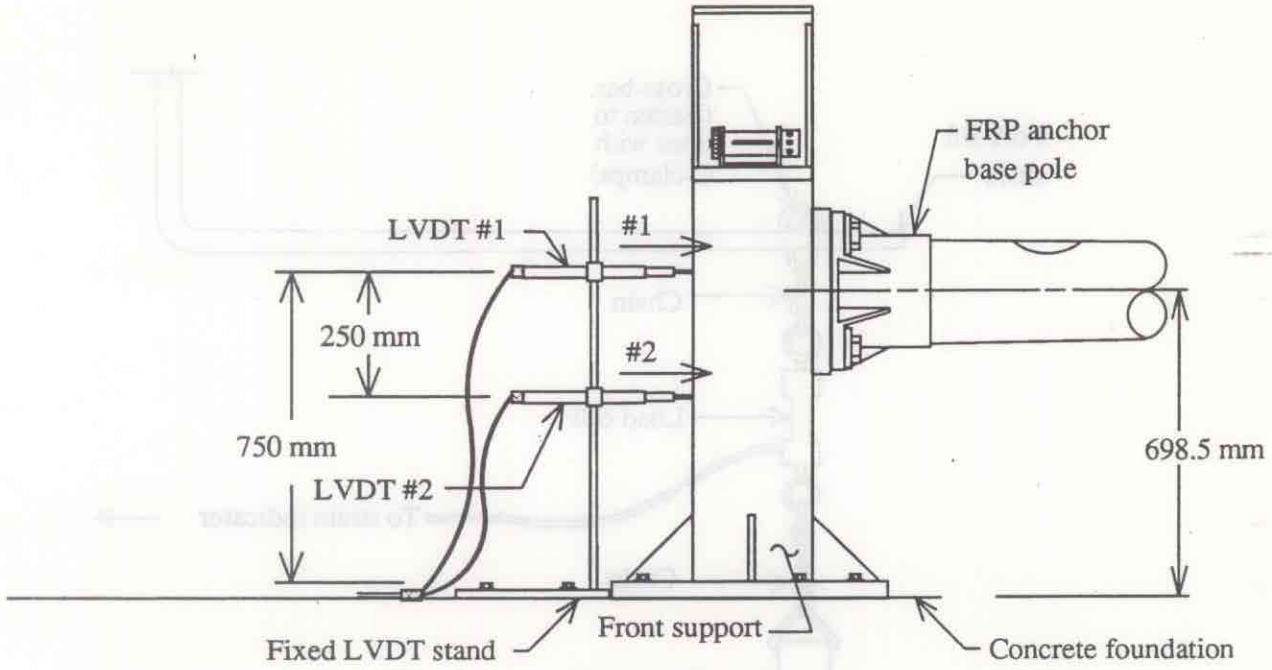
16. A listing of observers of the tests and a signature and title of the person responsible for testing.



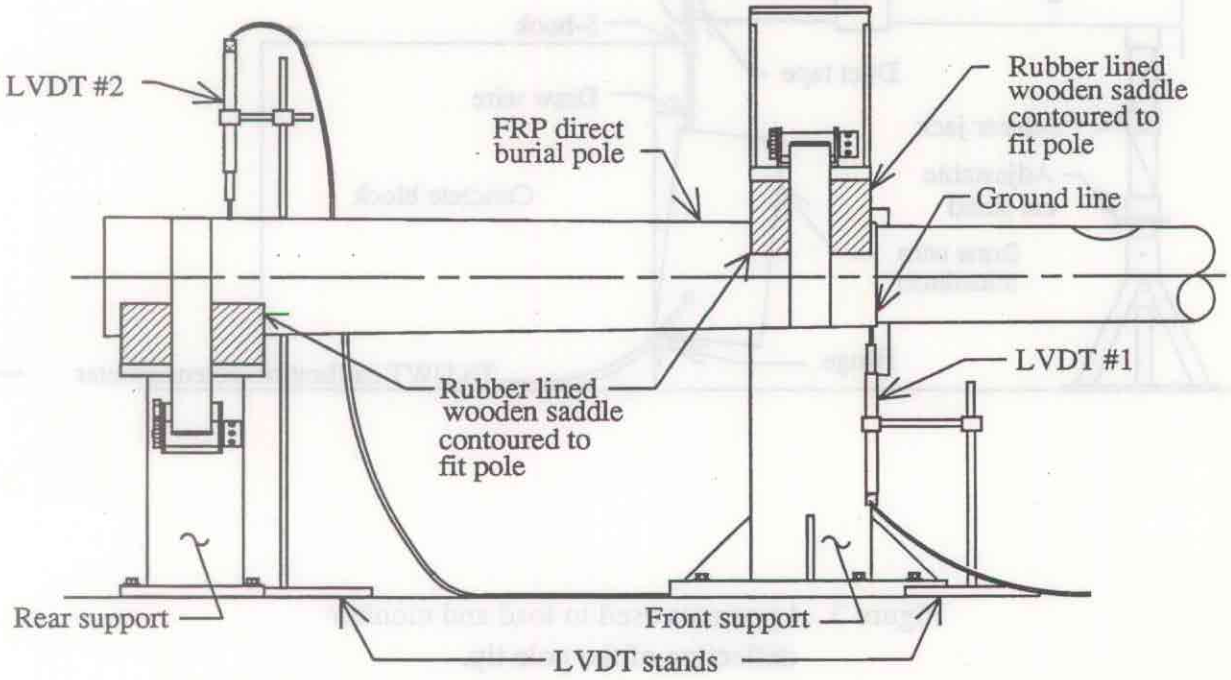
Front support: used for 1) supporting anchor base poles and 2) used with wooden saddle to support direct burial poles at ground line.

Rear support: used with wooden saddle to support lower end of direct burial poles.

Figure 1. Caltrans fixtures for supporting FRP poles to be loaded in bending.



A. LVDT PLACEMENT FOR TESTING OF ANCHOR BASE FRP POLES



B. LVDT PLACEMENT FOR TESTING OF DIRECT BURIAL FRP POLES

Figure 2. Placement of linear variable differential transformers (LVDTs)

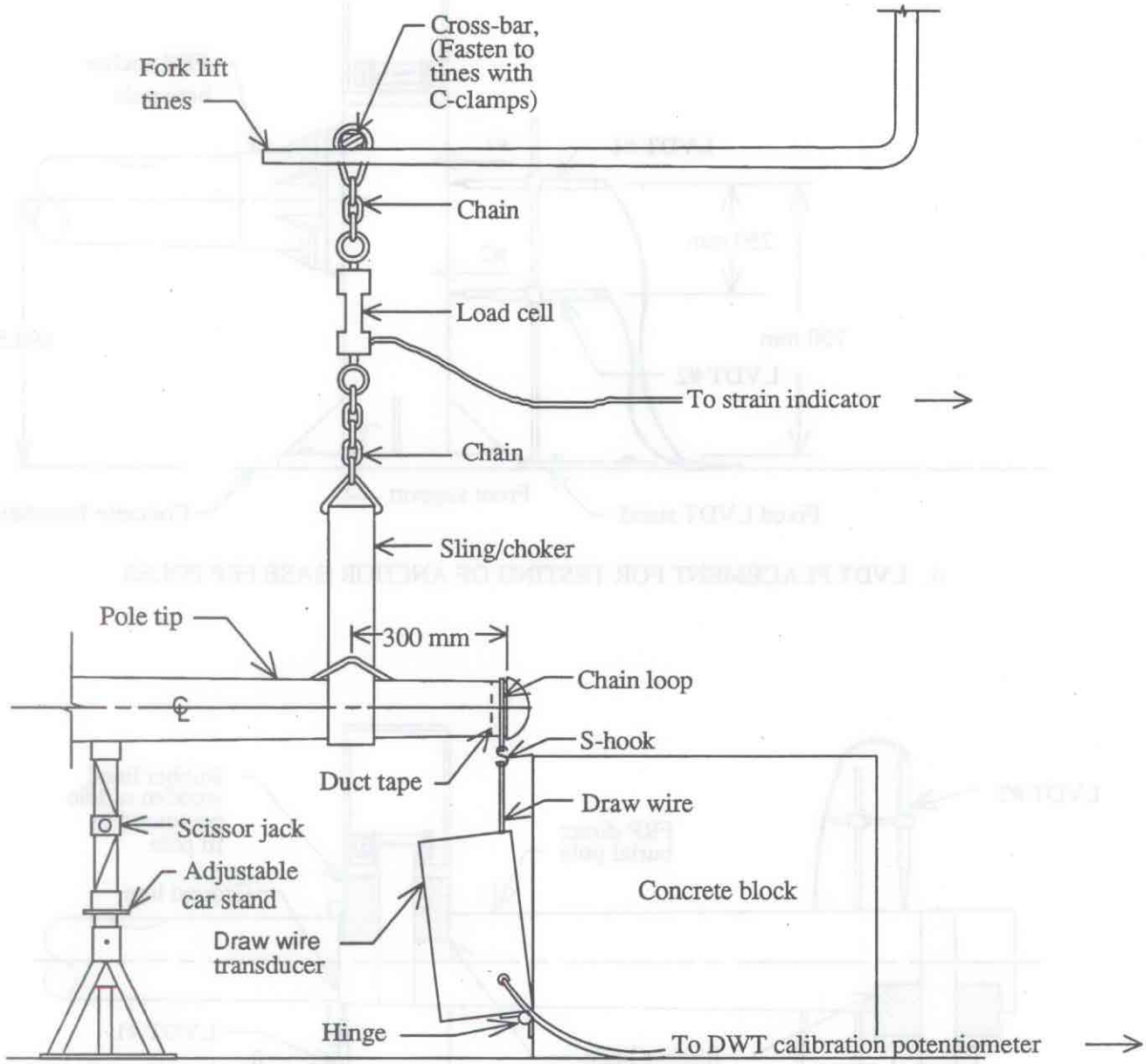
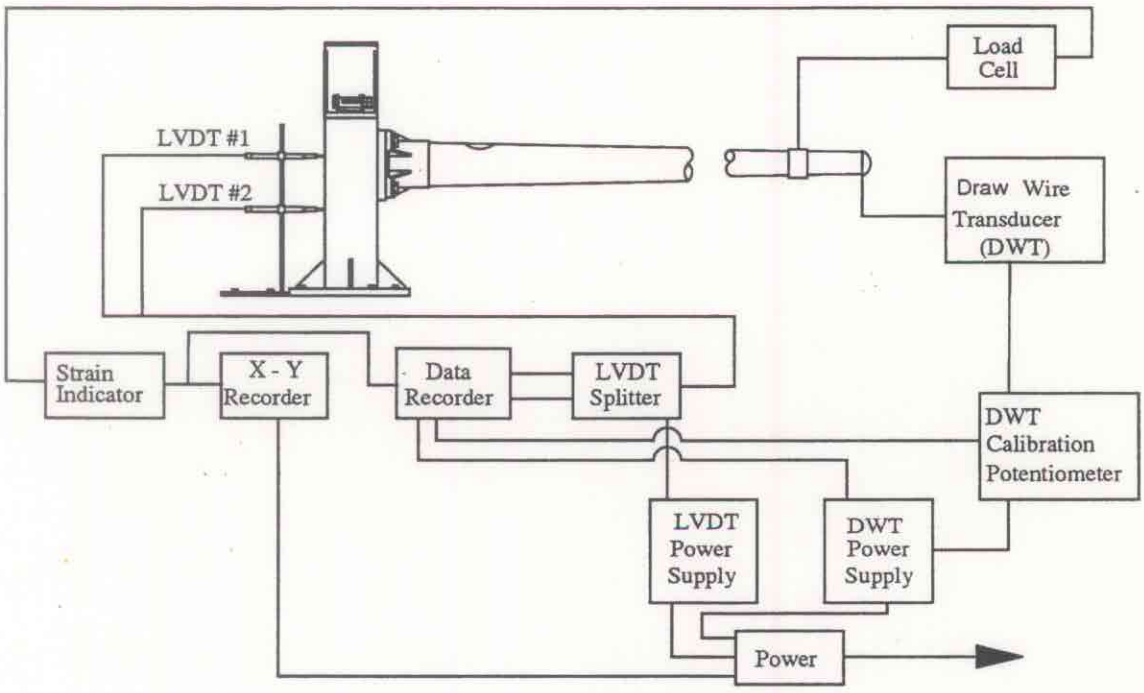


Figure 3. Apparatus used to load and monitor deflection of the pole tip.



Note: LVDT = linear variable differential transformer

Figure 4. Schematic of data aquisition equipment

Figure 5. Deflection and bending strength test of anchor base FRP pole in progress.

Figure 6. Deflection and bending strength test of direct burial FRP pole in progress.

APPENDIX D

Excerpt From ASTM Designation: D 4923 - 92, Standard Specifications for Reinforced Thermosetting Plastic Poles, Section 14.1, Bending Test.

ative Highway Research Program Report 230 are appropriate for acceptance testing of breakaway supports or for a direct-embedded, reinforced thermosetting plastic pole without a support.[11] However, the 60-mph (97-km/h) off-center impact recommended in Report 230 may be more stringent than can easily be met under the current state-of-the-art. Inasmuch as the AASHTO specification is lenient on test procedures and, over the 1975 specification, the specification calls for a 20 % reduction in the mass of the test vehicle and a 4.7 % reduction in allowable vehicle change in velocity, acceptable performance under the high-speed, off-center impact may be considered a goal and acceptance may be based on a centerline, high-speed test.

13.2.4 An approved Federal Highway Administration laboratory test using a pendulum or bogie may be substituted for the more expensive full-scale test.

14. Test Methods

14.1 *Bending Test*—Static-bending test of poles by the cantilever method.

14.1.1 Figure 3 depicts a typical apparatus for conducting the static-bending test. Principal features of the apparatus are noted. Figure 4 shows a device for measuring pole deflection during the test.

14.1.2 The test pole shall be held securely in a horizontal position to prevent movement at the butt and ground-line supports.

14.1.3 The load line shall be secured around the pole at the load application point 12 in. (30.48 cm) from the top of the pole.

14.1.4 The lifting point on the hoist shall be located perpendicular to the axis of the pole at the load point on the pole. The hoist line must remain perpendicular (±5°) to the original axis of the pole throughout the test.

14.1.5 A load-measuring device (dynamometer, load cell or scale), with a full scale no greater than five times the expected measurement value shall be attached in series with the hoist line. The measuring device shall be accurate to 1.0 % of the full-scale value.

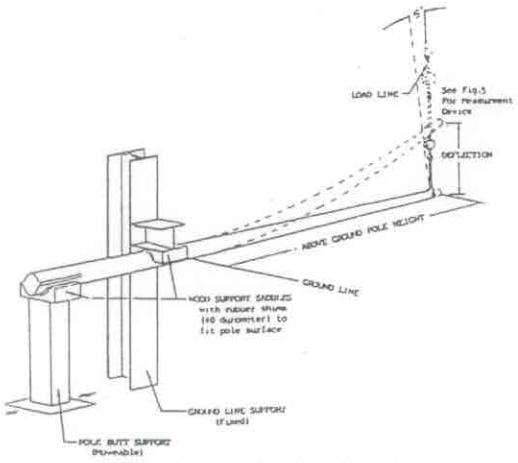


FIG. 3 Typical Bending Test Apparatus

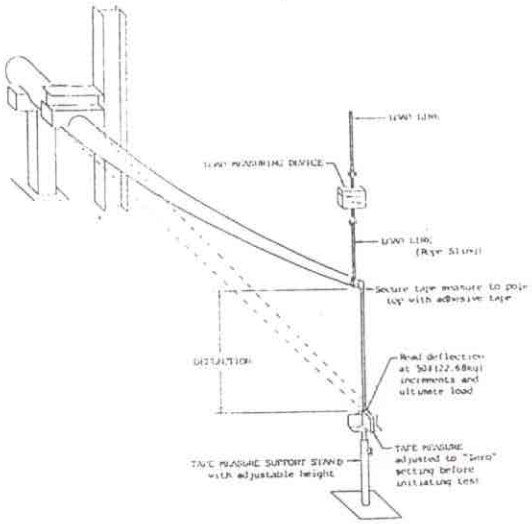


FIG. 4 Typical Pole Deflection Device

14.1.6 Pole deflection shall be measured to the nearest 0.5 in. (1.27 cm), using the unloaded pole-top position as base. Measurements shall be made perpendicular (±5°) to the unloaded pole axis. Figure 4 depicts a typical deflection-measurement device that allows deflection readings to be made a safe distance from the loaded pole during test.

14.1.7 *Test Procedure:*

14.1.7.1 Full in preparatory information on the Test Data Sheet (Fig. 5).

14.1.7.2 After marking designed ground-line location on pole, place pole in saddles with ground-line properly located (see Fig. 3). Rotate pole so that hand hole, with cover in place (if so equipped), is on the maximum compression surface, or, in the case of poles equipped with two opposed arms, oriented with maximum compression surface as it would be in actual service. Adjust supports and shims so that the longitudinal midpoint is level and saddles the contact surface of the pole through at least 120°.

14.1.7.3 Secure load line as described in 14.1.3.

14.1.7.4 Adjust hoist position so load line is vertical (±5°).

NOTE 7—If the hoist is positioned so that the 5° tolerance is toward the butt end of the pole, minimum adjustment to the hoist location will be required during the test. The load line must remain vertical (±5°) throughout the test.

14.1.7.5 Zero the deflection measuring device or take an initial reading that will be subtracted from subsequent measurements.

14.1.7.6 Tare load-indicating device or take an initial reading that will be subtracted from subsequent data.

14.1.7.7 Apply the load at a substantially uniform rate (N inches per minute) between increments until pole fails, or until a predetermined load is reached. Take deflection readings at load increments shown on the test data sheet and

Date_____ Recorder_____ Pole Test No._____

Location_____

Weather Conditions _____ Temp _____ C

Circumferences: Tip _____ Butt _____ GL _____

Weight _____ Length _____ Wall Thickness at Break _____

Butt to GL _____ GL to Load _____ Helix _____

Manufacturer _____ Model No. _____ Material _____

Holes (location and size) _____

Comments _____

Dynamometer Reading (Pounds f)	Tip Datum to Load Point Deflection (Feet and Inches)	Load Point Deflection (Inches)	Ground Line Deflection	Remarks
0				
50				
100				
150				
200				
250				
300				
350				
400				
450				
500				
550				
600				
650				
700				
750				
Note				

NOTE—Continue in 50 lbf increments until either failure occurs or a maximum desired load is reached.

Final Deflection_____ Breaking Point_____
For Metric Conversion (or Max Load)
ft—m pounds—newtons
Inches—mm

FIG. 5 Pole Deflection Test Data Sheet

at failure or at a predetermined load.

14.2 *Torsional Test Procedure for Poles with Arm-Mounted Luminaires:*

14.2.1 This test is established to determine the torsional capabilities of a given pole/arm combination and of the attachment of the arm to the pole.

14.2.2 Mount the pole and arm in a horizontal position with the butt end secured against rotation and the tips of the pole and arm support similar to Figs. 6 and 7.

14.2.3 Locate the load attachment point, etc., at the centroid of the combined projected areas of the arm and the luminaire for which the pole is designed, or for which the pole will be used. See Appendix X5 for computation method for centroid location.

14.2.4 The direction of the test load must remain vertical ±5° throughout the test.

14.2.5 Attach a load-measuring device, as described in 14.1.5, in series with the load-application device.

14.2.6 Take a total of three deflection measurements at each load increment:

14.2.6.1 Vertical pole tip deflection.

14.2.6.2 Horizontal pole tip deflection.

14.2.6.3 Vertical arm tip deflection.

14.2.6.4 Record the vertical pole tip deflection for use in Section 8 of this specification.

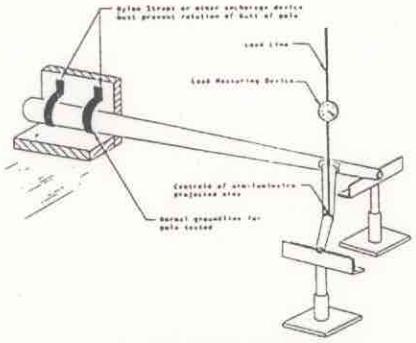


FIG. 6 Direct-Burial Torsional Test Setup

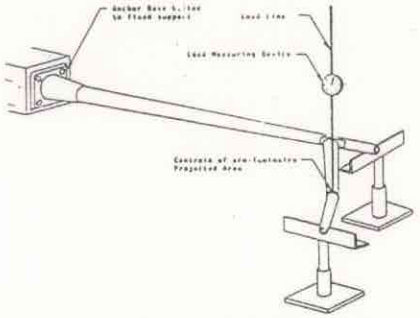


FIG. 7 Anchor-Base Torsional Test Setup

14.2.7 To remove the preload due to gravity, apply load until the arm tip just clears its support. At this time, either tare the load-measuring device, or record this load for subtraction from subsequent readings.

14.2.8 Apply load in predetermined increments until the structure fails, or until a predetermined load is reached (such as from wind-load analysis). At each load increment, record the deflection specified in 14.2.6.

14.2.9 Calculate the total torsional moment applied in this test.

14.2.10 *Data Sheet*—Keep a data sheet similar to that shown in Fig. 5 for each pole tested. Record the following data, along with any other data deemed useful by the supplier or the purchaser:

14.2.10.1 Date,

14.2.10.2 Person who performed the test,

14.2.10.3 Location,

14.2.10.4 Weather conditions,

14.2.10.5 Ambient temperature,

14.2.10.6 Pole weight,

14.2.10.7 Pole length,

14.2.10.8 Pole-mounting height,

14.2.10.9 Arm location with respect to pole tip,

14.2.10.10 Arm length/arm rise,

14.2.10.11 Location of load point,

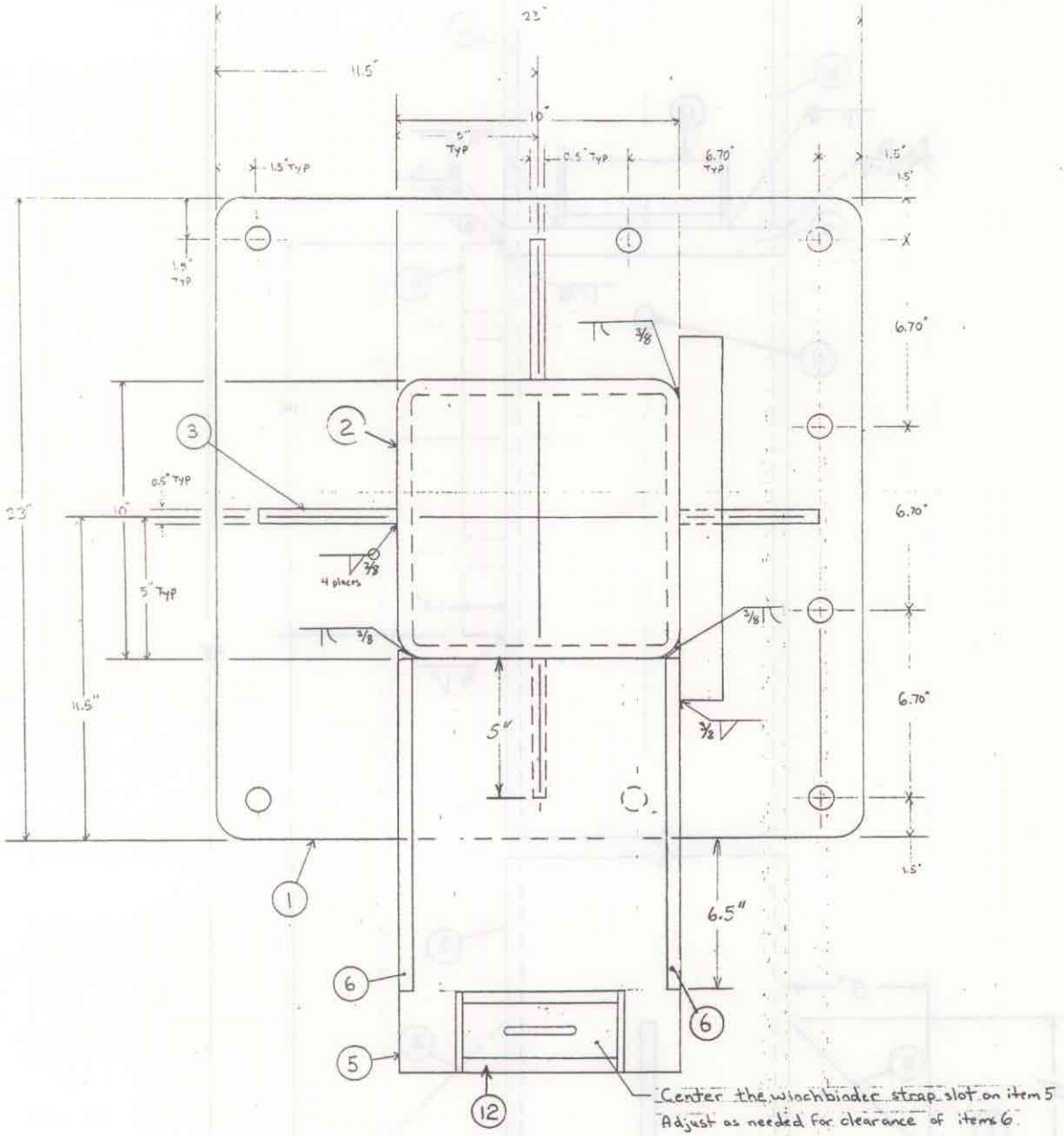
APPENDIX E Test Fixture Drawings and Specifications

MATERIALS LIST FOR FRP GROUNDLINE SUPPORT FIXTURE

ITEM	QUANTITY	DESCRIPTION	QUALITY
1	1	23" x 23" x 1.5" thick steel plate	ASTM A-36
2	1	10" x 10" x 0.5" wall x 48" long structural steel tubing	ASTM A-500
3	4	5" x 5" x 0.5" thick steel plate	ASTM A-36
4	1	13" x 14" x 1.5" thick steel plate	ASTM A-36
5	1	10" x 15" x 1" thick steel plate	ASTM A-36
6	2	12" x 12" x 0,5" thick steel plate	ASTM A-36
7	1	10" x 10" x 0.5" thick steel plate	ASTM A-36
11	1	0.75" diameter x 2" long round stock	
12	1	weld-on winch binder with 4" wide nylon web strap	

NOTES:

