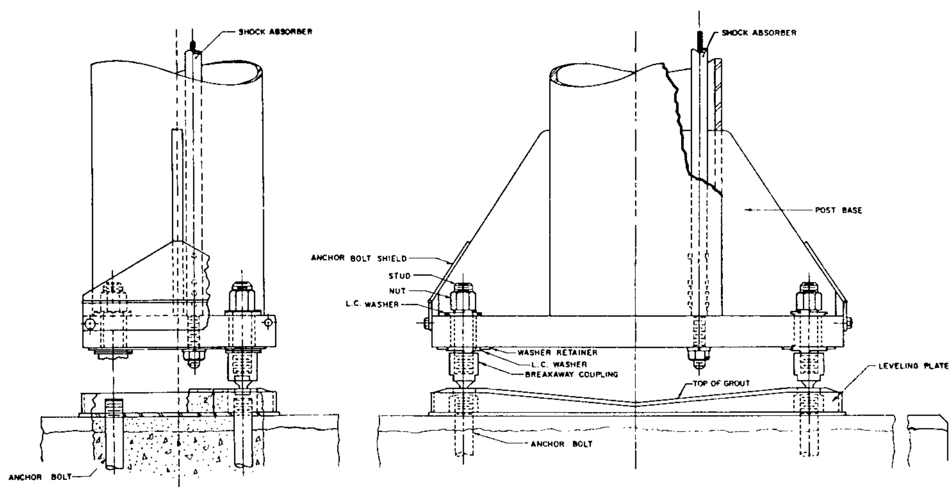
U.S. Department of Transportation
Federal Highway Administration

The New Jersey Breakaway Sign Support System

Office of Technology Applications

A State and Local Programs Report



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16. Abstract

This manual has been designed to provide individuals or organizations interested in roadside safety with the latest information concerning the concept, assembly and maintenance of the New Jersey Breakaway Sign Support System. This system was conceived and designed by the New Jersey Department of Transportation and has been in use in New Jersey since circa 1973. The manual details the assembly of the system as well as provides additional information regarding its function and construction.

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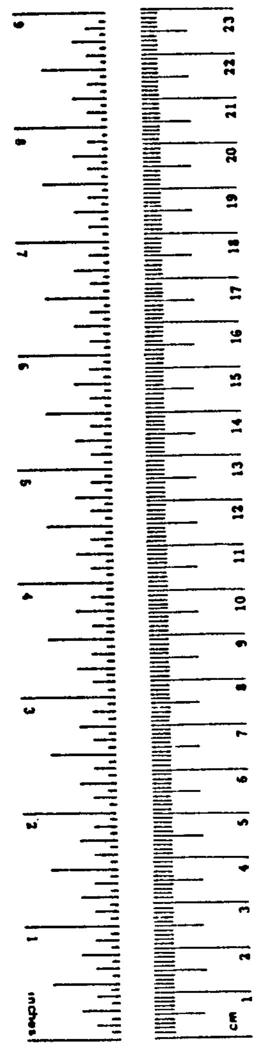
METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	2.54	millimetres	mm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
	AREA			
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.0929	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
mi^2	square miles	2.59	kilometres squared	km^2
ac	acres	0.395	hectares	ha
	MASS (weight)			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	VOLUME			
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.0328	metres cubed	m^3
yd^3	cubic yards	0.0765	metres cubed	m^3

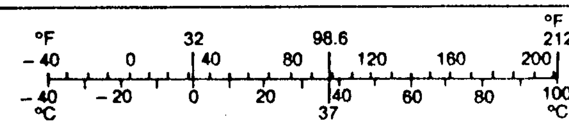
NOTE: Volumes greater than 1000 L shall be shown in m^3.

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



APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
	AREA			
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
km^2	kilometres squared	0.39	square miles	mi^2
ha	hectores (10 000 m^2)	2.53	acres	ac
	MASS (weight)			
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T
	VOLUME			
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

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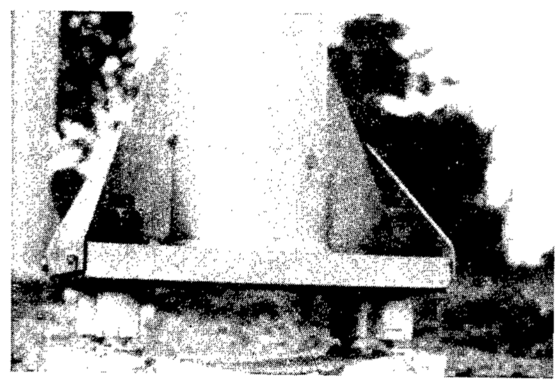
INTRODUCTION

As highway mileage and vehicle travel increased, so did collisions with roadside appurtenances. By the mid 1960's, with the enactment of the Highway Safety Act, research and development was initiated with the goal of saving lives on our nation's highways.

One of New Jersey's many contributions toward this goal was the development, testing and subsequent implementation of the New Jersey breakaway sign support system for large ground-mounted roadside signs.



The concept of the New Jersey breakaway sign support system is based on two components: the breakaway coupling and the load concentrating (L.C.) washer (see figure 1).

The L.C. washers are designed to prevent bending of the coupling's necked down section when normal wind loads are applied to the sign panel. However, when a vehicle impacts the post near the base, the washers are overpowered, allowing the base to move and the couplings to bend and break about the necked down section. The New Jersey breakaway sign support base assembly can be impacted safely from virtually any angle. A detailed typical analysis is included in appendix A.

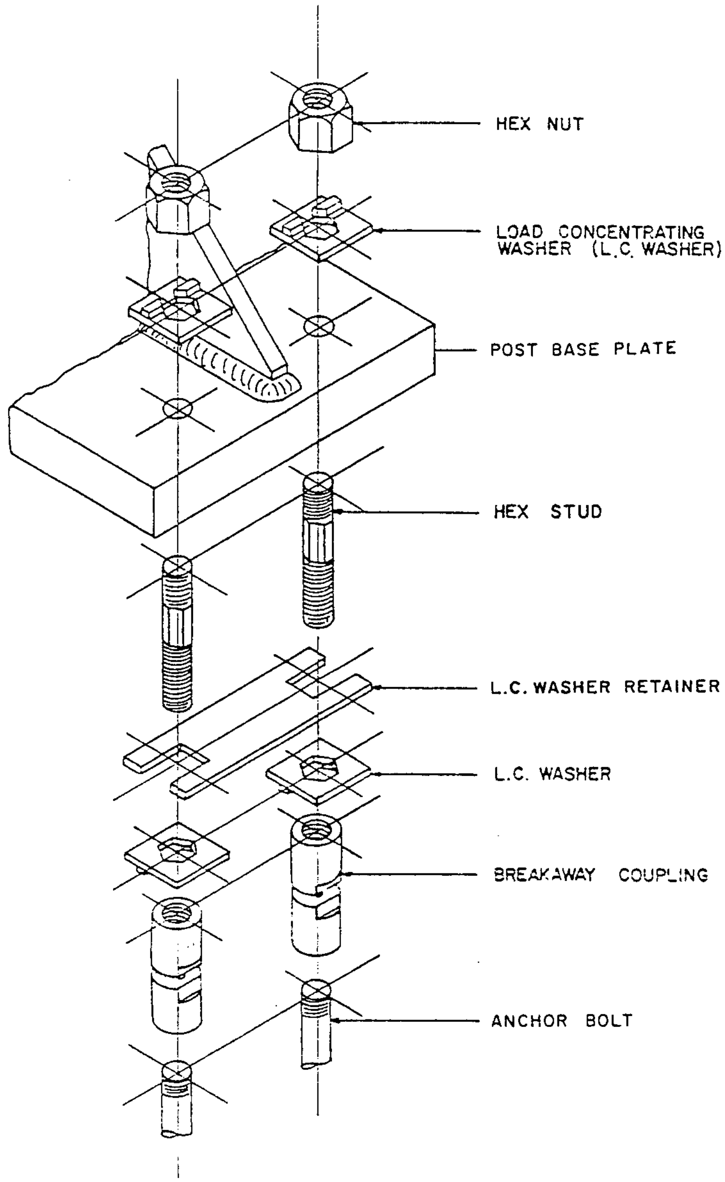
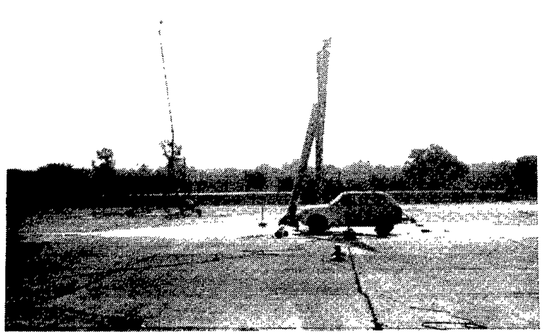