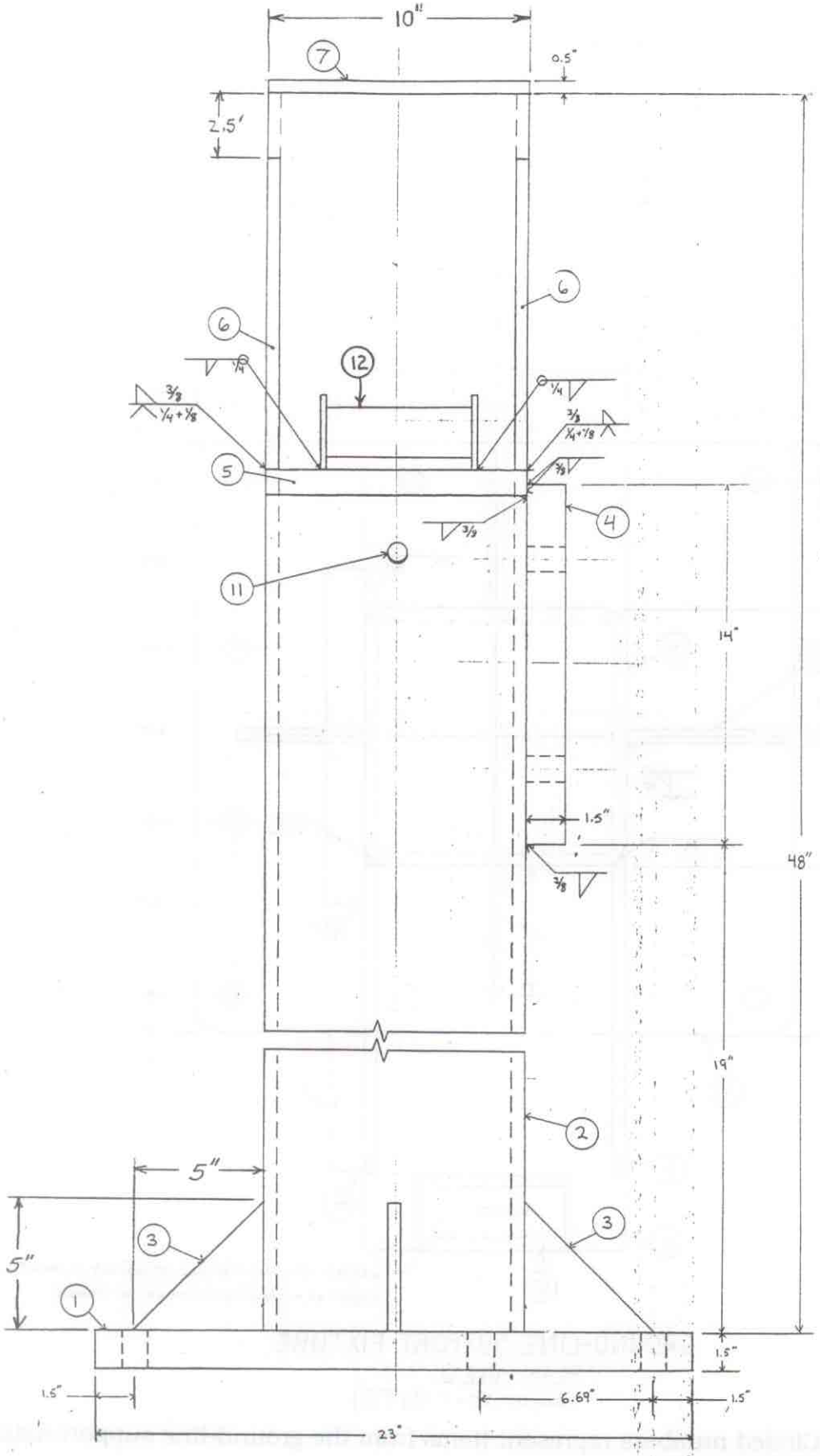
1. All welds shall be made with E7018 welding rod.
2. Grind and de-burr all sharp edges and corners.
3. Clean excess rust and scale prior to painting.
4. Bevel vertical edge of item 6 to mate with radiused corner of item 2.
5. Weld item 4 to item 2 before drilling and taping for 1"-8 UNC threads.
6. Item 2 shall be perpendicular to item 1 within 0.5° in both vertical planes.
7. Item 5 shall be perpendicular to item 2 within 0.5°.
8. Angle item 11 slightly upward for strap retention.
9. Center item 12's web strap slot as close as possible on the 10" dimension of item 5 while still providing clearance between the winch binder tightening mechanisms and item(s) 6.



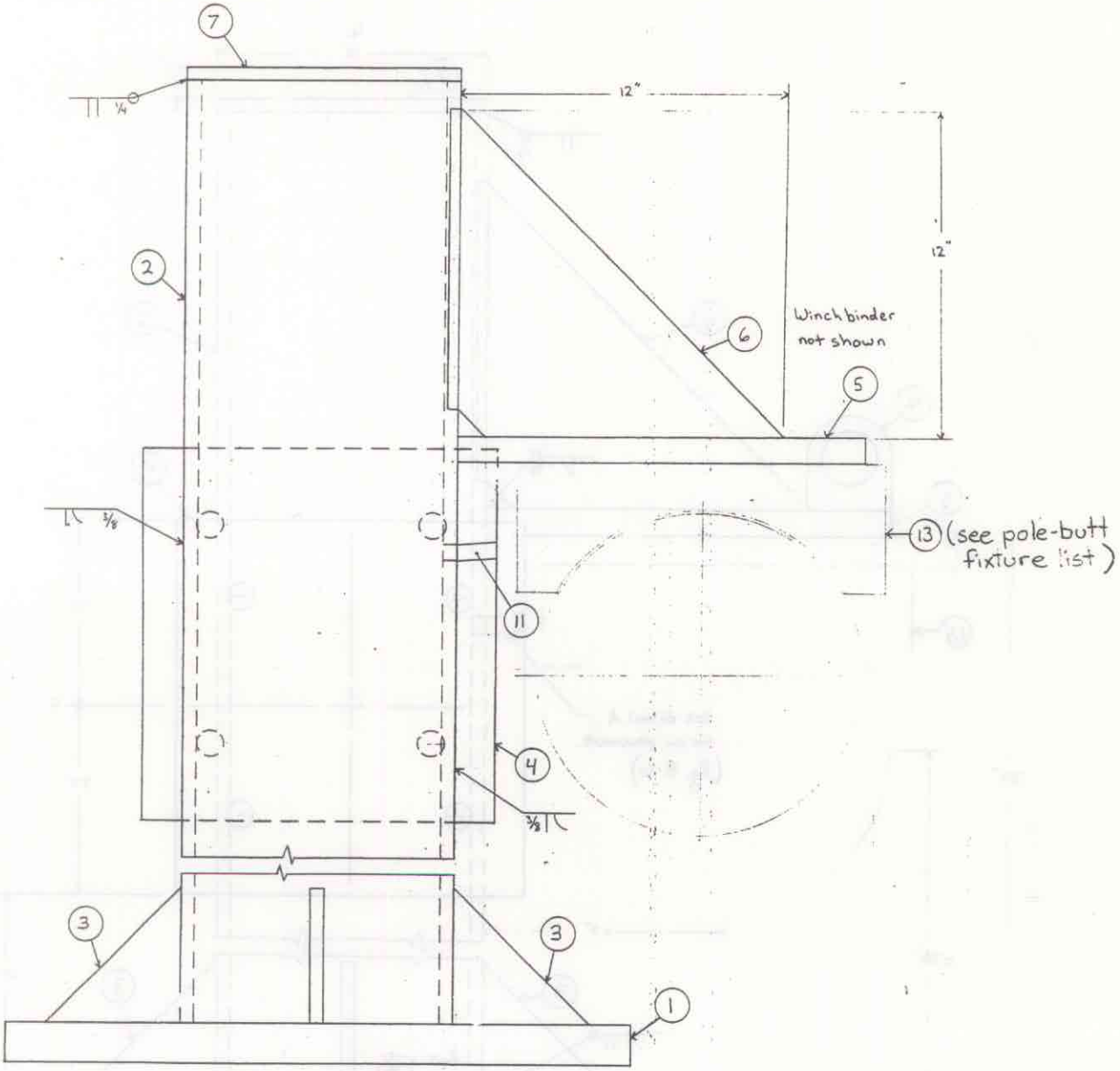
GROUND-LINE SUPPORT FIXTURE
PLAN VIEW
Scale: 1/4" = 1" (NTS)

NOTE: Circled numbers represent items from the ground-line support fixtures materials list

NOTE: Circled numbers represent items from the ground-line support fixtures materials list



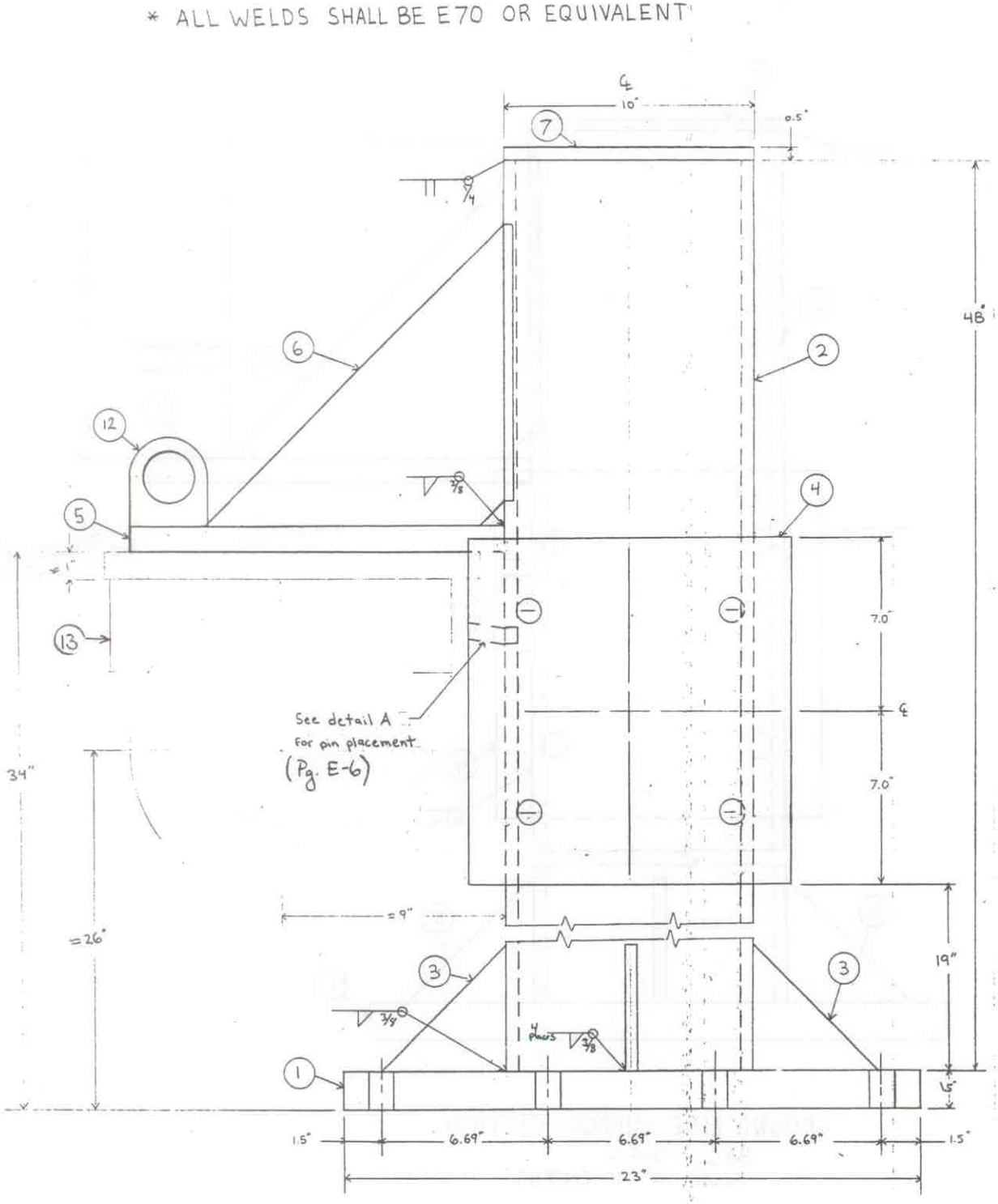
GROUND LINE SUPPORT FIXTURE



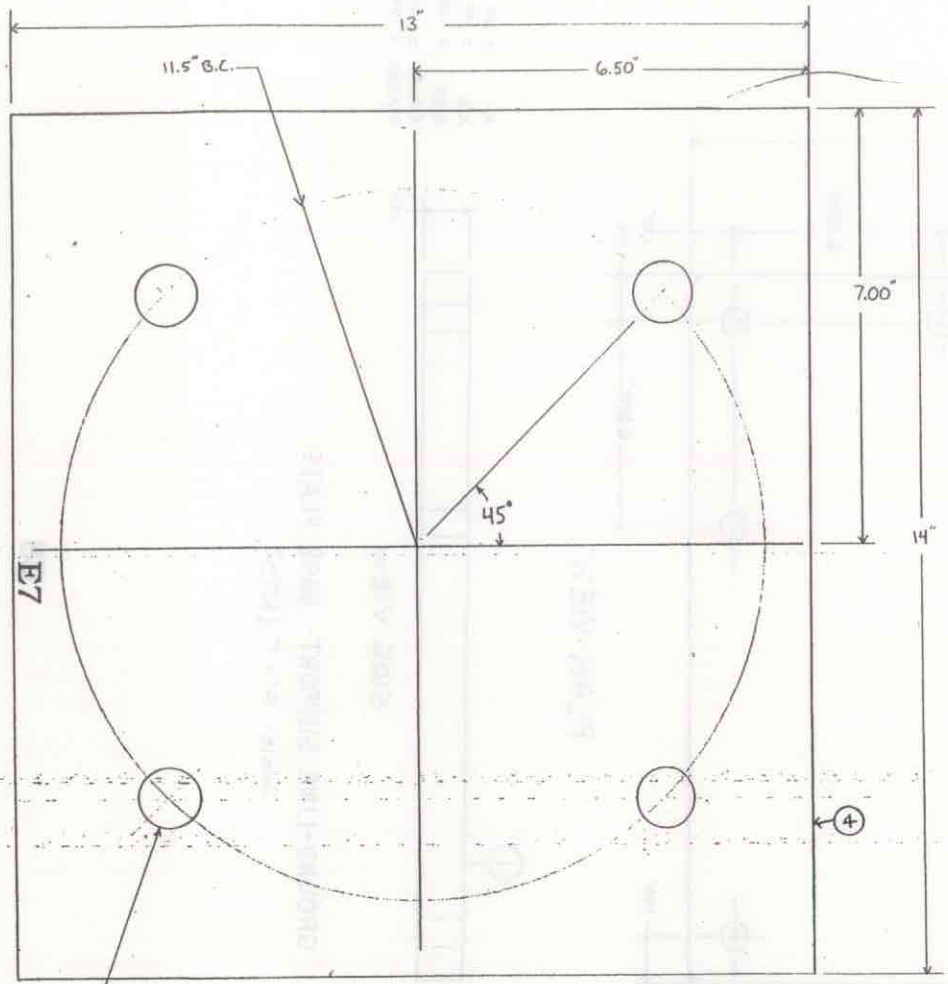
GROUND LINE SUPPORT FIXTURE
BACK VIEW
Scale: 1/4" = 1' (NTS)

NOTE: **Circled numbers represent items from the ground-line support fixtures materials list**

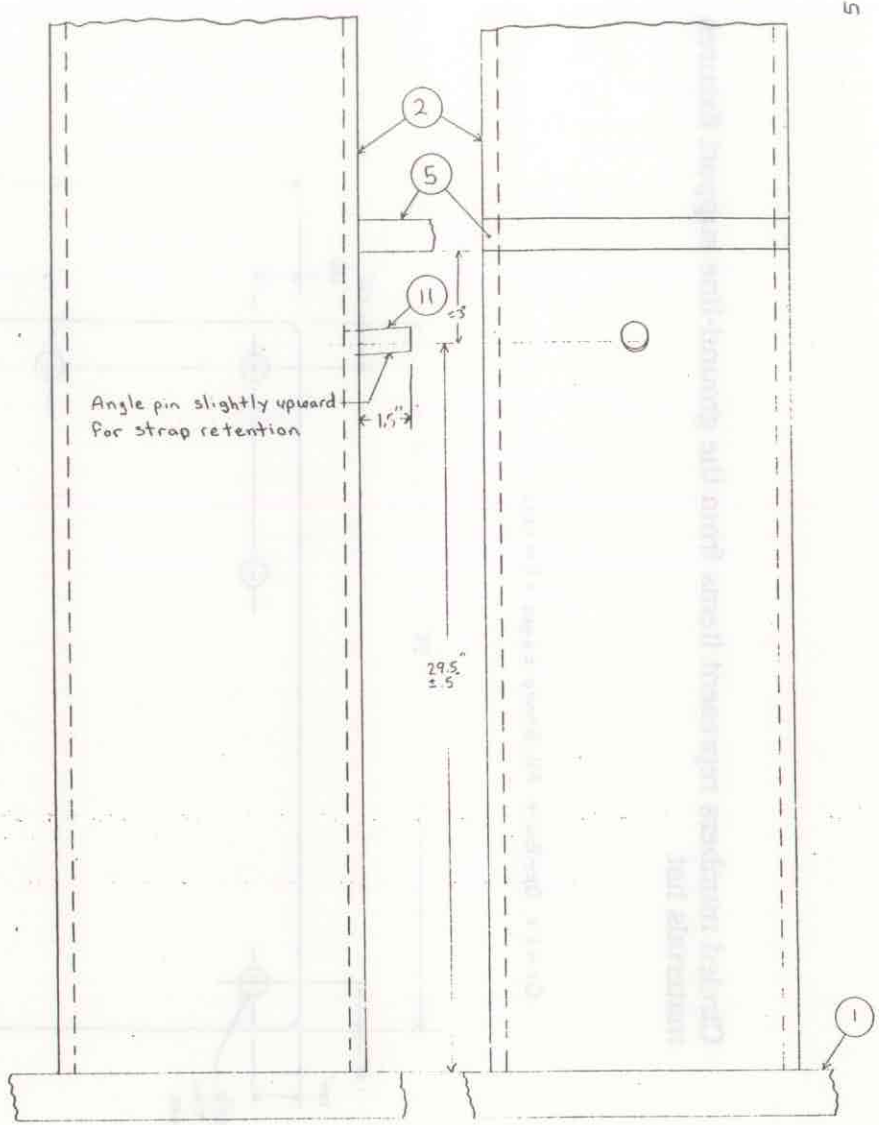
NOTE: Circled numbers represent items from the ground-line support fixtures materials list



GROUND LINE SUPPORT FIXTURE
FRONT VIEW
Scale: ¼" = 1" (NTS)



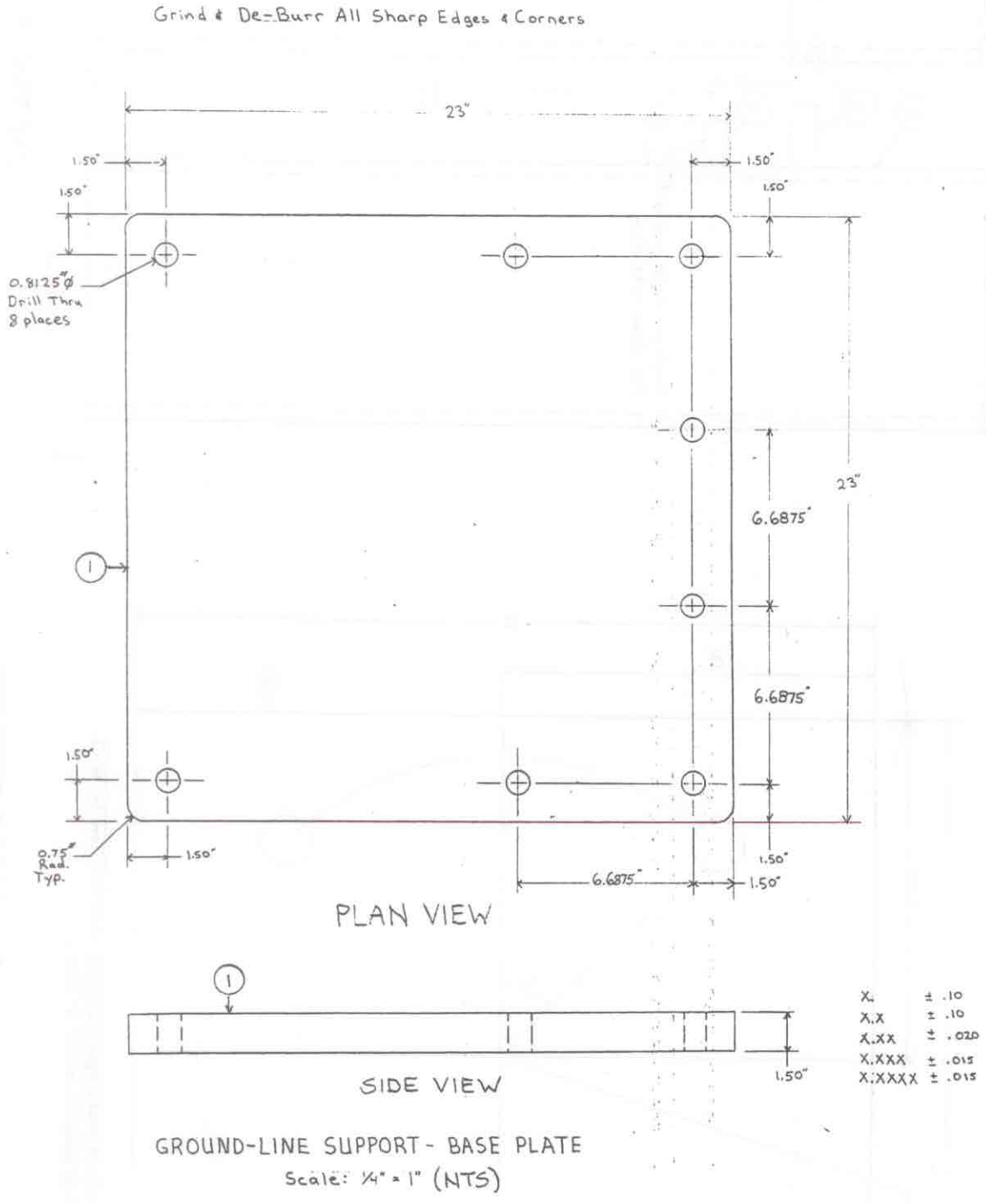
GROUND LINE SUPPORT FIXTURE
ANCHOR BASE MOUNTING PLATE
Scale 1/2" = 1" (NTS)



DETAIL A
GROUND LINE SUPPORT FIXTURE
STRAP RETENTION PIN
Scale 1/4" = 1" (NTS)

NOTE: Circled numbers represent items from the ground-line support fixtures materials list

NOTE: Circled numbers represent items from the ground-line support fixtures materials list



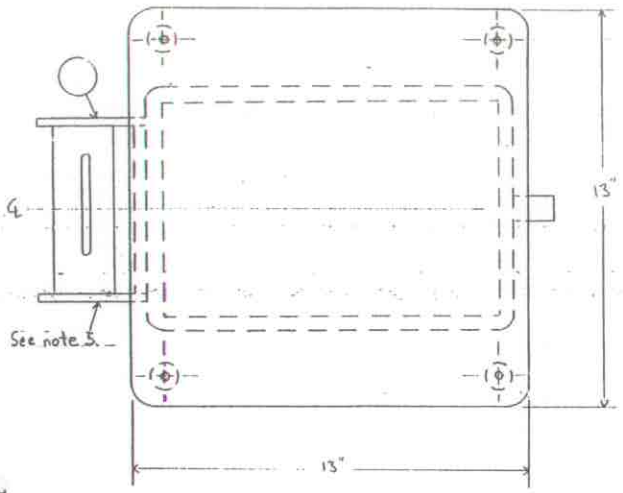
MATERIALS LIST FOR FRP POLE-BUTT SUPPORT FIXTURE

ITEM	QUANTITY	DESCRIPTION	QUALITY
8	1	13' x 13" x 1" thick steel plate	ASTM A-36
9	1	13" x 13 x 1" thick steel plate	ASTM A-36
10	1	8" x 10" x 0.5" wall x 16" long structural steel tubing	ASTM A-500
11	1	0.75" diameter x 2" long round stock	
12	1	weld-on winch binder with 4" nylon web strap	
13	2	13" x 13" x 0.25" thick (40 durometer) rubber pads	
14	2	13" x 13" x 8" contoured wooden (plywood) support saddle block	

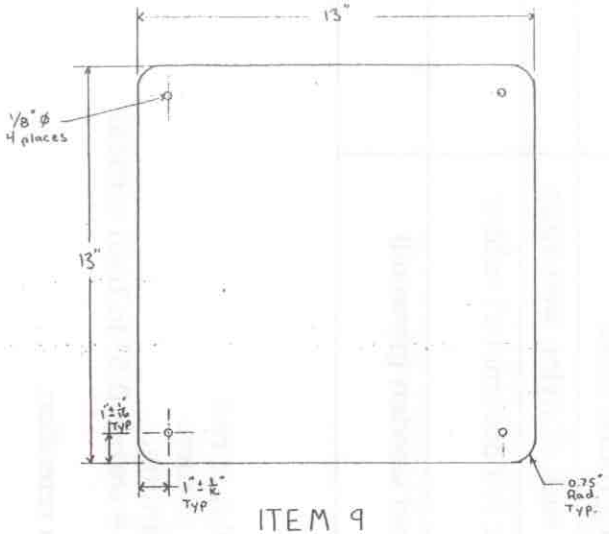
NOTES:

1. All welds shall be made with E7018 welding rod.
2. Grind and de-burr all sharp edges and corners.
3. Clean excess rust and scale prior to painting.
4. Item 10 shall be perpendicular to item 8 within 0.5° in both vertical planes.
5. Angle item 11 slightly upward for strap retention.

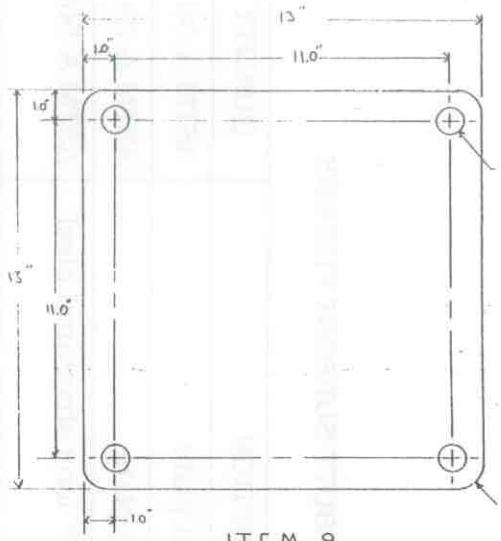
NOTE: Circled numbers represent items from the pole-butt support fixture materials list



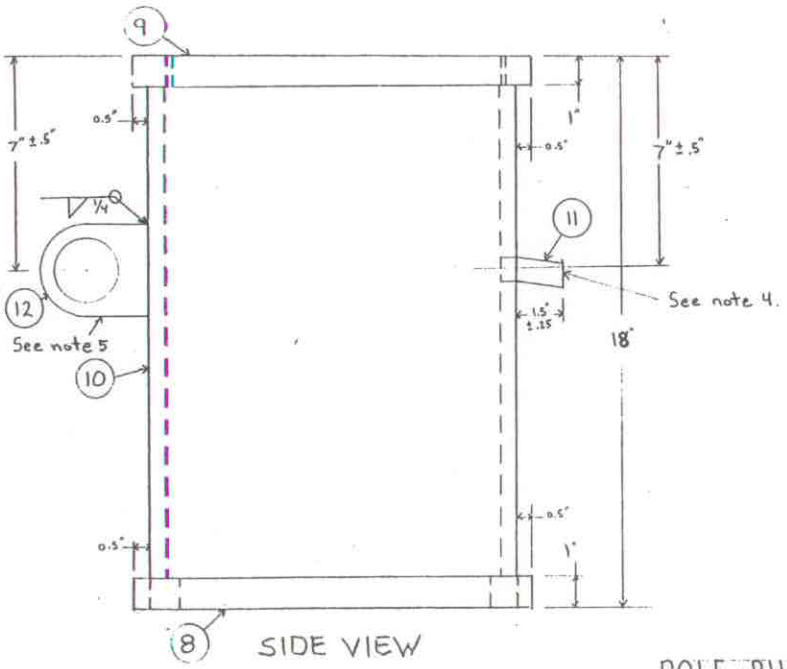
PLAN VIEW



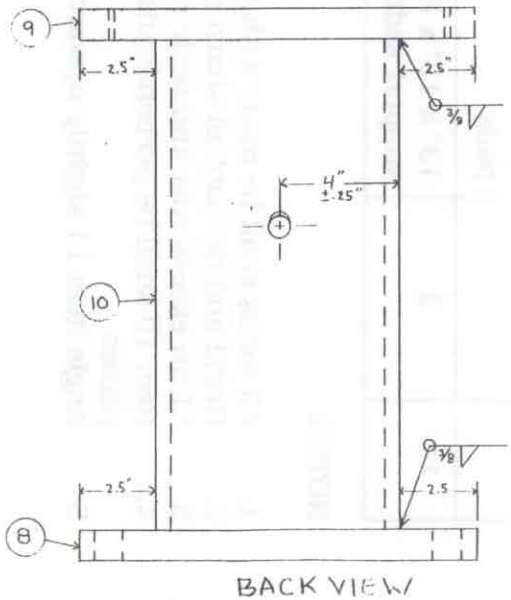
ITEM 9
TOP PLATE



ITEM 8
BOTTOM PLATE



SIDE VIEW



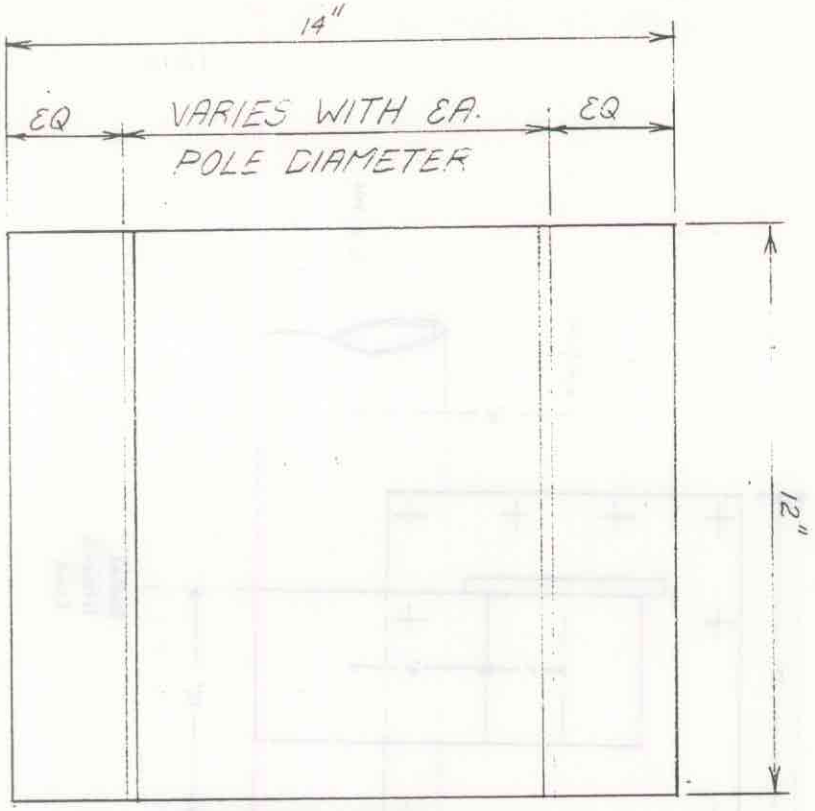
BACK VIEW

BILL OF MATERIALS		
ITEM	QTY	DESCRIPTION
8	1	13"x13"x1" Thick steel plate A-36
9	1	13"x13"x1" Thick steel plate A-36
10	1	8" x 10" x 0.500" Wall x 16" TS A-500
11	1	0.75" Dia x 2" long round stock
12	1	Weld-on winchbinder 4" strap

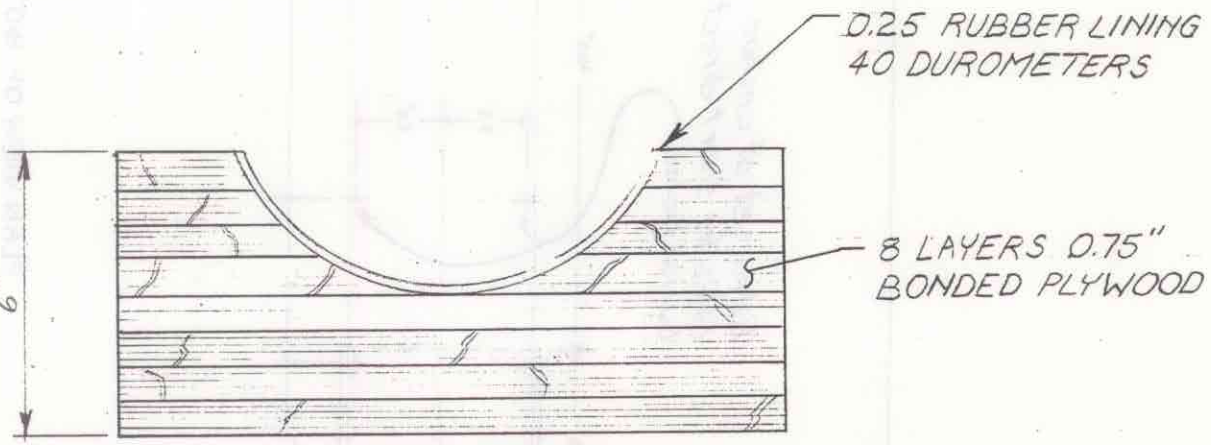
Notes:
1. All welds shall be E70 or better
2. Items 8 & 9 shall be parallel ± 0.5°
3. Grind & de-burr all sharp edges & corners
4. Angle pin slightly down for strap retention
5. Center the winchbinder strap slot on the TS 8" dimension

POLE-BUTT SUPPORT FIXTURE

E10

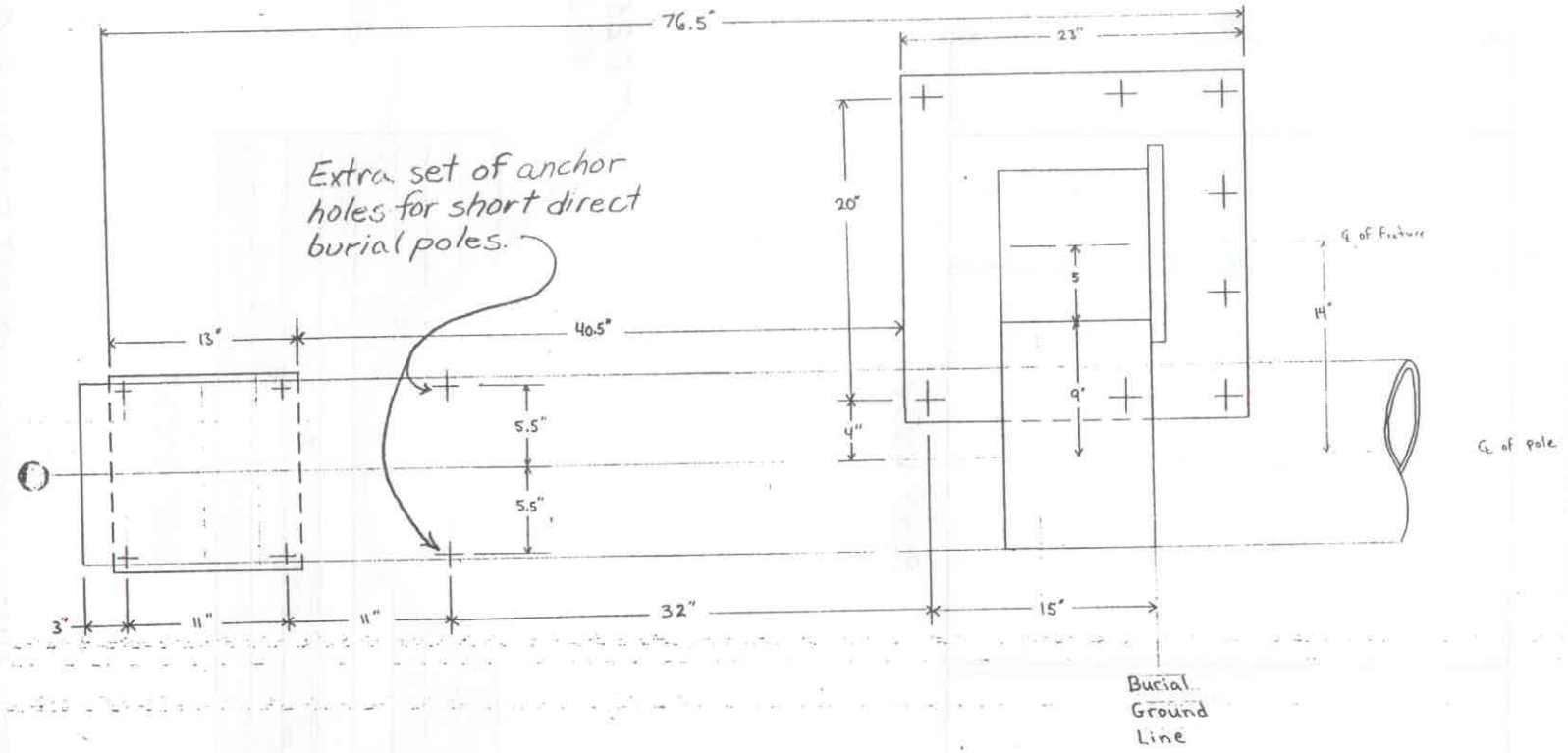


PLAN VIEW



SIDE VIEW

RUBBER LINED WOODEN SUPPORT SADDLE BLOCKS



PLAN VIEW OF BOTH FRP FIXTURES- ANCHOR LOCATIONS

Scale: 1/8" = 1" (NTS)

APPENDIX F Plots of Load Versus Deflection

Model and Test Number **Page**

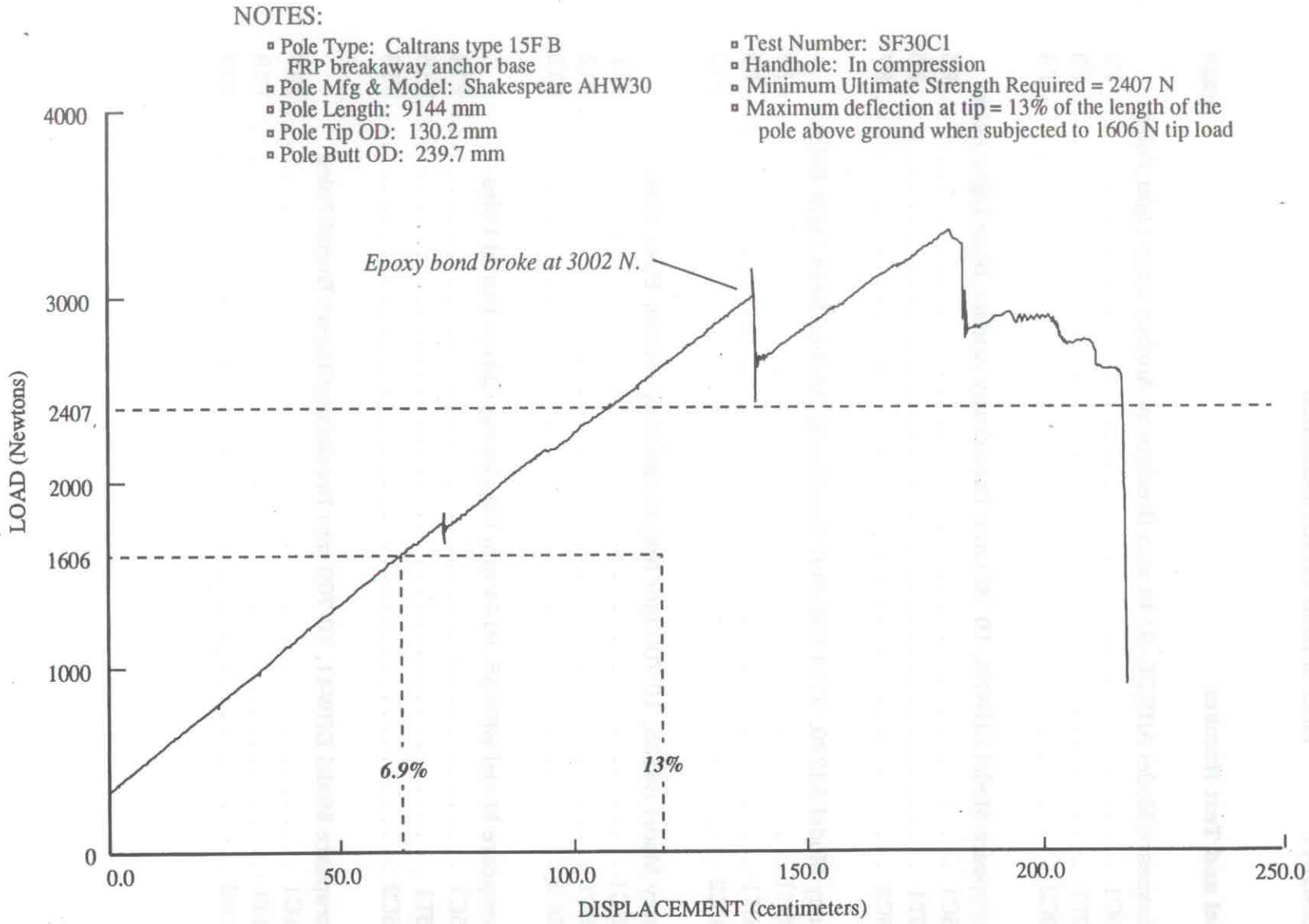


Figure F-1. Load versus displacement of Shakespeare AHW30 fiberglass lighting standards.

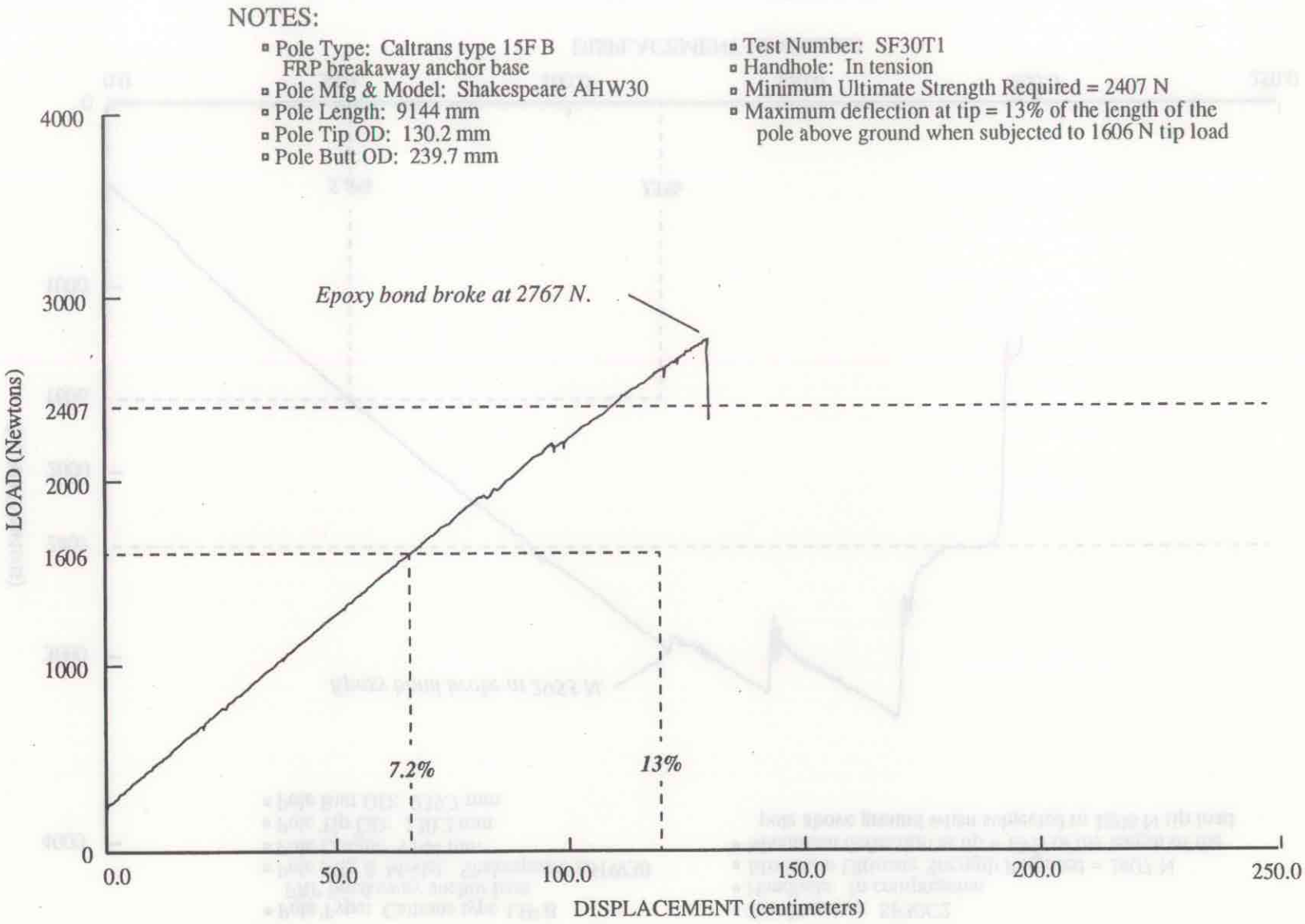


Figure F-2. Load versus displacement of Shakespeare AHW30 fiberglass lighting standards.

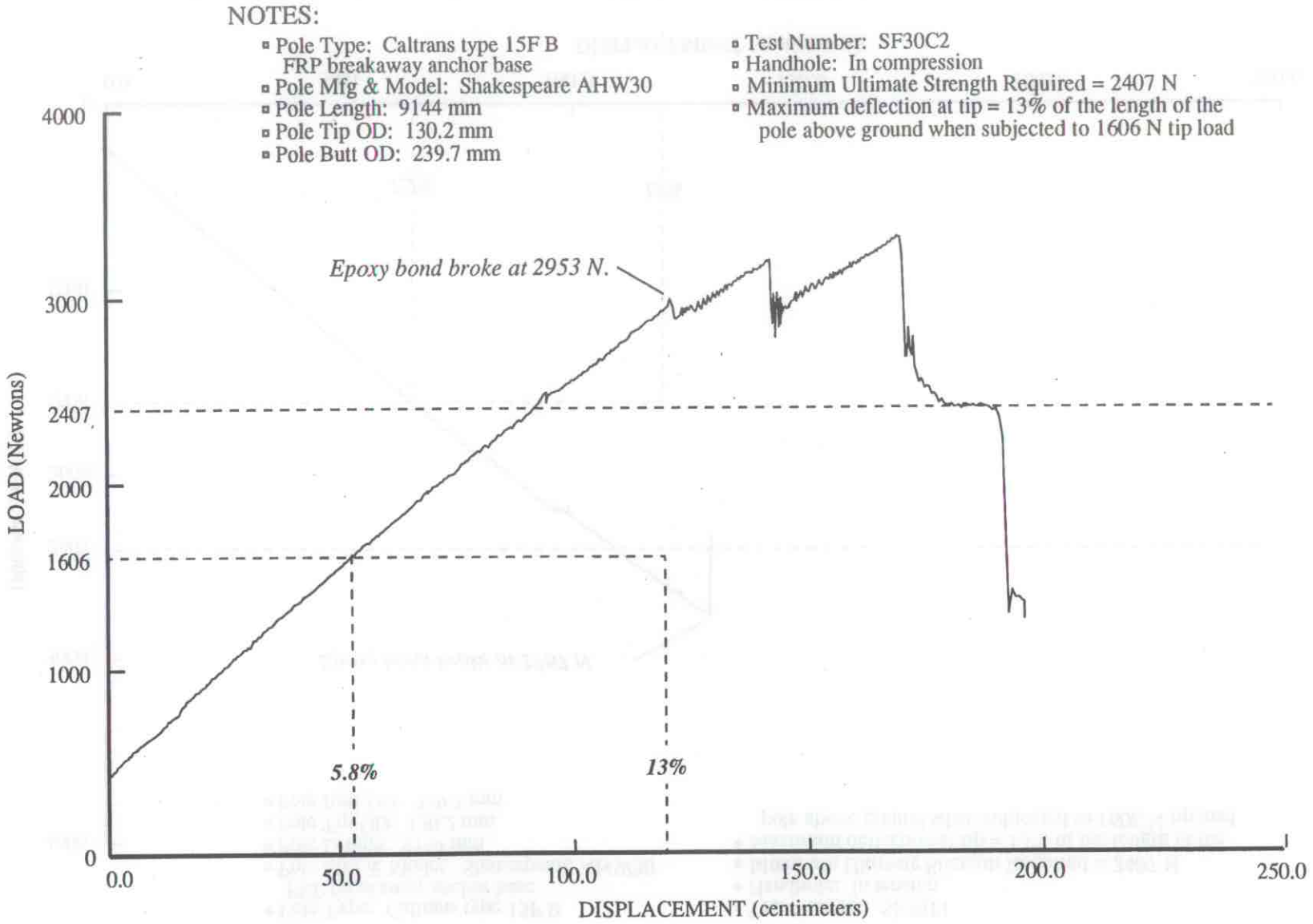


Figure F-3. Load versus displacement of Shakespeare AHW30 fiberglass lighting standards.

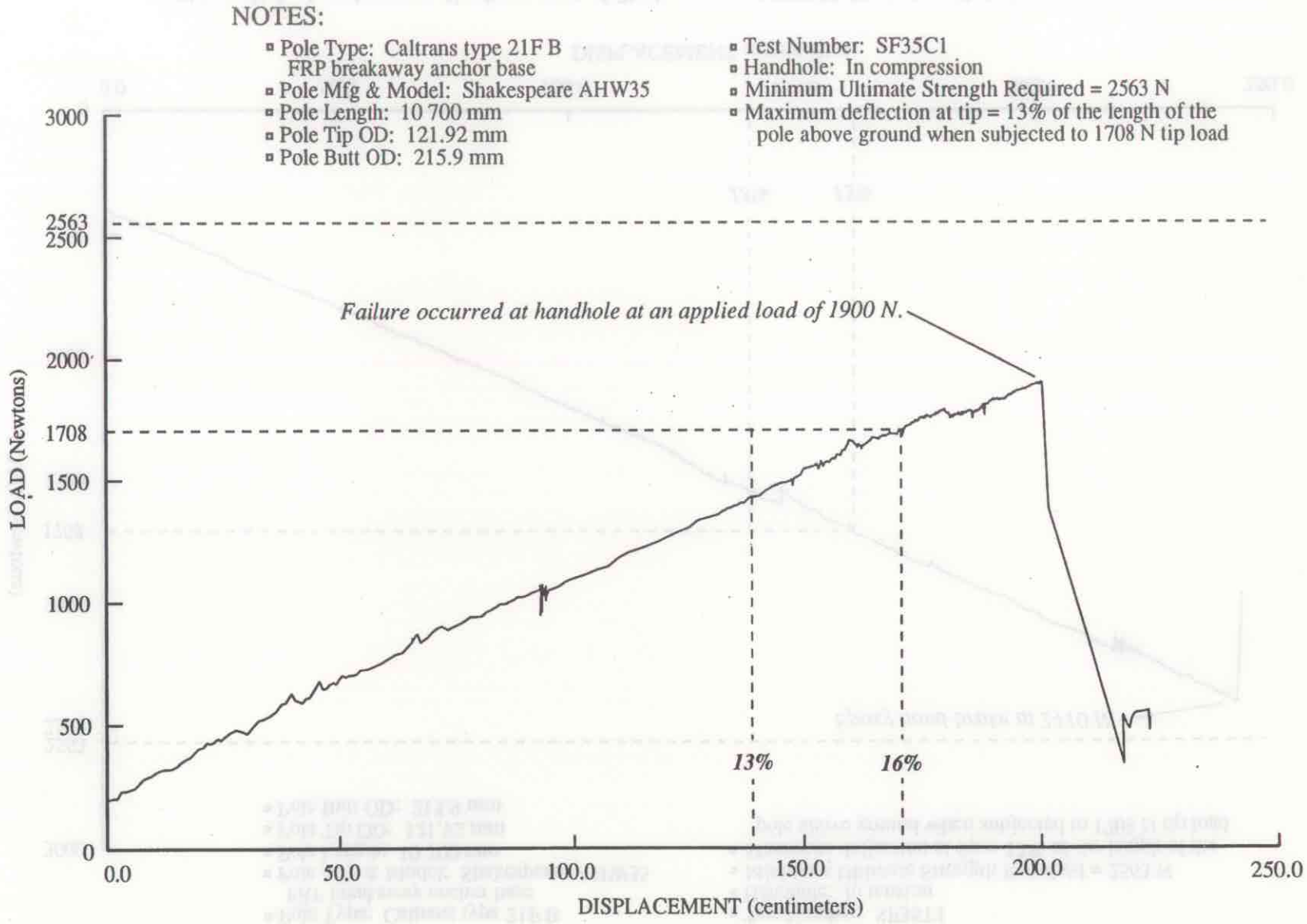


Figure F-4. Load versus displacement of Shakespeare AHW35 fiberglass lighting standards.