Figure 1. Breakaway Base Assembly



Once the couplings break, the post base separates from its foundation as shown here. Figure 2 demonstrates how it then rotates up and out of the way of the errant vehicle.

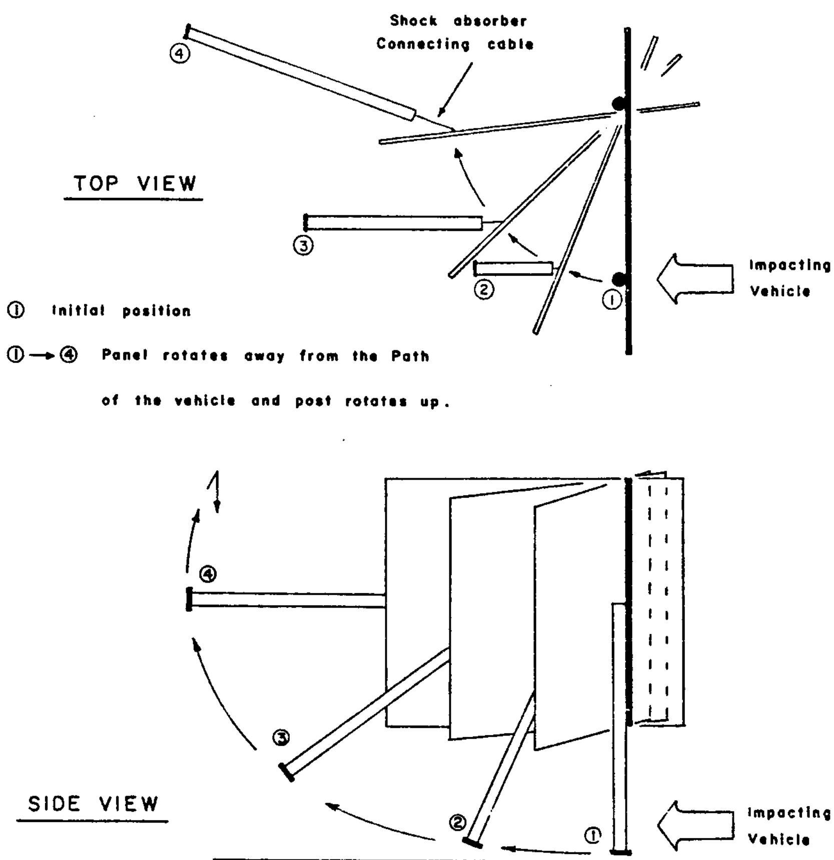
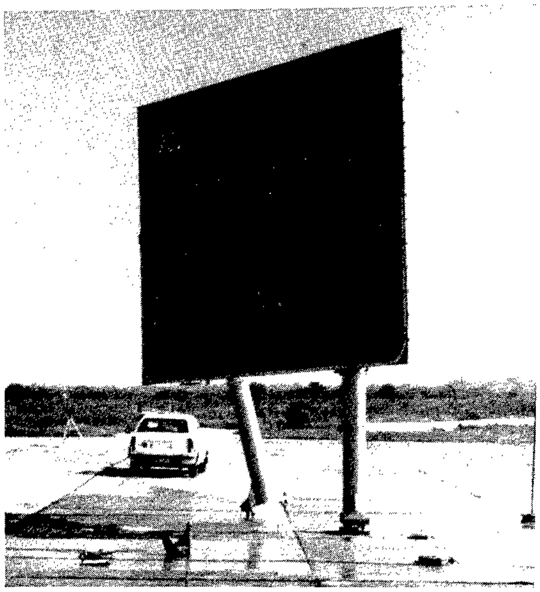