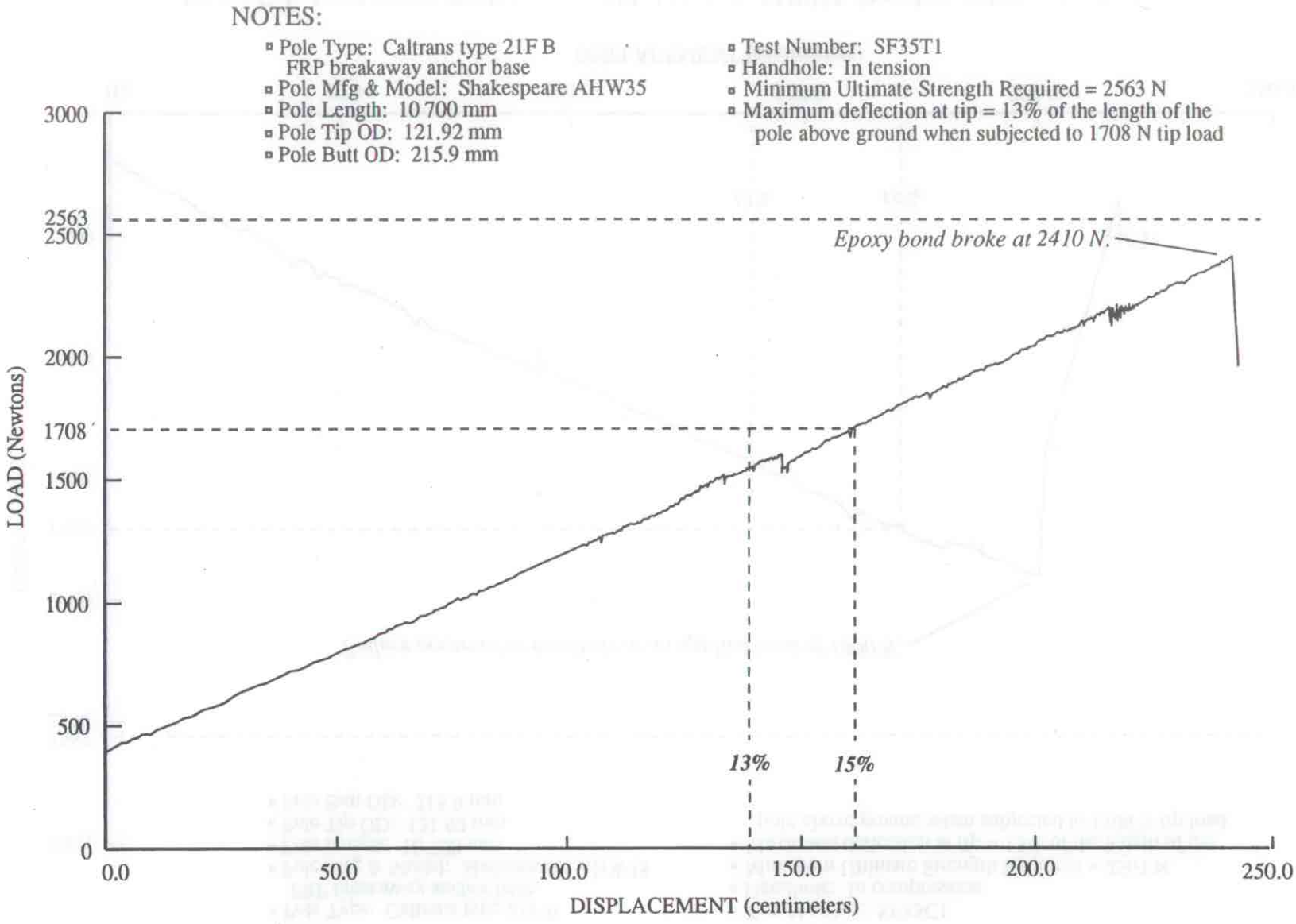


Figure F-5. Load versus displacement of Shakespeare AHW35 fiberglass lighting standards.

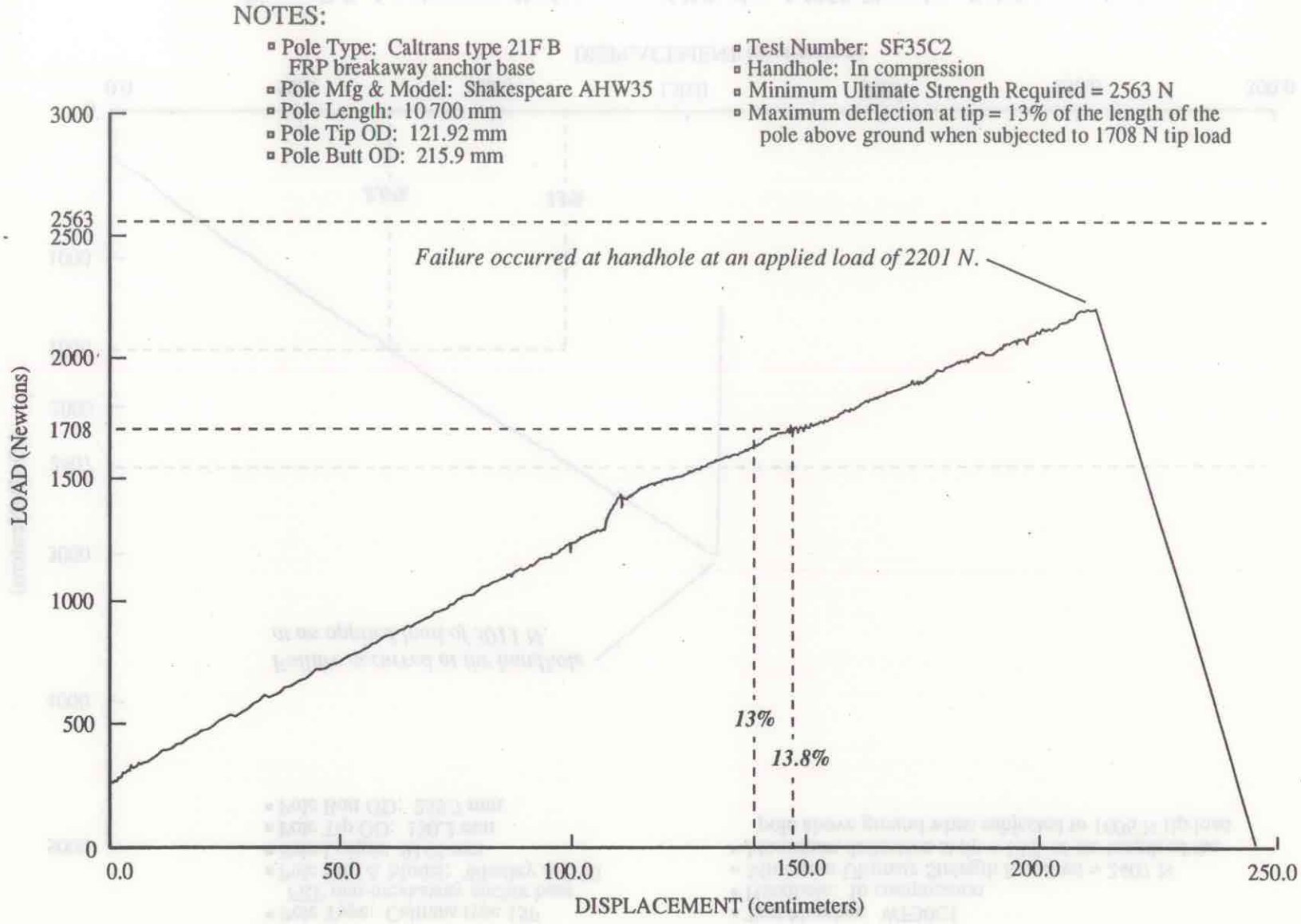


Figure F-6. Load versus displacement of Shakespeare AHW35 fiberglass lighting standards.

NOTES:

- Pole Type: Caltrans type 15F FRP non-breakaway anchor base
- Pole Mfg & Model: Whatley A4330
- Pole Length: 9144 mm
- Pole Tip OD: 130.2 mm
- Pole Butt OD: 239.7 mm
- Test Number: WF30C1
- Handhole: In compression
- Minimum Ultimate Strength Required = 2407 N
- Maximum deflection at tip = 13% of the length of the pole above ground when subjected to 1606 N tip load

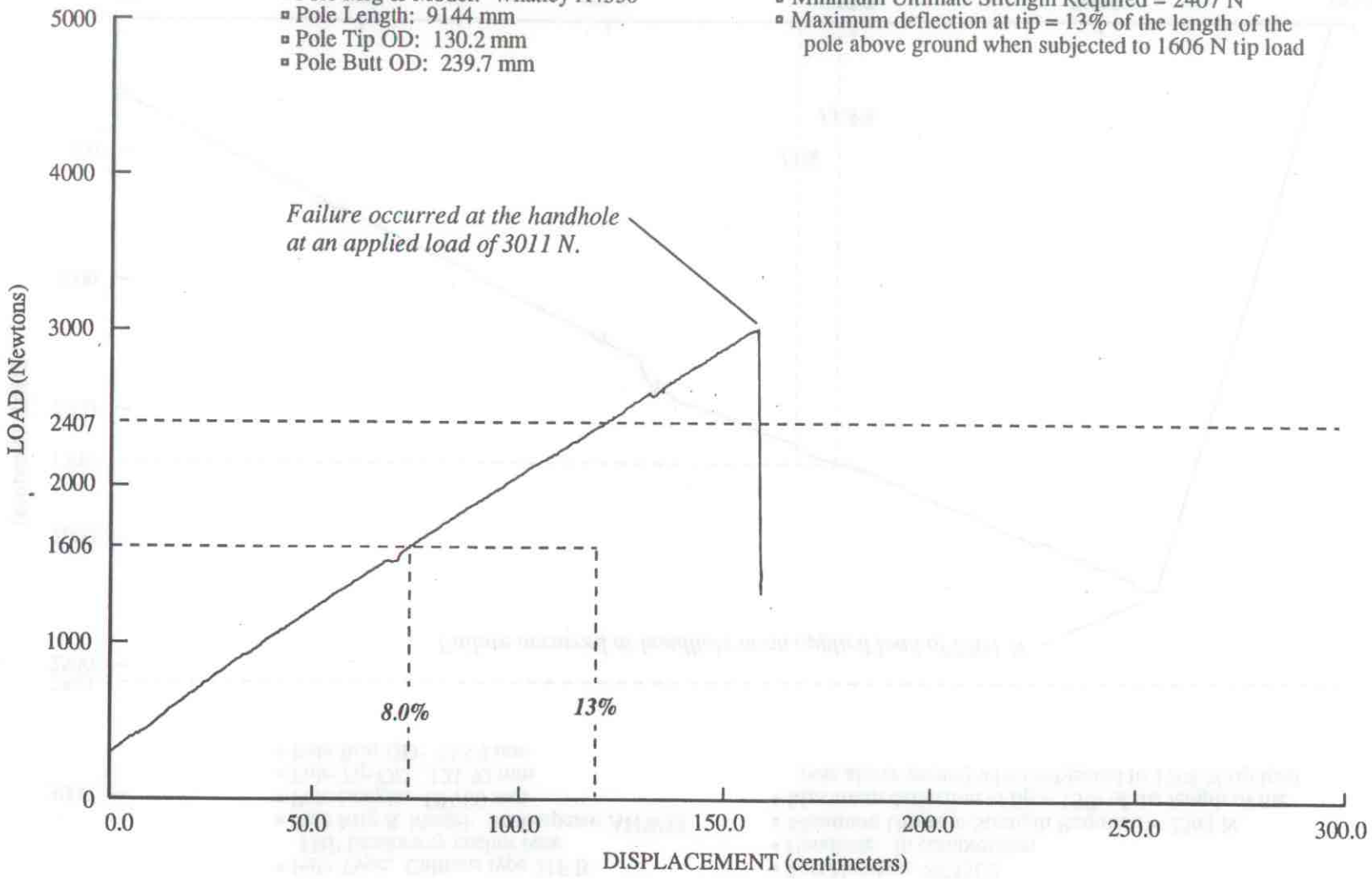


Figure F-7. Load versus displacement of Whatley A4330 fiberglass lighting standards.

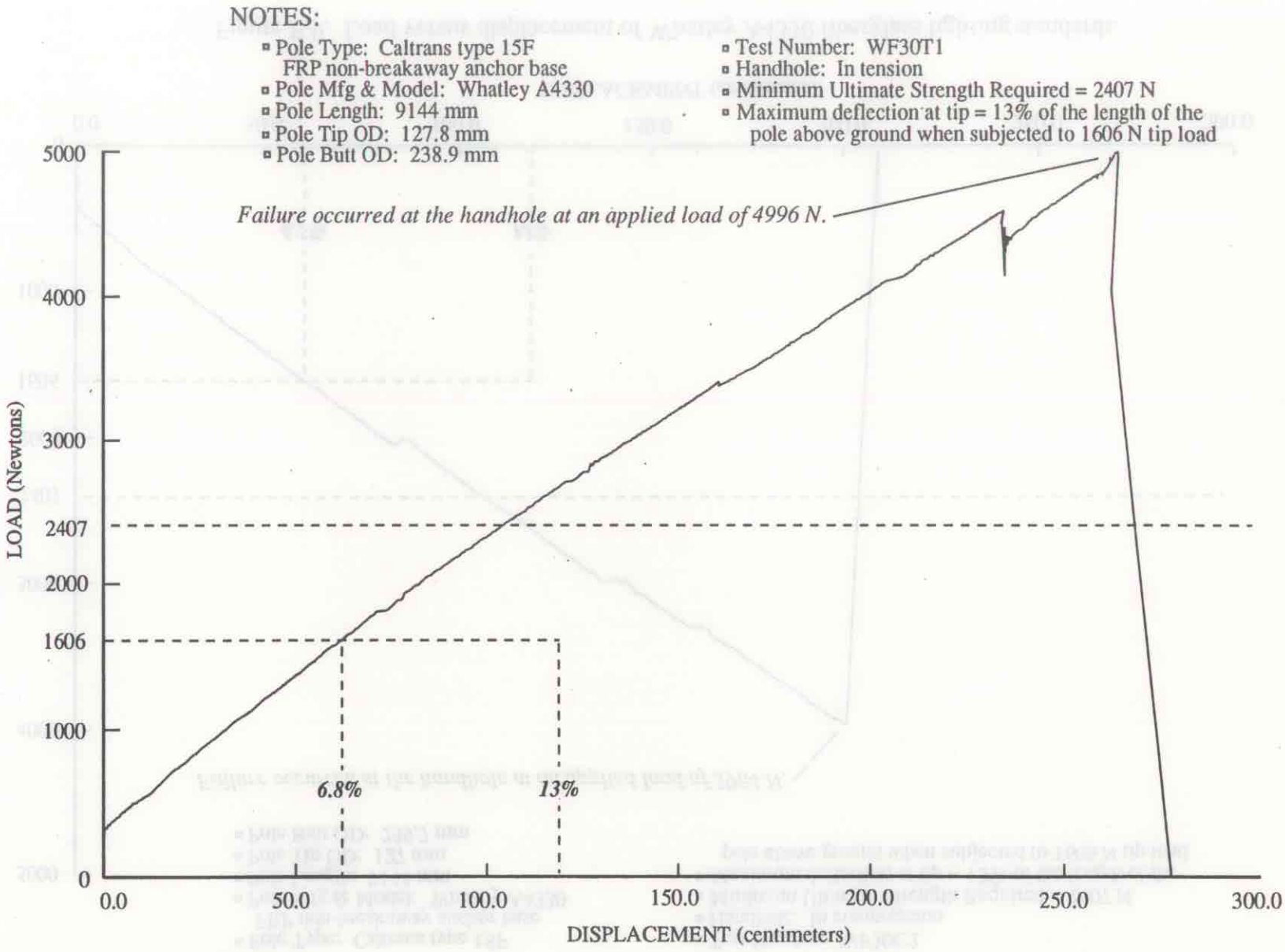


Figure F-8. Load versus displacement of Whatley A4330 fiberglass lighting standards.

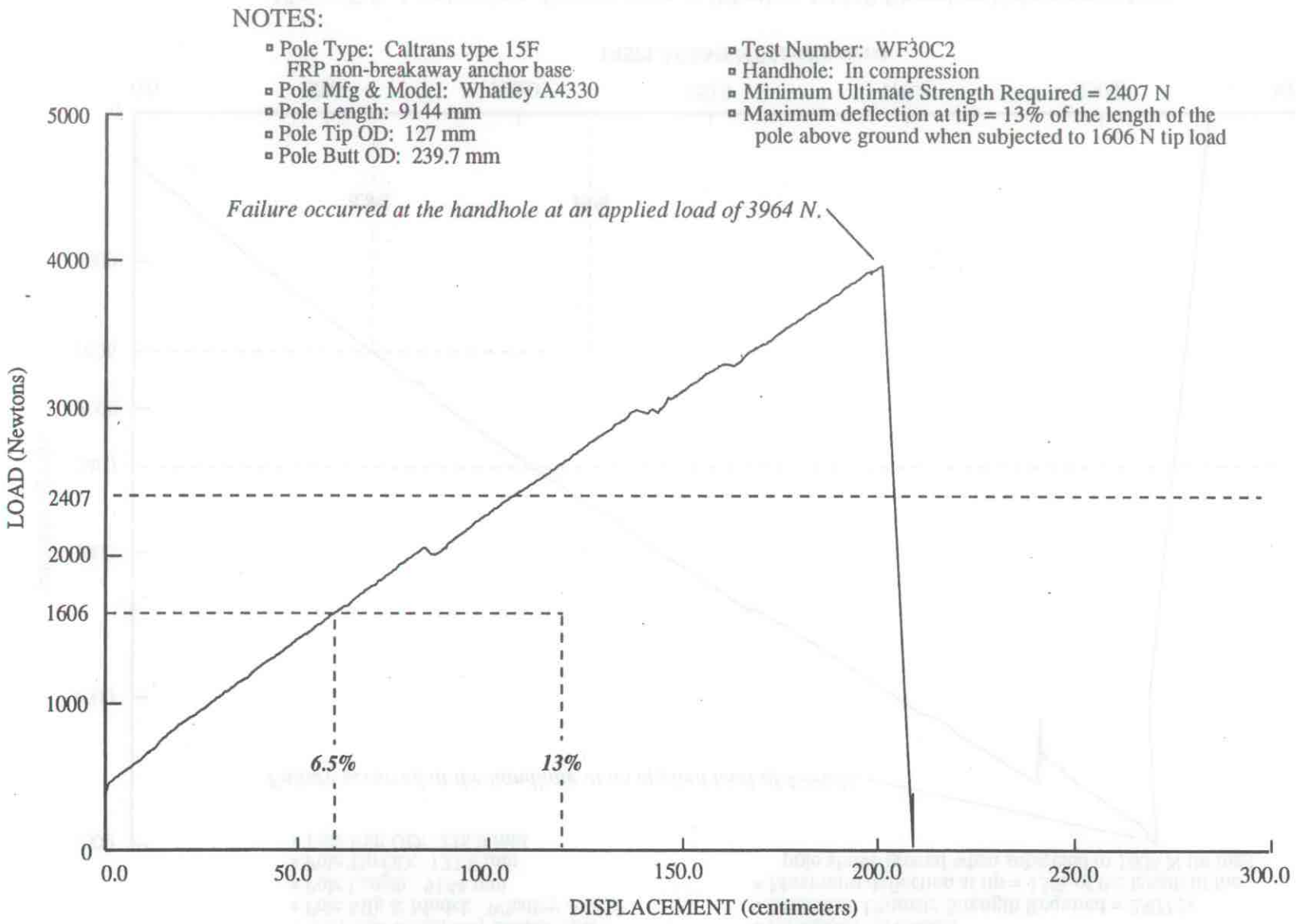


Figure F-9. Load versus displacement of Whatley A4330 fiberglass lighting standards.

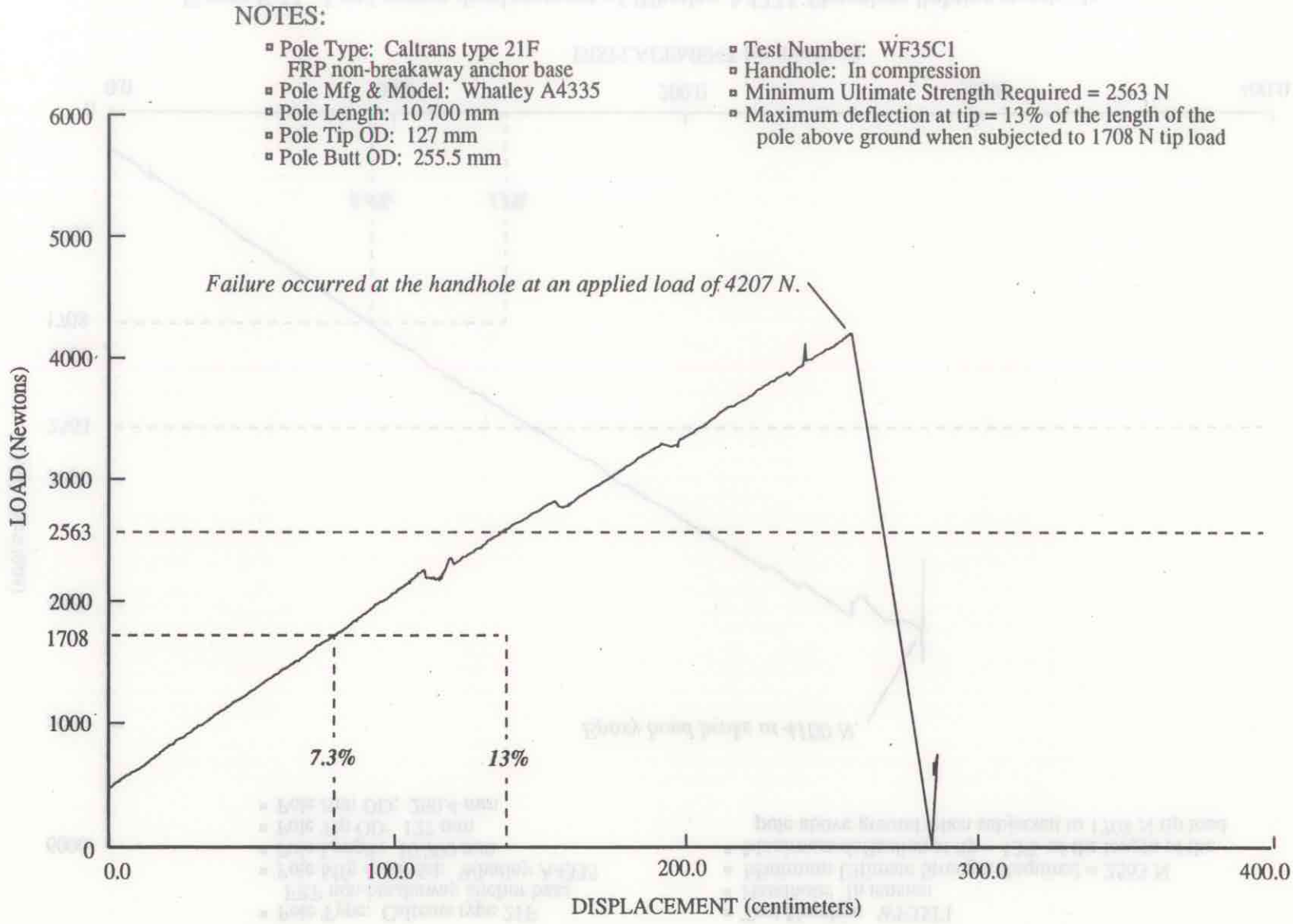


Figure F-10. Load versus displacement of Whatley A4335 fiberglass lighting standards.

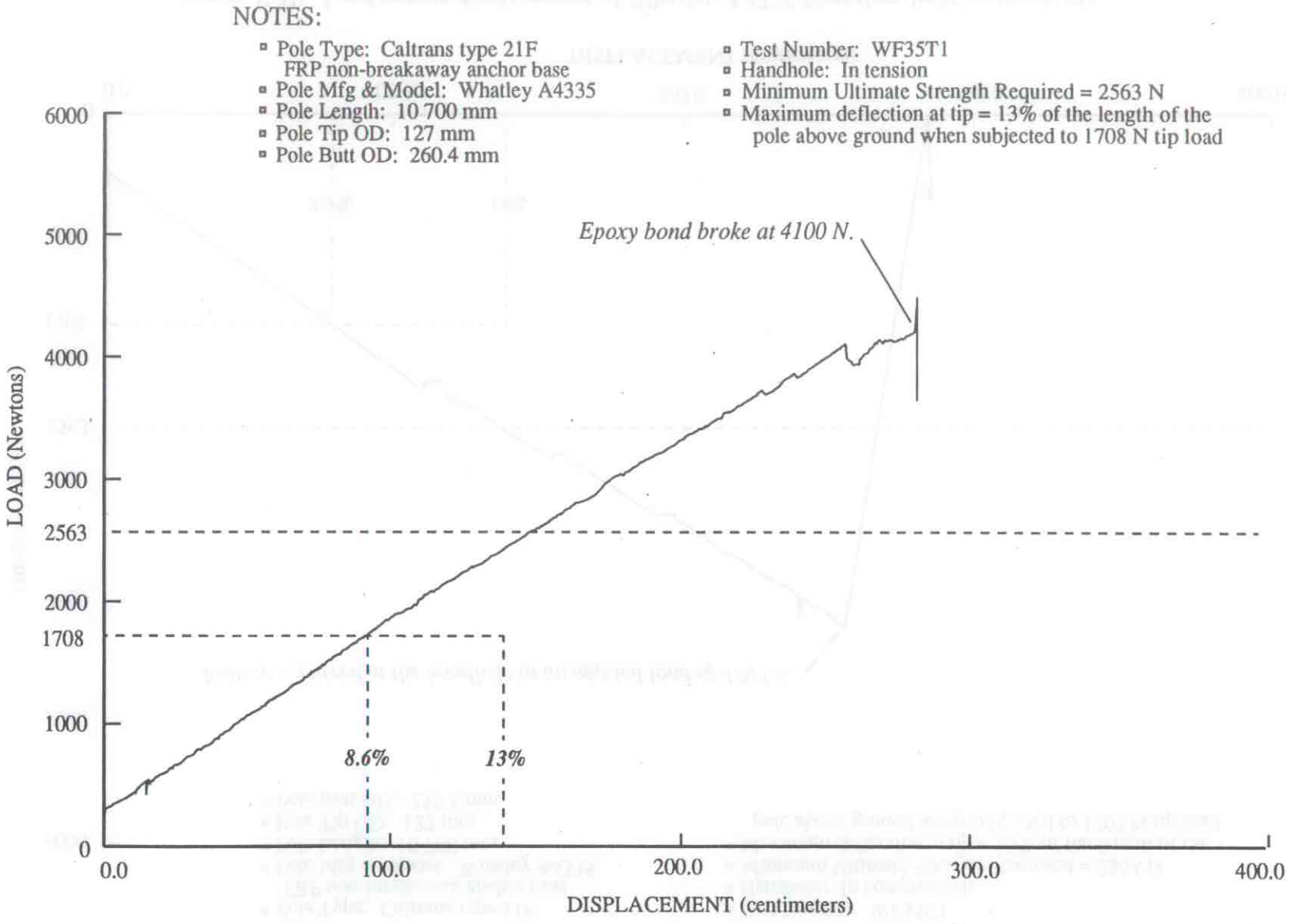


Figure F-11. Load versus displacement of Whatley A4335 fiberglass lighting standards.

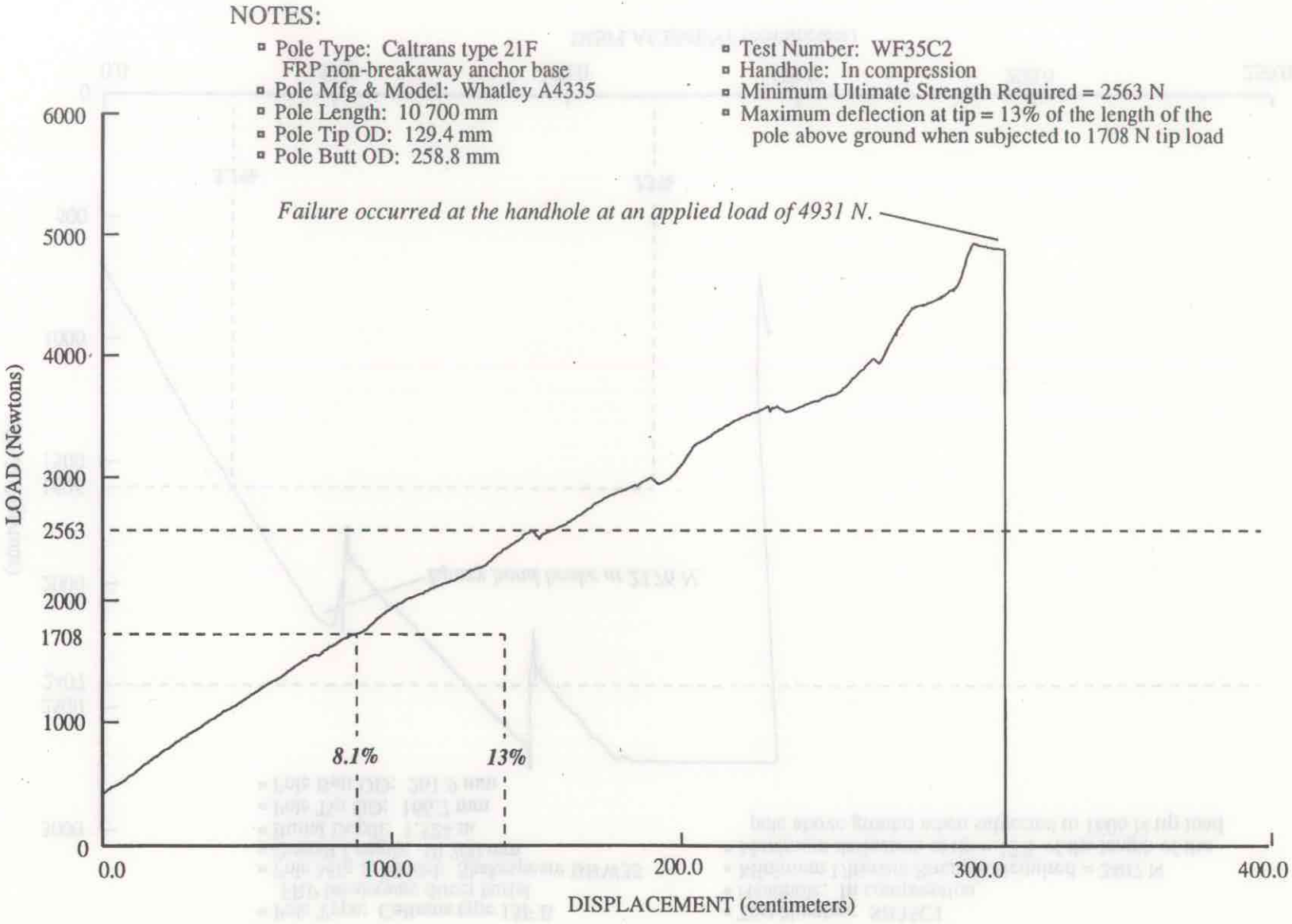


Figure F-12. Load versus displacement of Whatley A4335 fiberglass lighting standards.

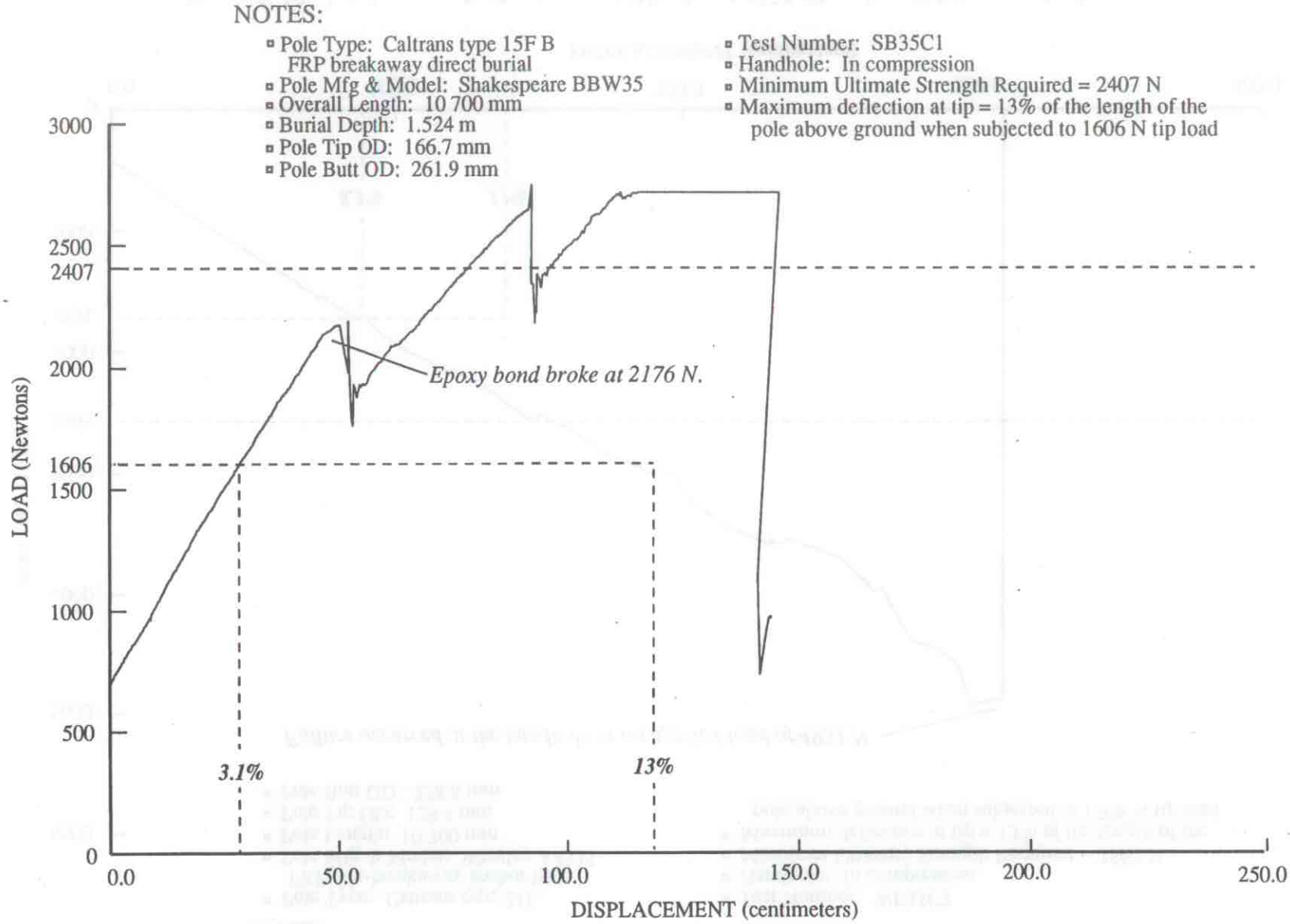


Figure F-13. Load versus displacement of Shakespeare BBW35 fiberglass lighting standards.

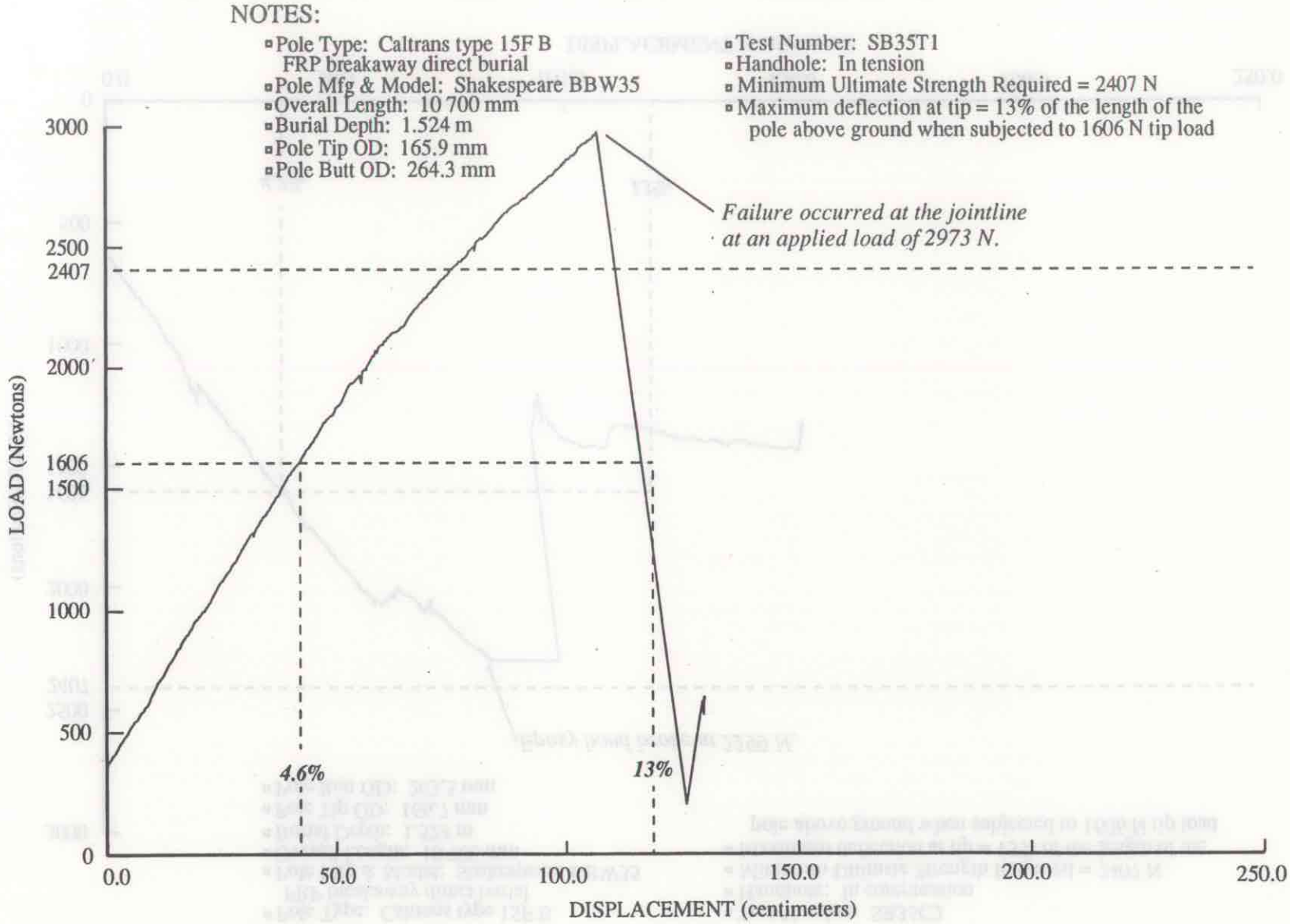


Figure F-14. Load versus displacement of Shakespeare BBW35 fiberglass lighting standards.

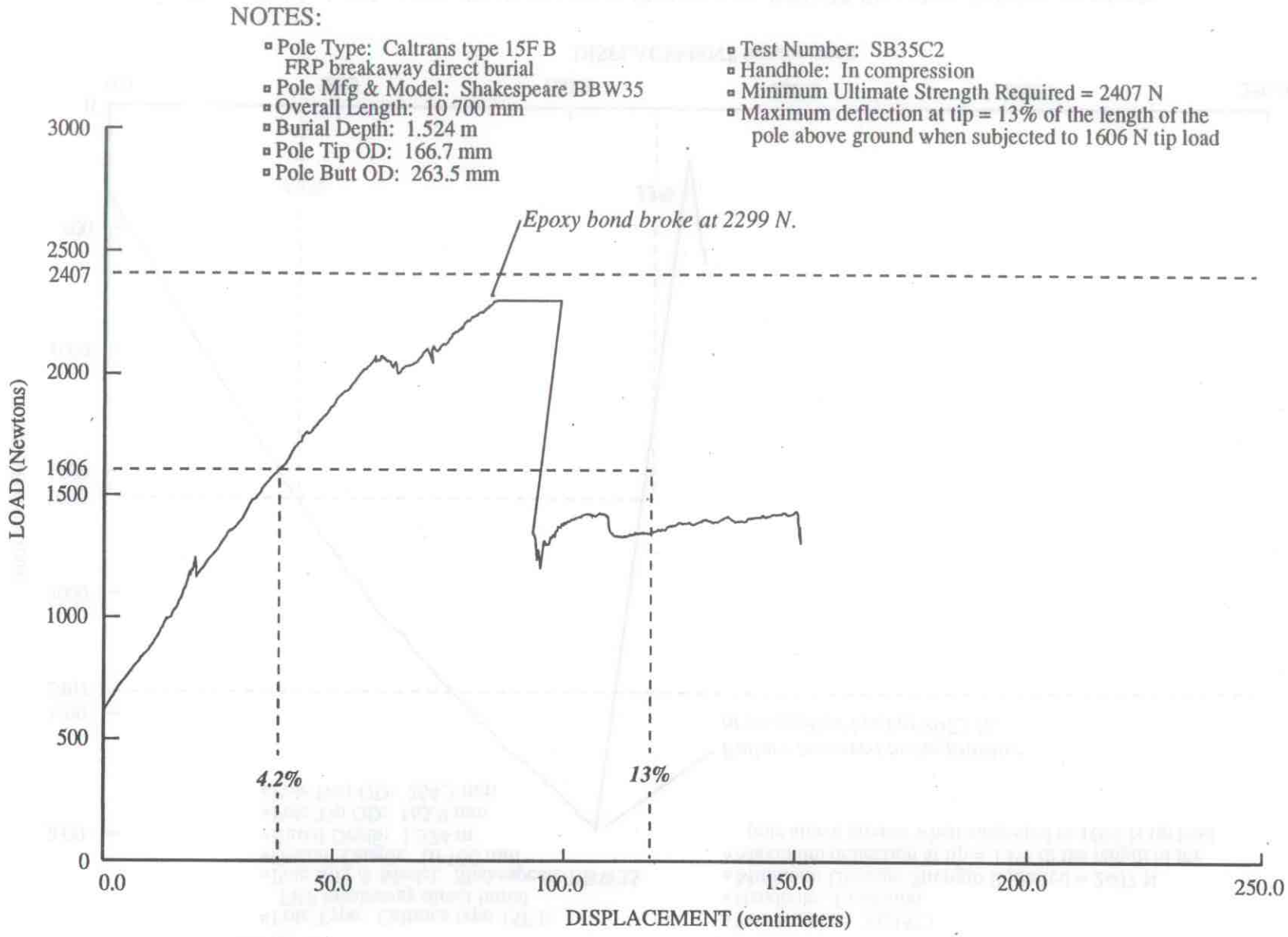


Figure F-15. Load versus displacement of Shakespeare BBW35 fiberglass lighting standards.

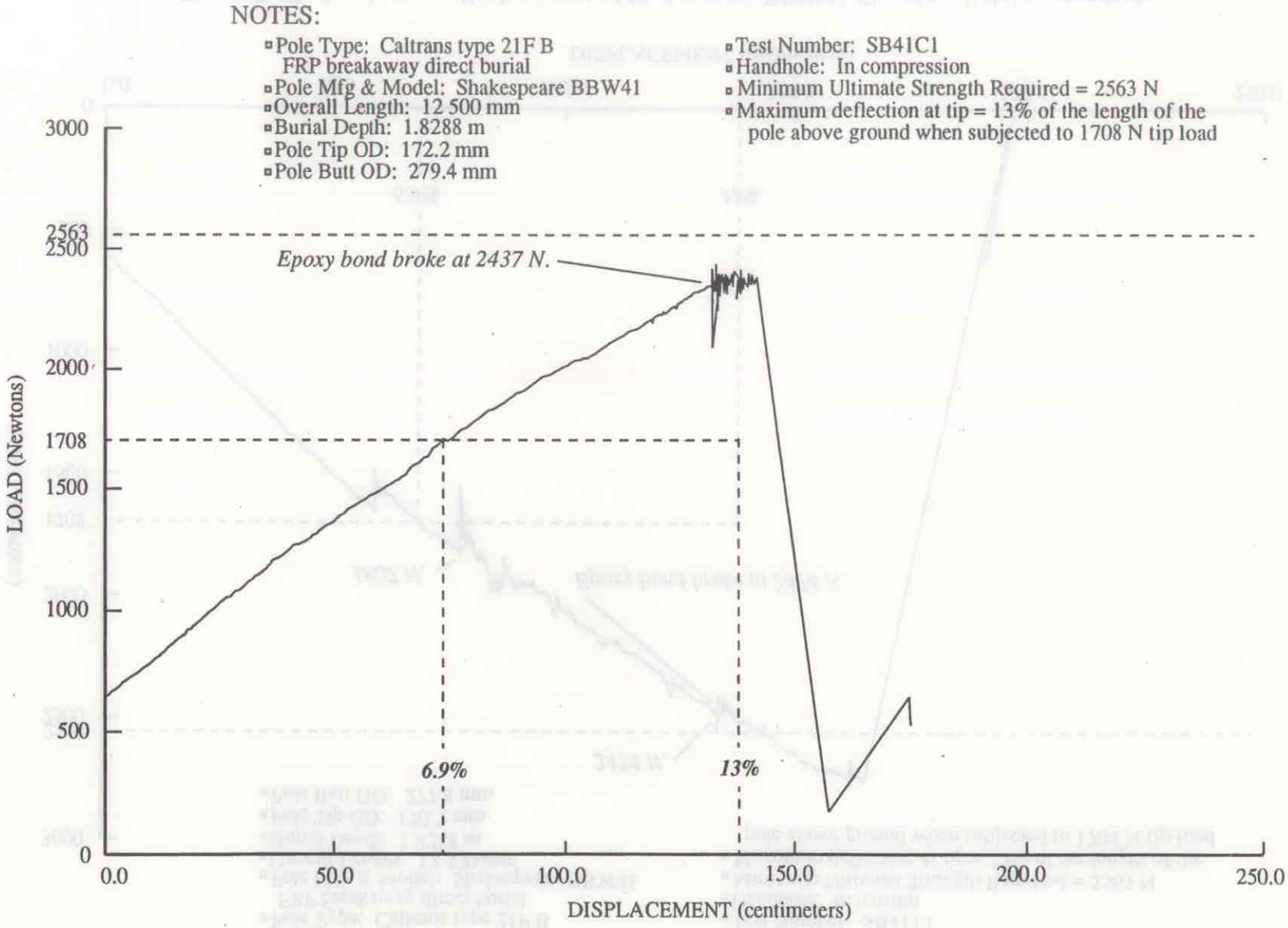


Figure F-16. Load versus displacement of Shakespeare BBW41 fiberglass lighting standards.

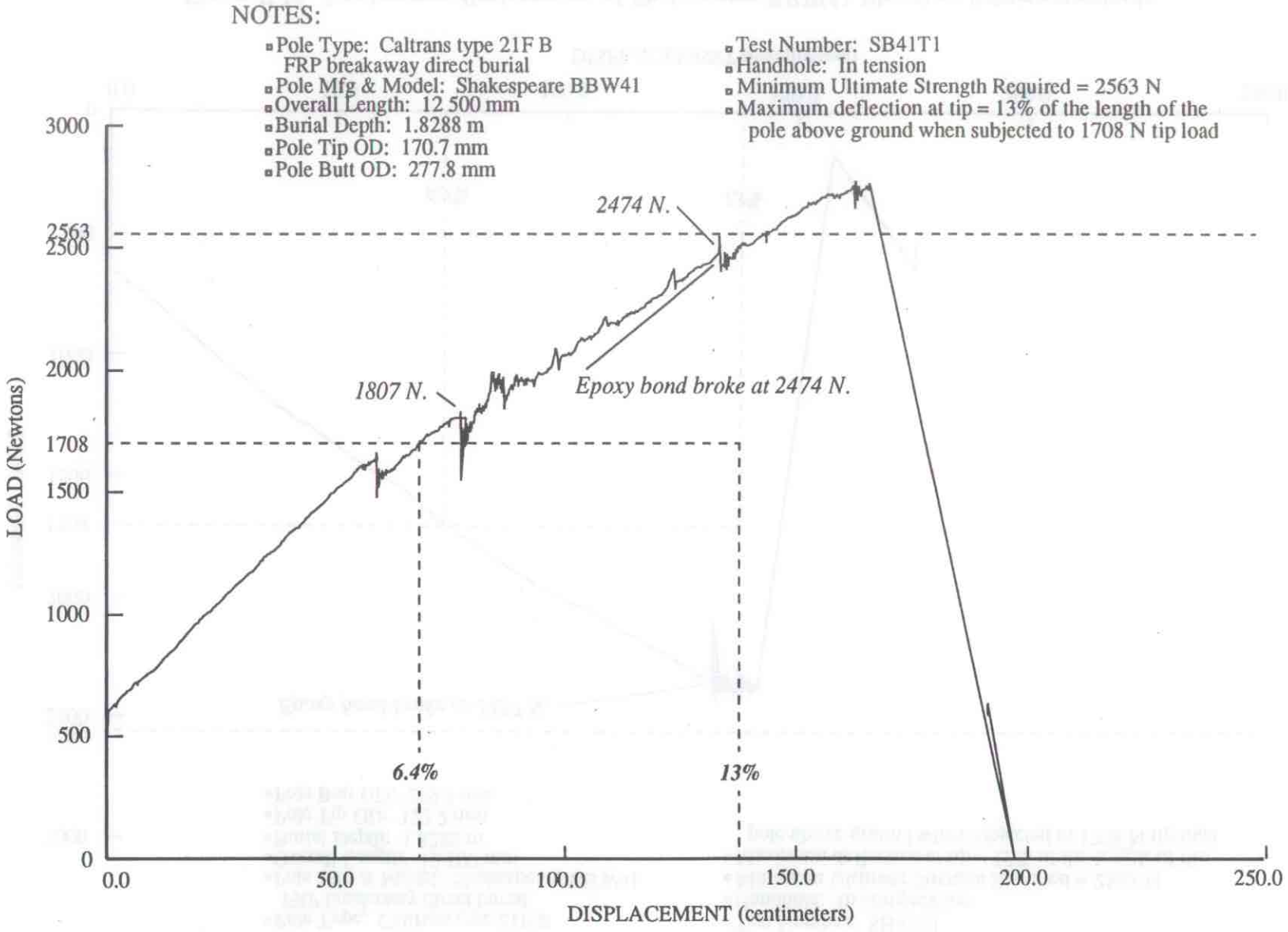


Figure F-17. Load versus displacement of Shakespeare BBW41 fiberglass lighting standards.

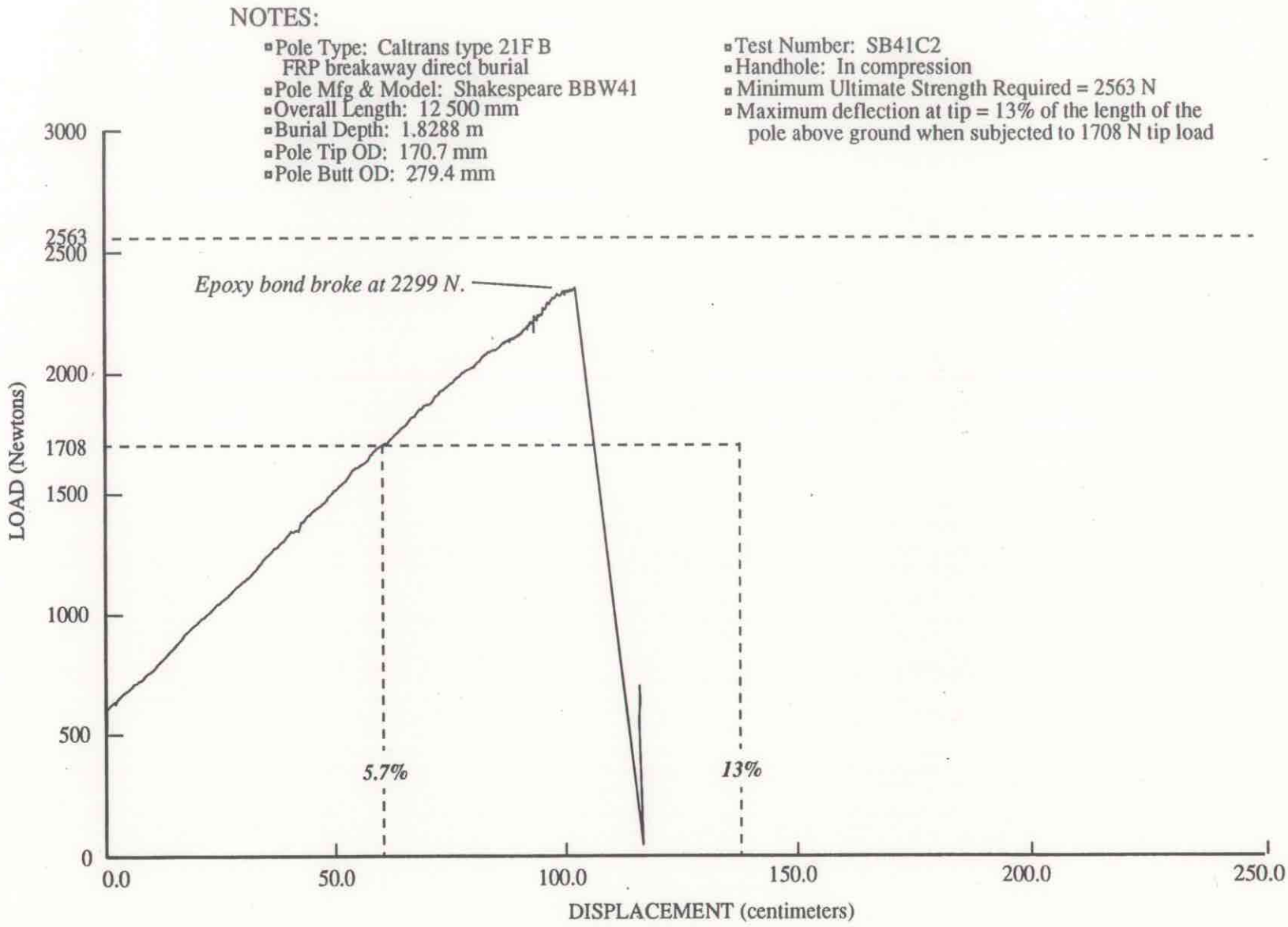
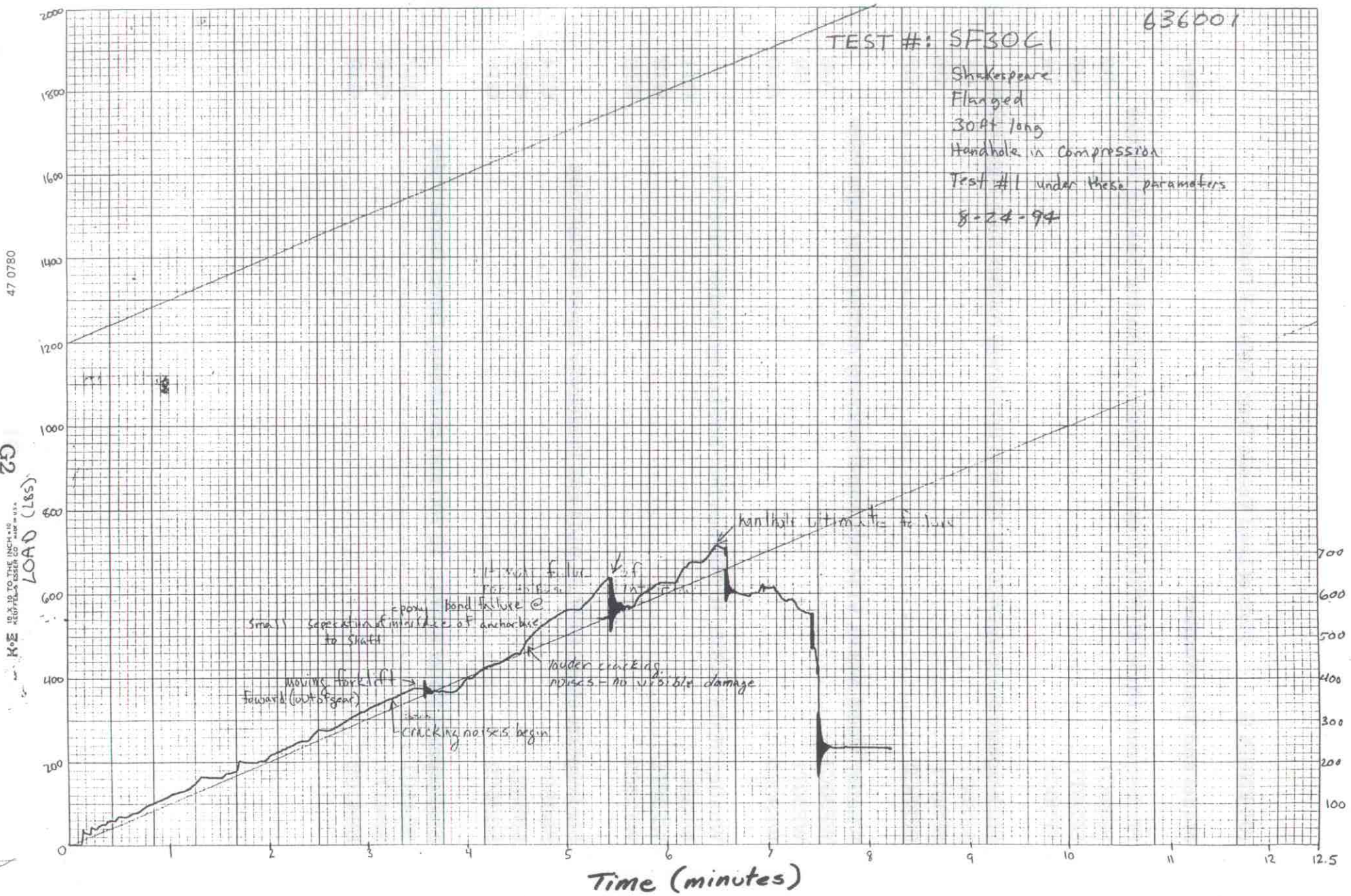


Figure F-18. Load versus displacement of Shakespeare BBW41 fiberglass lighting standards.

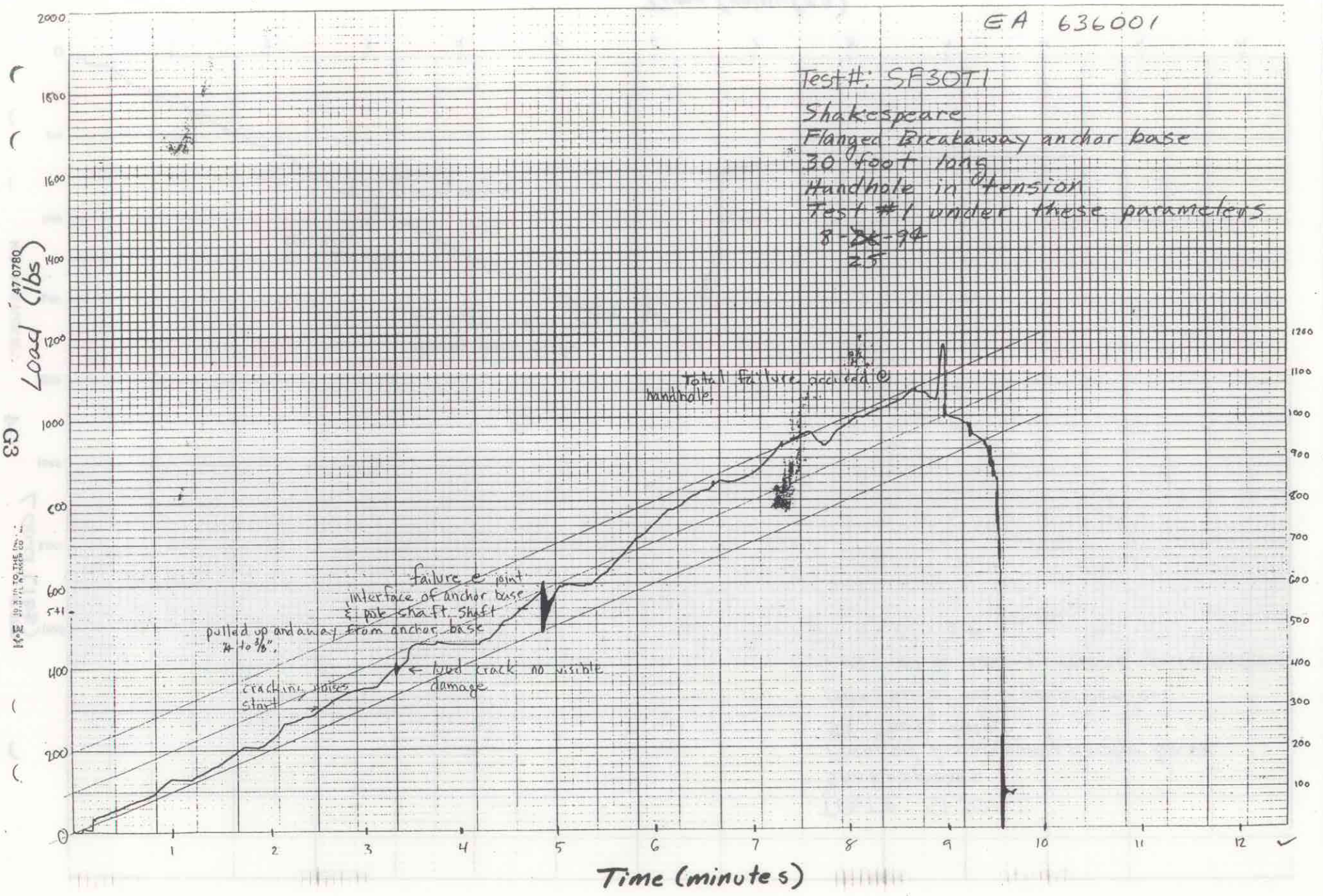
APPENDIX G Plots of Load Versus Time From X-Y Plotter

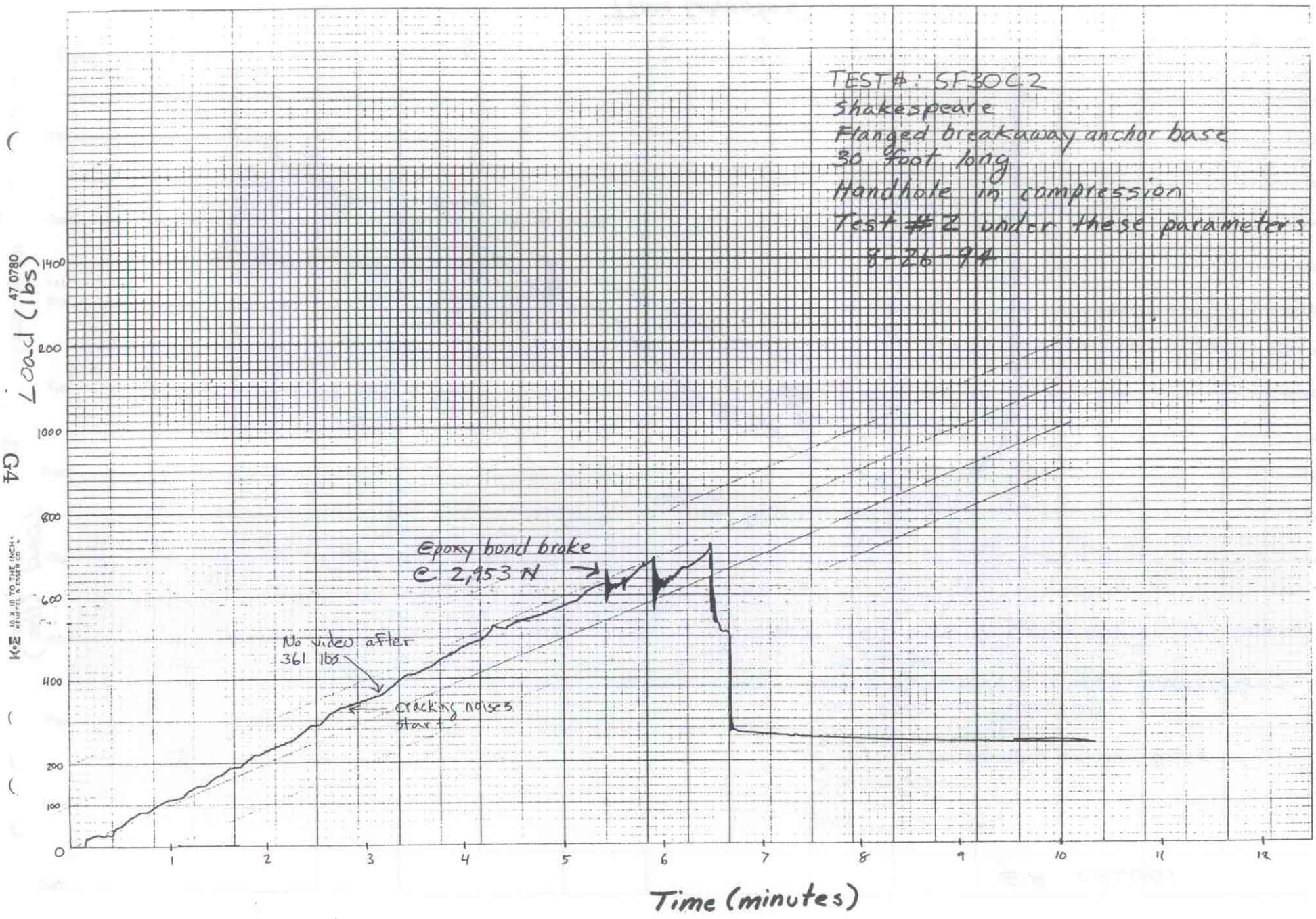
Model and Test Number **Page**


636001
TEST #: SF30C1
Shakespeare
Flanged
30 ft long
Handhole in Compression
Test #1 under these parameters
8-24-94
LOAD (1BS)
Time (minutes)
Moving forklift forward (out of gear)
Cracking noises begin
Small seperation of interface of anchorbase to shaft
epoxy bond failure @
Louder cracking noises - no visible damage
handhole ultimate failure
0
200
400
600
800
1000
1200
1400
1600
1800
2000
100
300
500
700
1
2
3
4
5
6
7
8
9
10
11
12
12.5

1030

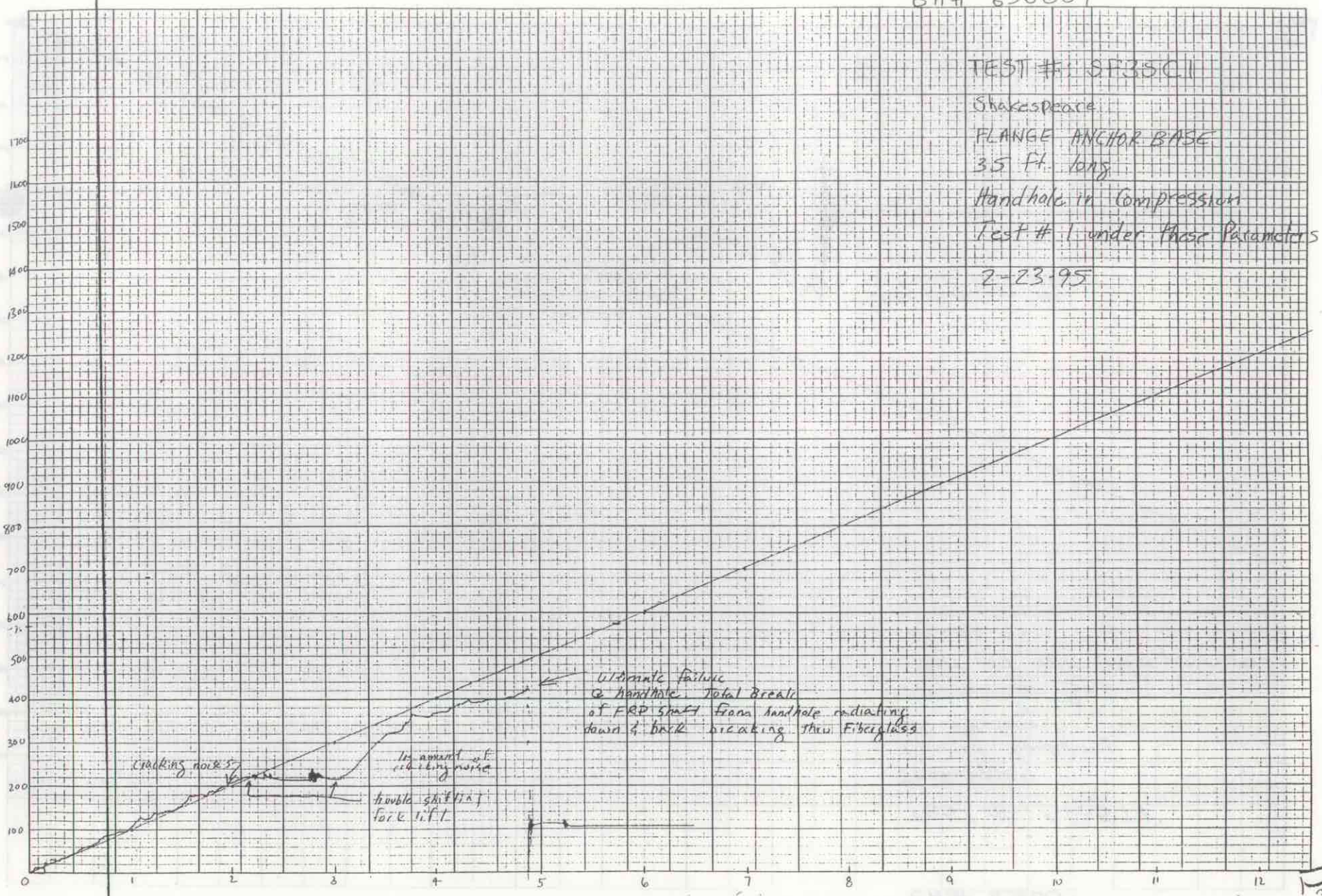
EA 636001




TEST #: SF30C2
Shakespeare
Flanged breakaway anchor base
30 foot long
Handhole in compression
Test #2 under these parameters
8-26-94
Epoxy bond broke
@ 2,953 N
No video after
361 lbs
cracking noises
start
Load (lbs)
Time (minutes)
0
100
200
400
600
800
1000
1400
1
2
3
4
5
6
7
8
9
10
11
12

EA# 63600 1

TEST #: SF35C II
Shakespeare
FLANGE ANCHOR BASE
35 ft. long
Handhole in Compression
Test # 1 under Phase Parameters
2-23-95

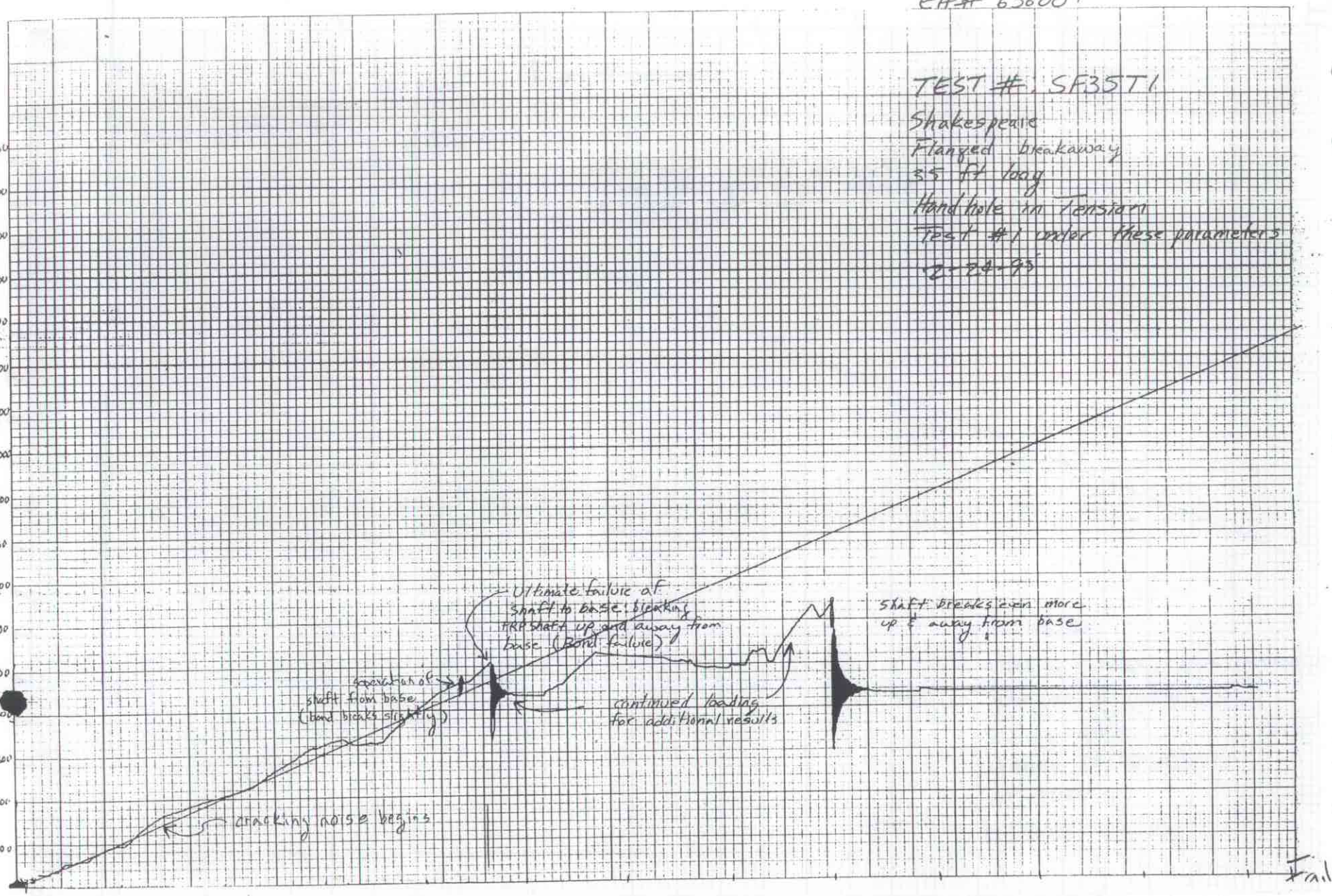


G5

HEWLETT-PACKARD 9270-1004

EA# 63600 1

TEST #: SF35T1
Shakespeare
Flanged breakaway
35 ft long
Hand hole in Tension
Test #1 under these parameters
2-24-93



G6

K&E MADE IN U.S.A. 10 X 10 TO THE INCH 46 10 X 10 INCHES

47 0780

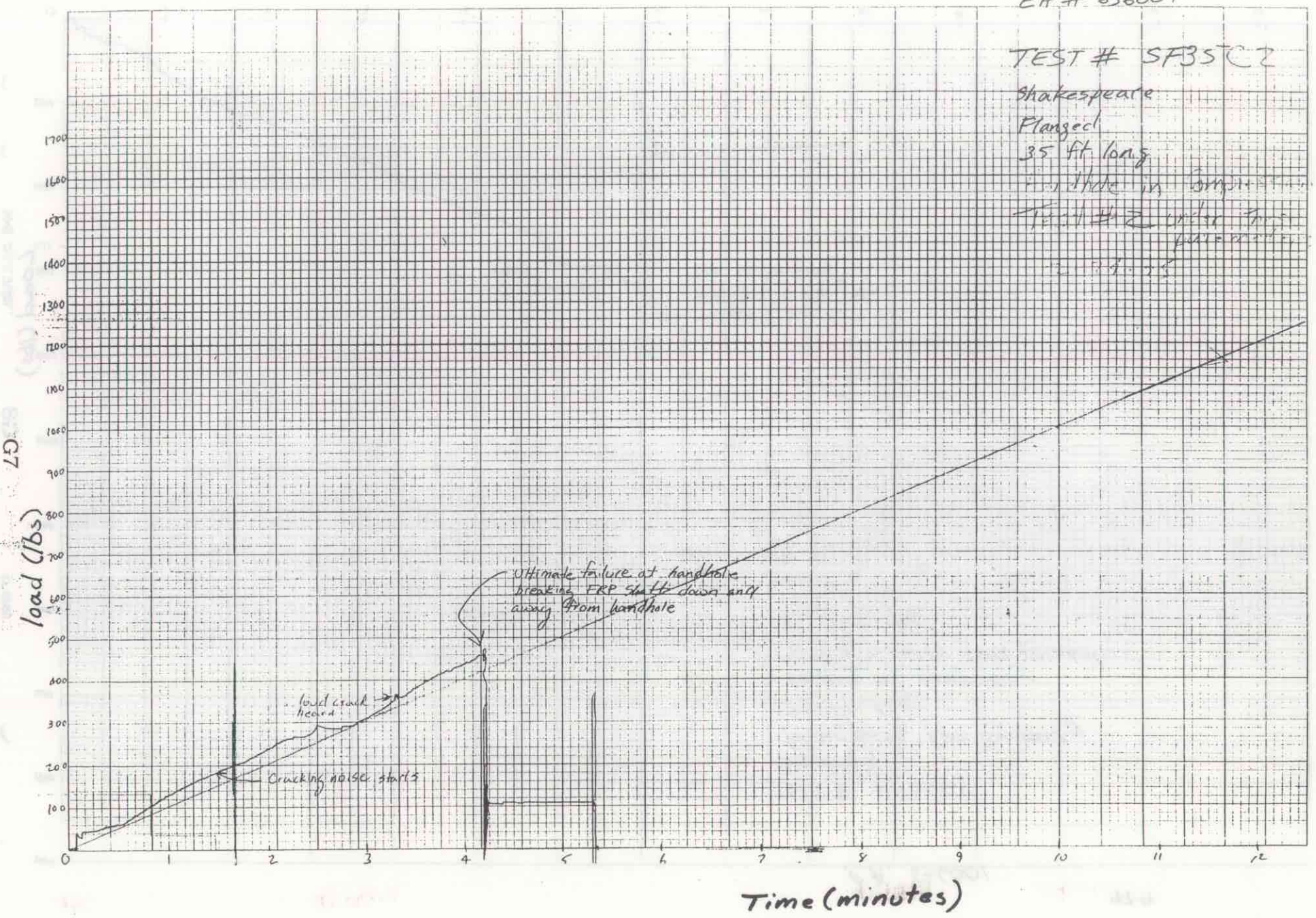
EA # 636001

TEST # SF35C2

Shakespeare

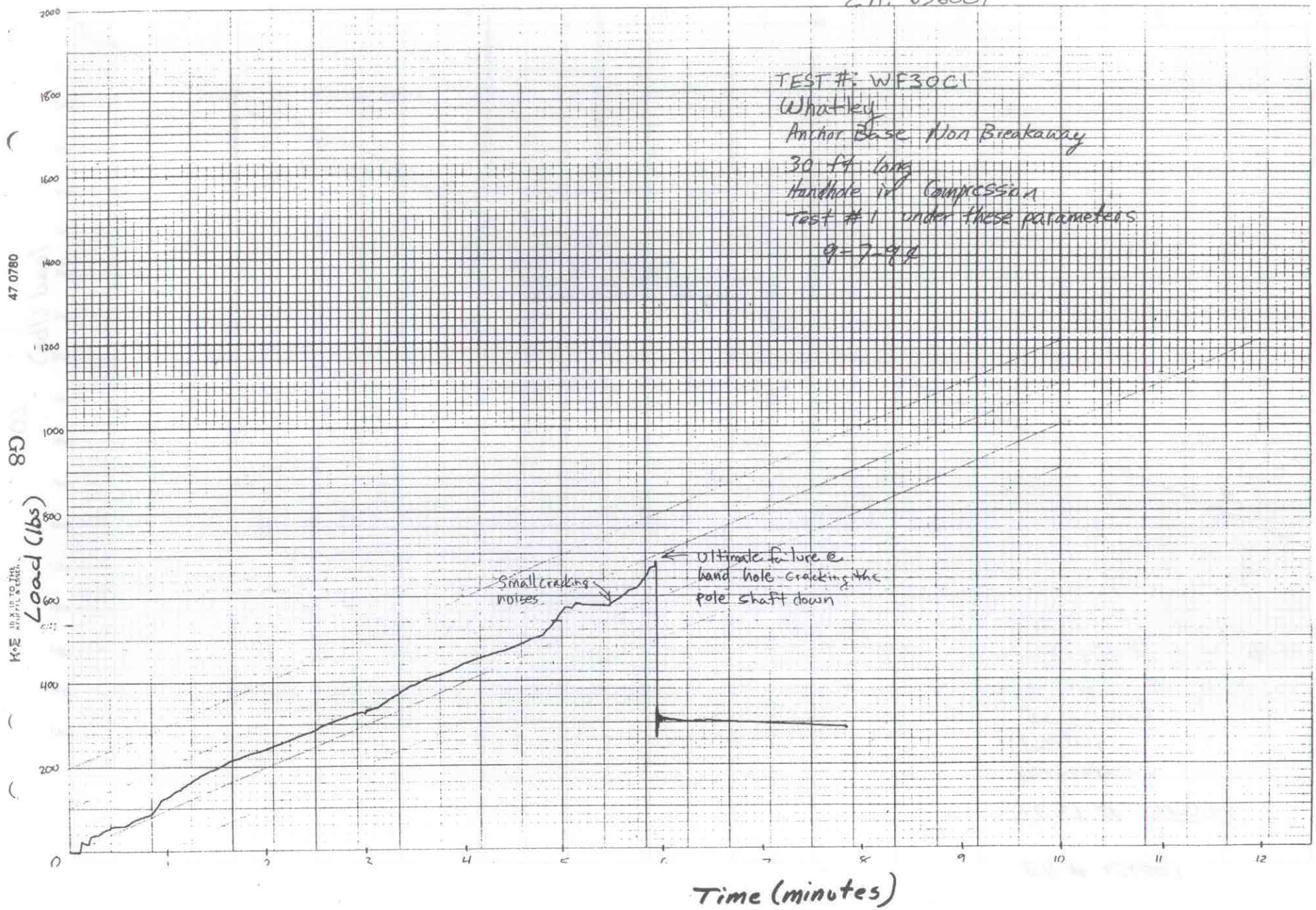
Flanged

35 ft long



9-7-94

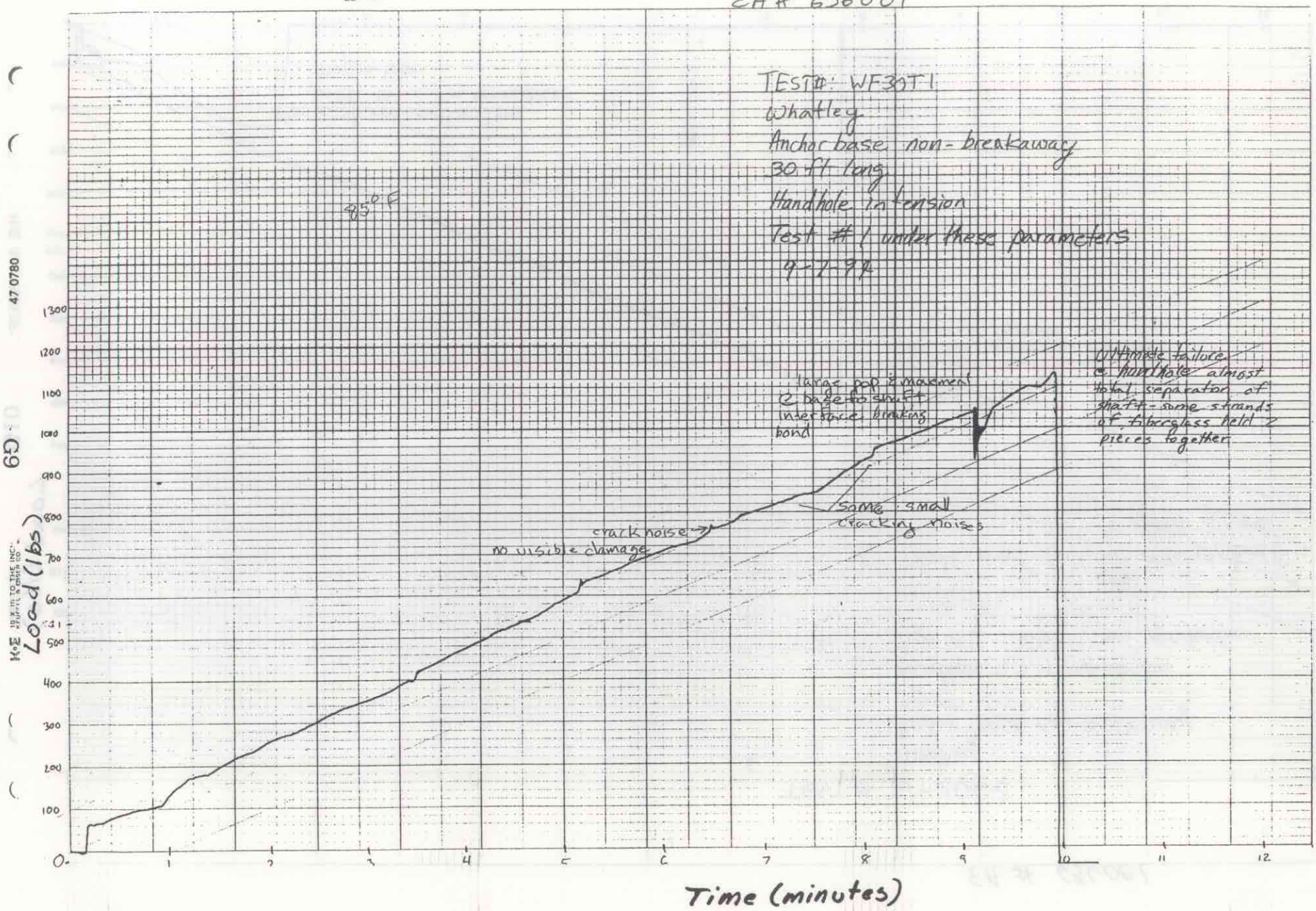
E.A. 636001



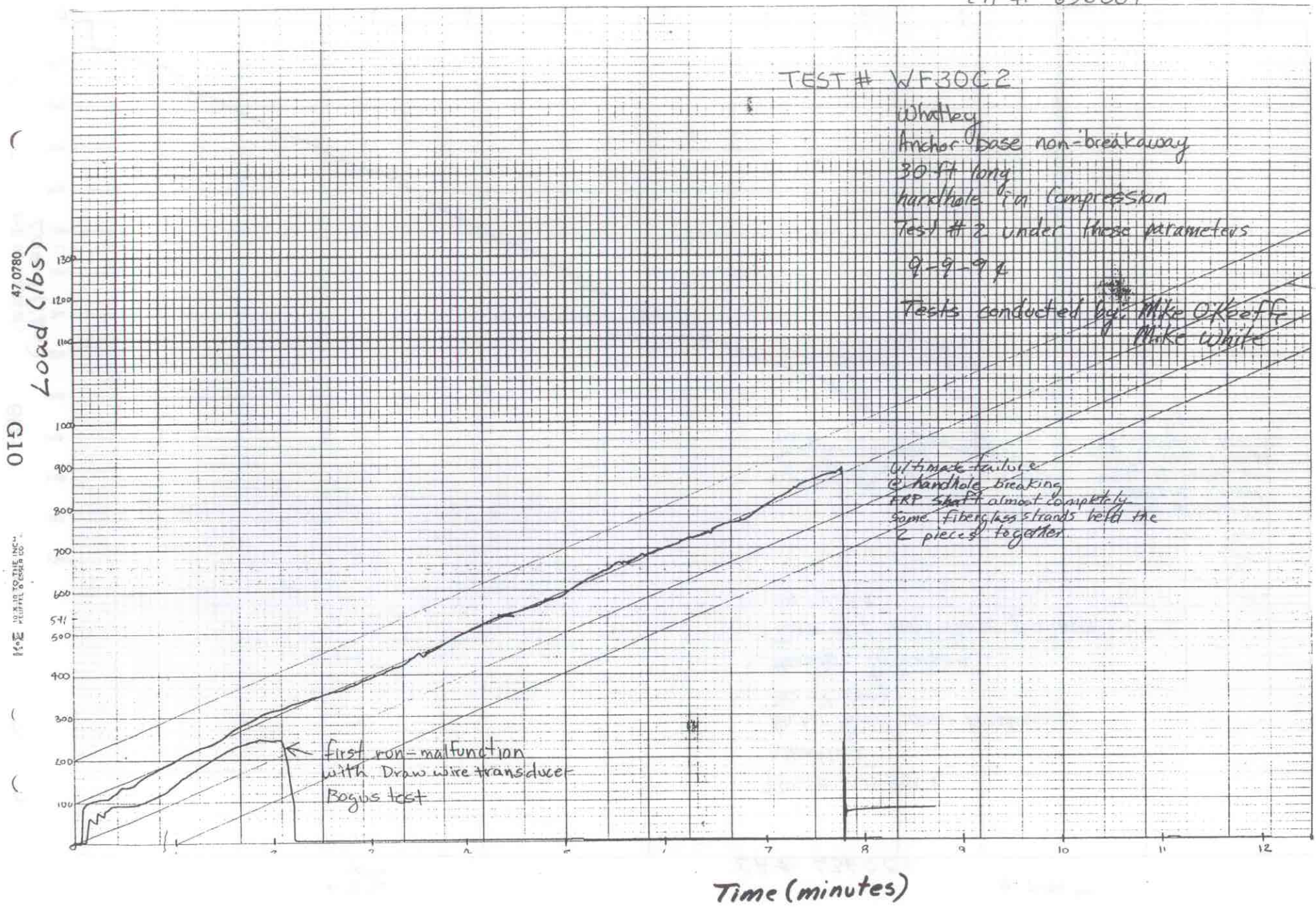
#: 31 7/16
20 7/8

9-7-94 mv

EA# 636001

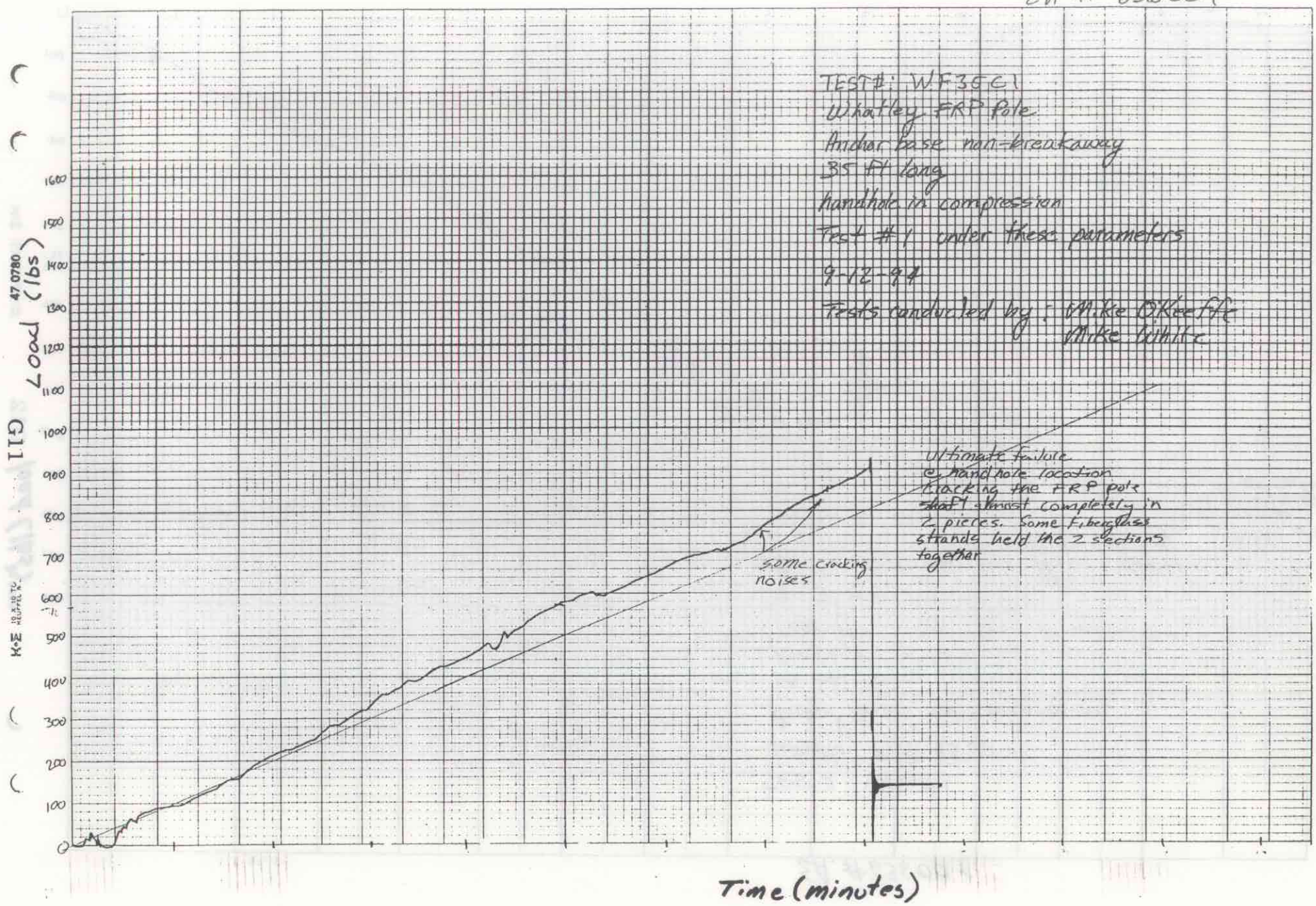


EA # 636001


TEST # WF30C2
Whatley
Anchor base non-breakaway
30 ft long
handhole in compression
Test # 2 under these parameters
9-9-94
Tests conducted by: Mike O'Keeffe
Mike White
Ultimate failure
@ handhole breaking
FRP shaft almost completely
some fiberglass strands held the
2 pieces together
first run - malfunction
with Draw wire transducer
Bogibs test
Load (lbs)
Time (minutes)
1300
1200
1100
1000
900
800
700
600
541
500
400
300
200
100
1
2
3
4
5
6
7
8
9
10
11
12

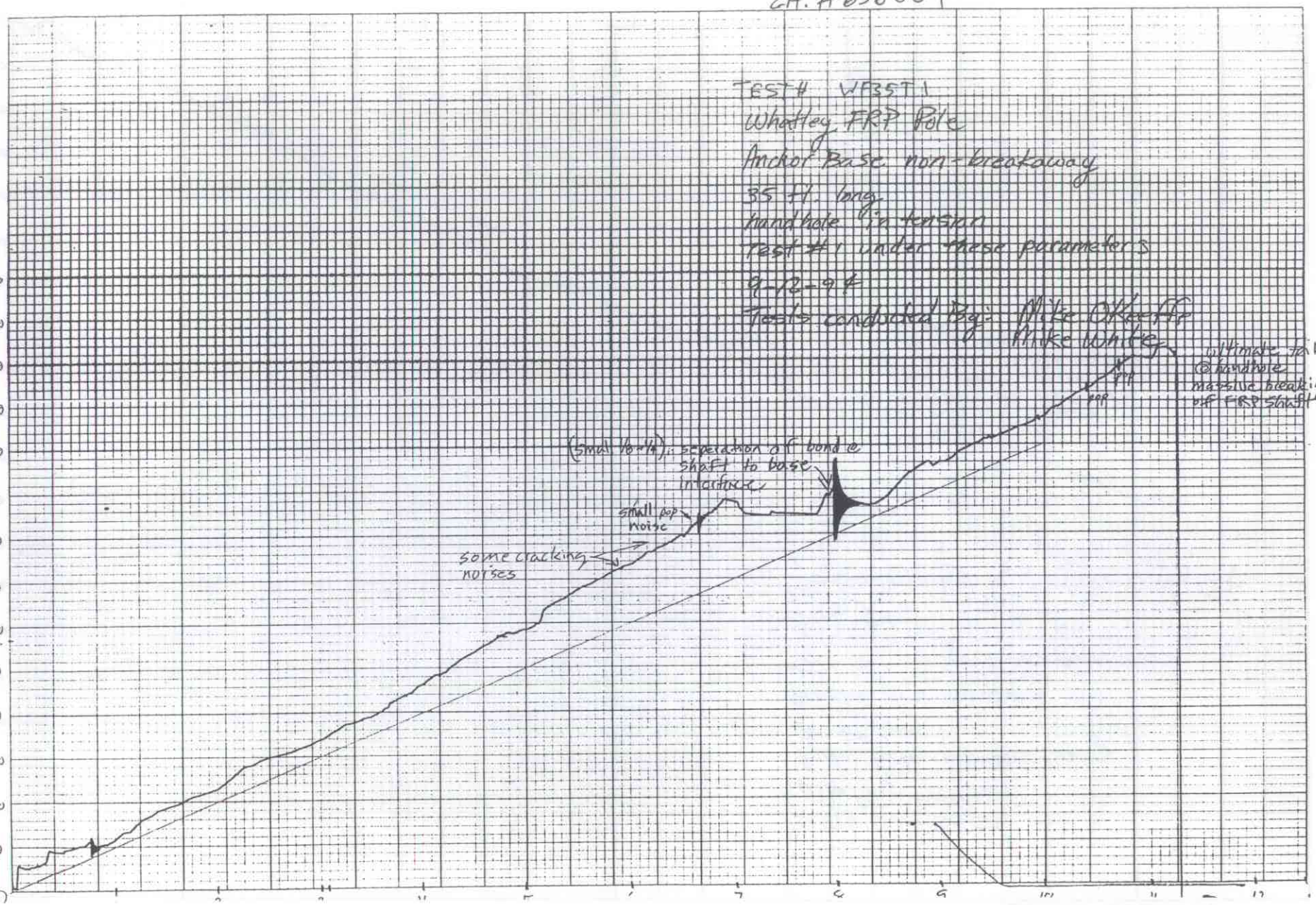
9-12-94
mw

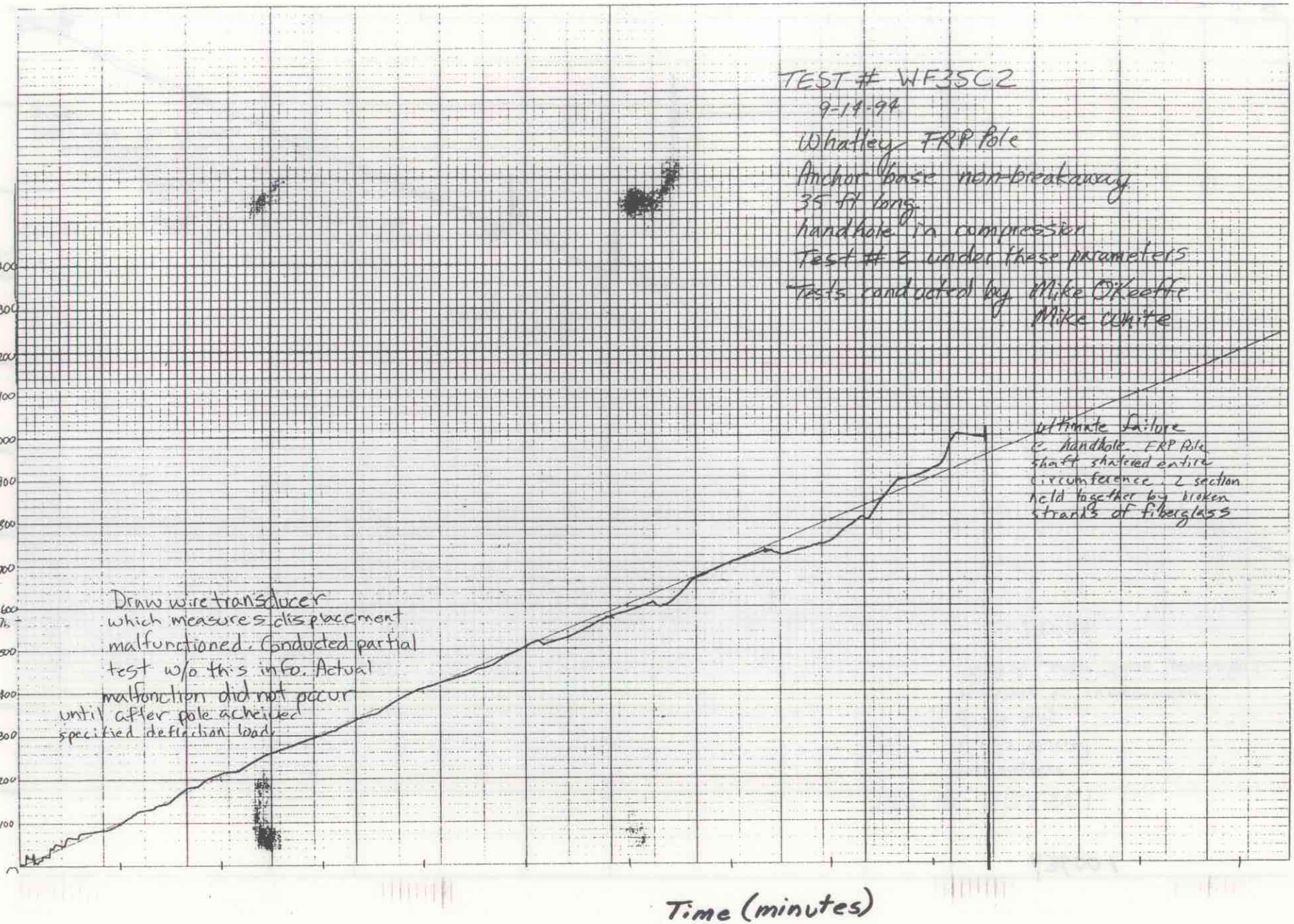
EA # 63600(

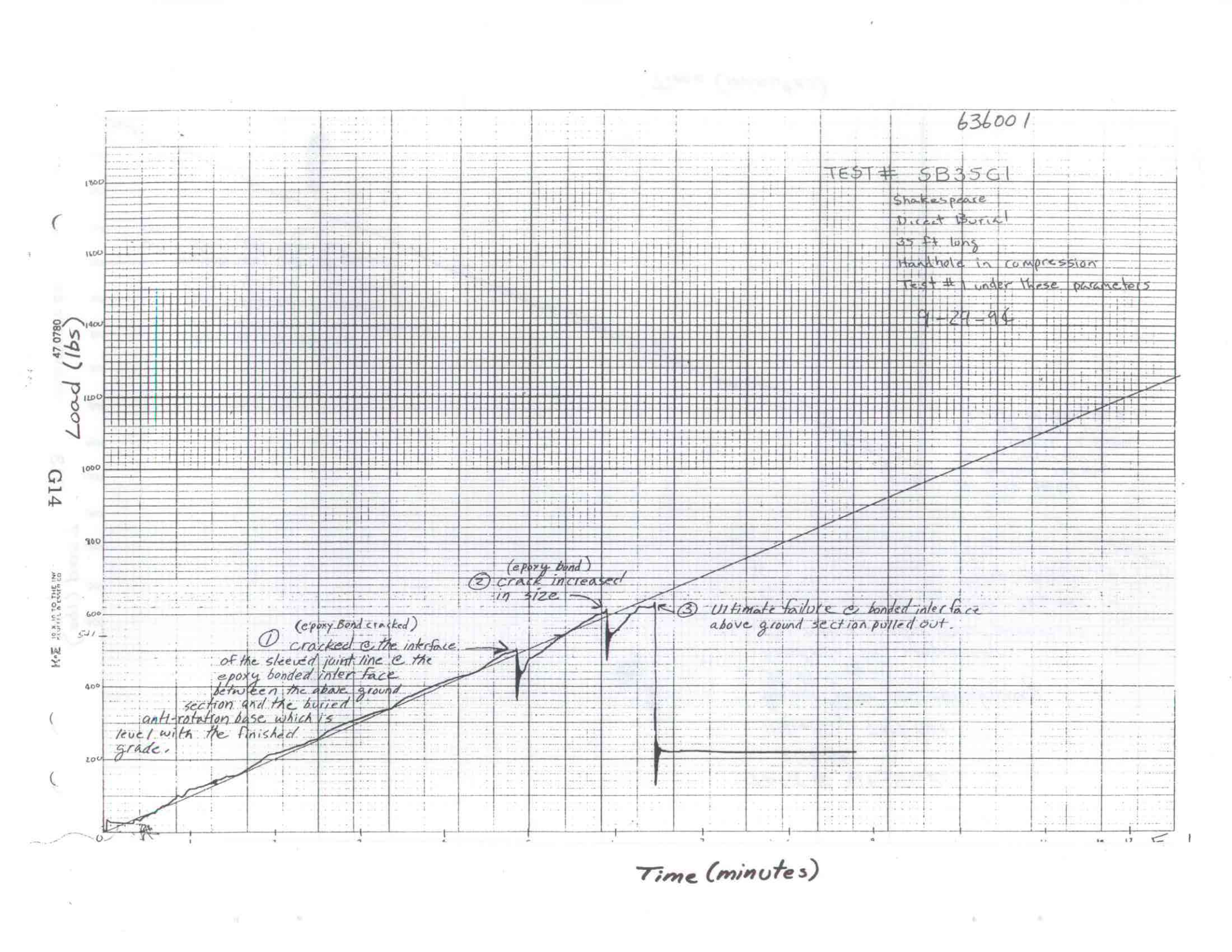


EA. #63600(

TEST # WEST 1
Whatley FRP Pole
Anchor Base non-breakaway
35 Ft. long
handhole in tension
test #1 under these parameters
9-12-94
Tests conducted by: Mike O'Keeffe
Mike White



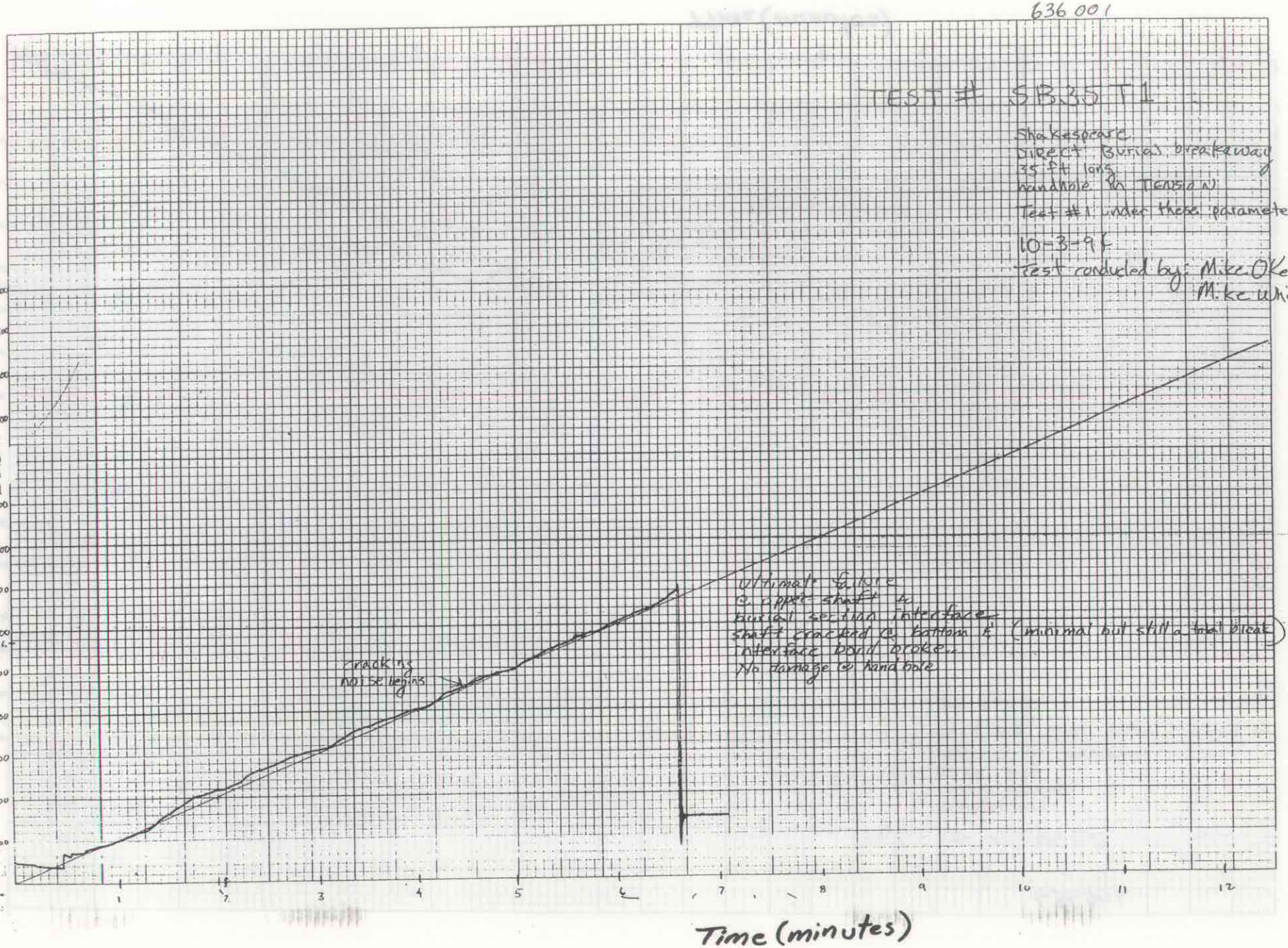

TEST # WF35C2
9-14-94
Whatley FRP pole
Anchor base non-breakaway
35 ft long
handhole in compression
Test # 2 under these parameters
Tests conducted by Mike O'Keeffe
Mike White
ultimate failure
@ handhole. FRP pole
shaft shattered entire
circumference, 2 section
held together by broken
strands of fiberglass
Draw wire transducer
which measures displacement
malfunctioned. Conducted partial
test w/o this info. Actual
malfunction did not occur
until after pole achieved
specified deflection load.
Load (lbs)
Time (minutes)
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400


636001
TEST # SB35G1
Shakespeare
Direct Burial
35 ft long
Handhole in compression
Test # 1 under these parameters
9-27-94
Load (lbs)
Time (minutes)
(epoxy Bond cracked)
① cracked @ the interface of the sleeved joint line @ the epoxy bonded inter face between the above ground section and the buried anti-rotation base which is level with the finished grade.
(epoxy bond)
② crack increased in size
③ Ultimate failure @ bonded interface above ground section pulled out.
G14

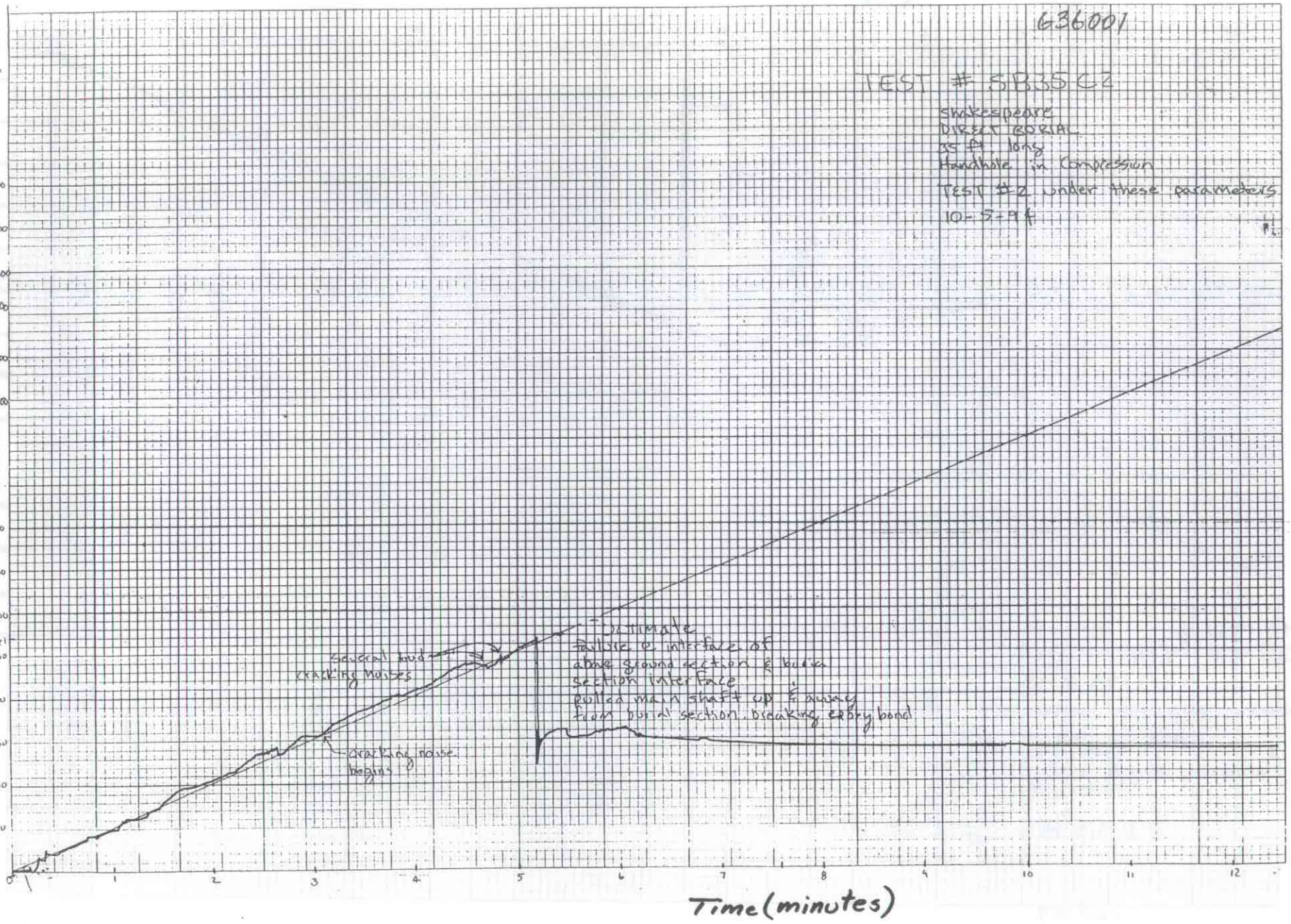
636 001

TEST # SB35T1

Shakespeare
Direct Burial breakaway
35 ft long
handhole in TENSION
Test #1 under these parameters
10-3-95
Test conducted by: Mike O'Keeffe
Mike White



G15


636001
TEST # SB35 C4
Shakespeare
DIRECT BURIAL
35 ft. long
Handhole in Compression
TEST #2 under these parameters
10-5-94
G16
Load (lbs)
Time (minutes)
Several audible cracking noises
cracking noise begins
Ultimate failure @ interface of above ground section & buried section interface pulled main shaft up & away from burial section, breaking epoxy bond

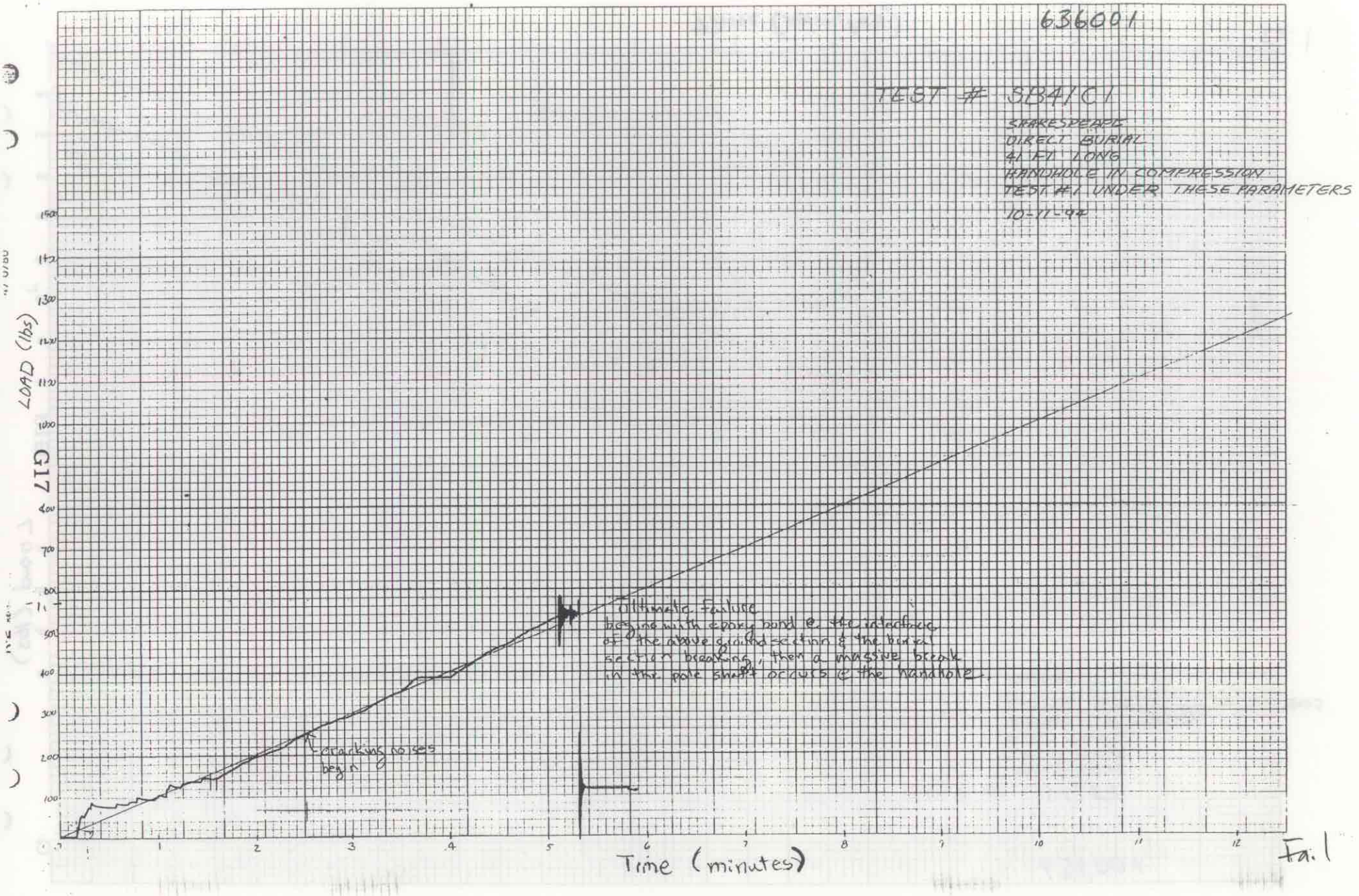
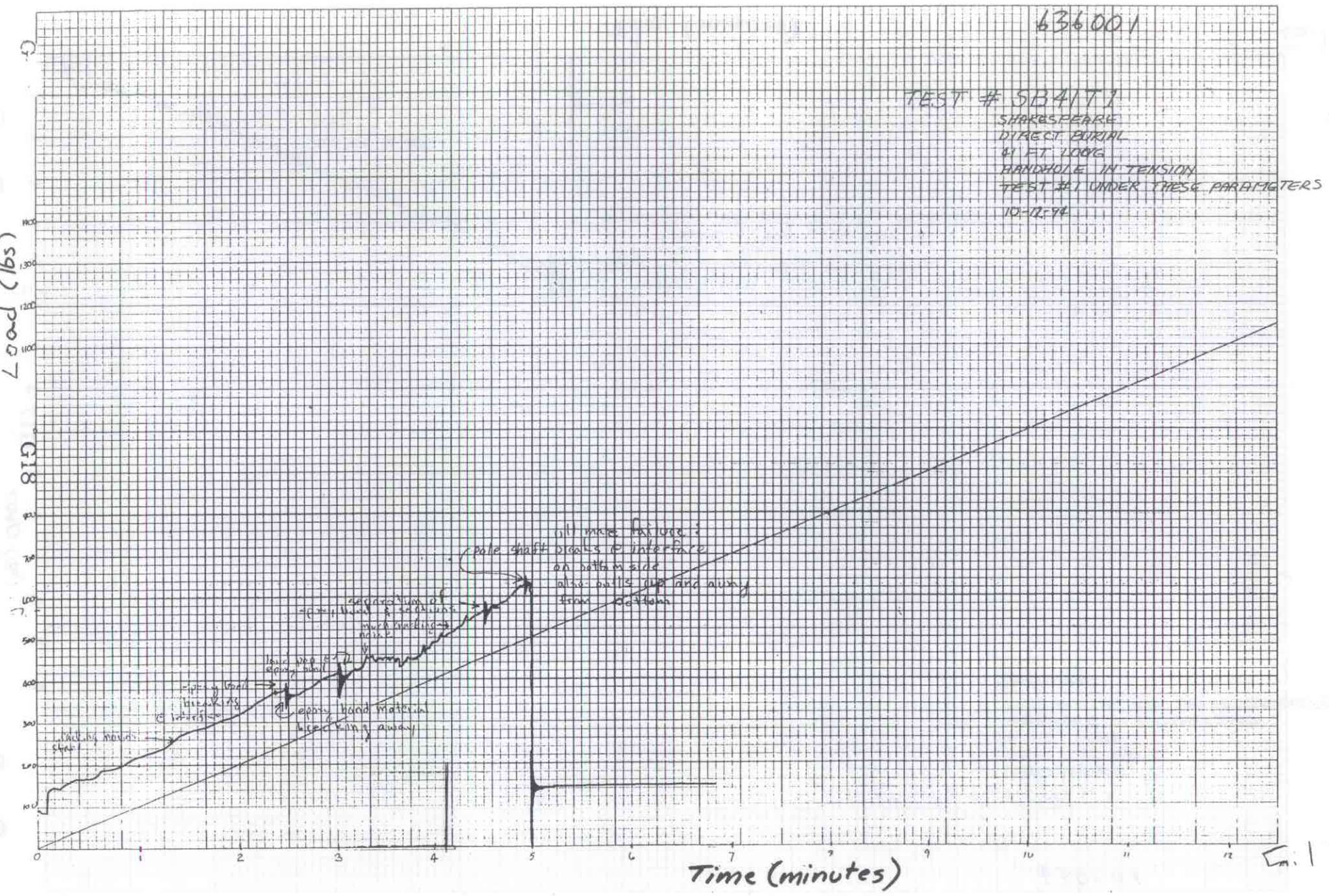
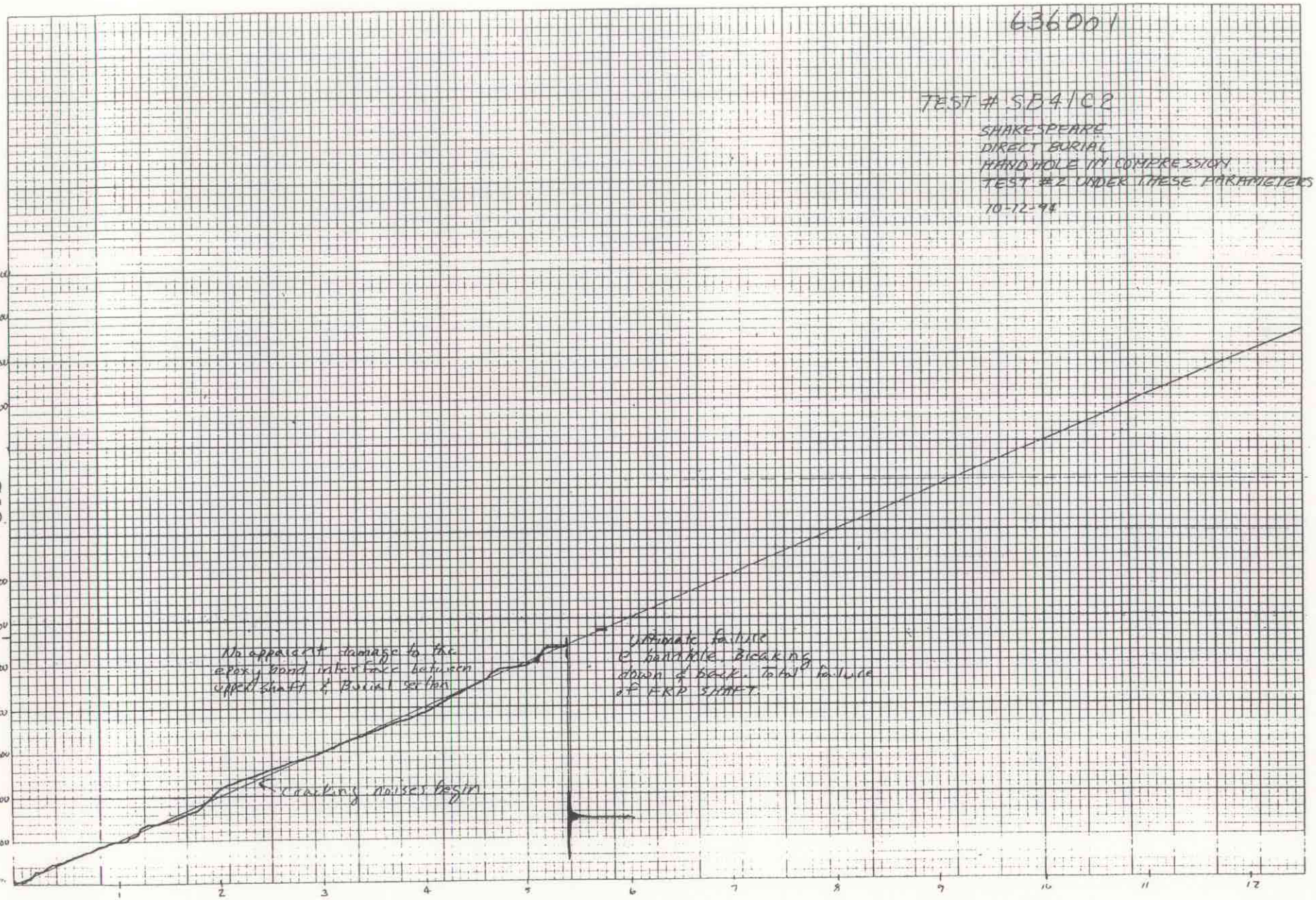

636091
TEST # SB4IC1
SHAKESPEARE
DIRECT BURIAL
4' FT LONG
HANDHOLE IN COMPRESSION
TEST #1 UNDER THESE PARAMETERS
10-11-92
LOAD (lbs)
G17
Time (minutes)
Cracking noises begin
Ultimate failure beginning with epoxy bond @ the interface of the above ground section & the buried section breaking, then a massive break in the pole shaft occurs @ the handhole.

Fig. 1


636001
TEST # SB41T1
SHAKESPEARE
DIRECT BURIAL
41 FT 100G
HANDHOLE IN TENSION
TEST #1 UNDER THESE PARAMETERS
10-12-94
Load (lbs)
Time (minutes)
all more failure?
pole shaft starts to interfere on bottom side also pulls up and away from bottom
separation of
epoxy bond material
epoxy bond material
0
1
2
3
4
5
6
7
9
10
11
12


636001
TEST # SB4/C2
SHAKESPEARE
DIRECT BURIAL
HANDHOLE IN COMPRESSION
TEST #2 UNDER THESE PARAMETERS
10-12-94
Load (lbs)
G19
No apparent damage to the epoxy bond interface between upper shaft & burial section
cracking noises begin
ultimate failure @ laminate. Cracking down & back. Total failure of FRP SHAFT.
Fail

APPENDIX H Dry Film Thickness Readings of Exterior Paint.

STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

CHEMICAL LABORATORY TEST FORM

MR 0457 (Rev. 8/92)

FROM

REPORT OF TESTS ON	INITIAL	TEST NUMBER	CONT., W.O., OR P.O. NUMBER
FRP Poles	HOURS	LOT NUMBER	DATE RECEIVED 9/28/94

AGENCY

SOURCE | TRADE NAME

OWNER OR MANUFACTURER: SHAKESPEARE | MANUFACTURER'S BATCH NO.

TEST RESULTS

Measured Coating thickness on poles using Tooke gauge - ASTM-D 4138

Pole # / Reading #	SF30T1	SF30C2	SF30C1
1	3.5 mils	3.0 mils	2.5 mils
2	1.5	3.5	3.0
3	2.5	3.0	2.5
4	2.5	2.5	3.0
5	2.5	5.0	2.0
average:	2.5 mils	3.4	2.6

Coating type identified by Diffuse Reflectance FTIR: ~~aliphatic~~ polyurethane with acrylic additives. detected aromatic components - need to evaluate light stability

REMARKS (FOR LAB USE ONLY)

G82 0169

STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION
CHEMICAL LABORATORY TEST FORM
MR 0457 (Rev. 8/92)

FROM

REPORT OF TESTS ON	INITIAL	TEST NUMBER	CONT., W.O., OR P.O. NUMBER
FRP Poles	AR	9131665	
AGENCY	HOURS	LOT NUMBER	DATE RECEIVED 9/28/94
SOURCE	TRADE NAME		
OWNER OR MANUFACTURER WATLEY			MANUFACTURER'S BATCH NO.

TEST RESULTS

Measured coating thickness on poles using Tooke gauge. ASTM D 4138
identified a primer beneath finish coats.
both coatings identified as polyurethanes by FTIR
both coating appear to have aromatic substituents
and light stability should be evaluated.

Pole #	WF35C1	WF35T1	WF35C2
Loc #	(mils finish + mils primer)		
1	1.5 + 1.0 = 2.5 mils tot.	2.0 + 1.0 = 3.0	1.5 + 1.5 = 3.0
2	2.0 + 3.0 = 5.0	1.5 + 1.5 = 3.0	1.5 + 2.0 = 3.5
3	1.5 + 2.0 = 3.5	1.5 + 1.5 = 3.0	2.0 + 1.0 = 3.0
4	2.0 + 1.5 = 3.5	2.0 + 1.0 = 3.0	1.5 + 1.0 = 2.5
5	1.0 + 1.5 = 2.5	1.0 + 1.5 = 2.5	1.5 + 1.0 = 2.5
6	1.0 + 1.5 = 2.5	1.5 + 1.5 = 3.0	2.0 + 1.5 = 3.5
#	WF30C2	WF30T1	WF30C1
1	2.0 + 1.0 = 3.0	1.0 + 2.0 = 3.0	2.0 + 2.0 = 4.0
2	2.0 + 1.5 = 3.5	2.0 + 3.0 = 5.0	2.0 + 2.0 = 4.0
3	2.0 + 2.0 = 4.0	1.0 + 2.0 = 3.0	2.5 + 1.5 = 4.0
4	2.0 + 2.0 = 4.0	1.5 + 2.0 = 3.5	2.5 + 1.0 = 3.5
5	2.0 + 2.0 = 4.0	1.5 + 1.5 = 3.0	2.0 + 1.5 = 3.5

MARKS (FOR LAB USE ONLY)

MAY 2 9 1995

STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION
CHEMICAL LABORATORY TEST FORM
MR 0457 (Rev. 8/92)

p. 3/27/95

BACK

TEST NUMBER 9S80293

FRP poles
Manufactured by Shakespeare

CHARGE	EXPENDITURE AUTH.	SPECIAL DESIGNATION	AMOUNT
[illegible] 65	6360001		

RESULTS

Fiberglass Poles, Coating Thickness per ASTM D-4138 (mils)			
Measurement #	Pole # SF35C1	Pole # SF35T1	Pole # SF35C2
1	2.5	1.0	2.0
2	1.5	1.0	1.0
3	1.5	1.5	1.0
4	2.5	2.5	1.5
5	2.5	2.0	2.0
6	2.0	1.5	2.0
Average:	2.08	1.58	1.58

DE ACCT
DME STRUCTURES
RE CONST
SM MATERIEL OPERATIONS
BERK PROCUREMENT
LA BAY TOLL
CONT FILES BDR
✓ OTHER ~~J. Daset~~ M. O'Keefe
~~(copy front and back)~~

CHIEF, DIVISION OF NEW TECHNOLOGY, MATERIALS AND RESEARCH

BY [signature] 3/27/95