Figure 2. Typical "During Impact" Action

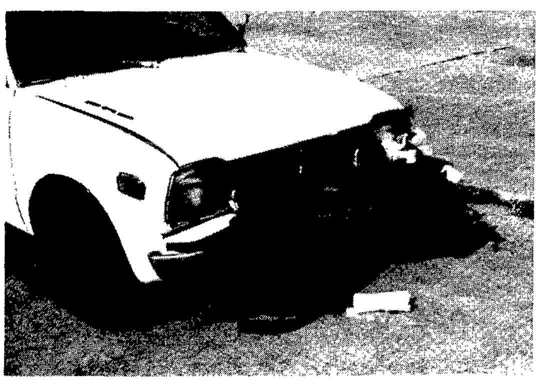
The post is prevented from flying completely free of the sign structure by a wire rope cable attached to the back of the sign panel. This cable is part of a shock absorbing device installed vertically within each support post, as noted in figure 2 and shown in detail on the plans in appendix G.

Even though from a safety point of view the system was accomplishing its main objective, that of saving lives, components in the system were periodically modified in an effort to reduce the amount of hardware damage being sustained after an impact.



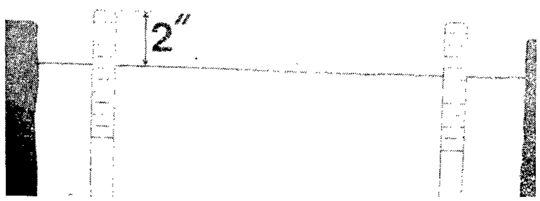
In October of 1983, a breakaway sign structure incorporating several significant modifications, including new low toughness couplings, was crash tested with 1800 lb vehicles under the guidelines of the National Cooperative Highway Research Program (NCHRP) Report #230, the latest procedures for the safety performance evaluation of highway appurtenances.

The modified design complied with the new safety requirements at high (60 mi/h) and low (20 mi/h) speed impacts and resulted in minimal damage to the test vehicle and sign structure components.

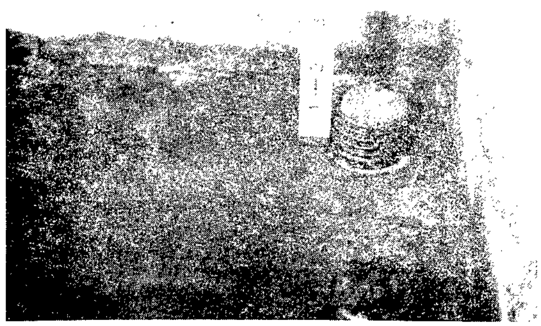


To ensure that the system affords the maximum level of safety to the motoring public, it is crucial that system operation be understood and that proper construction and maintenance procedures be followed. Hence, this technology transfer manual has been assembled to provide Construction and Maintenance personnel with the latest information regarding the operation, construction and maintenance of the New Jersey breakaway sign support system.

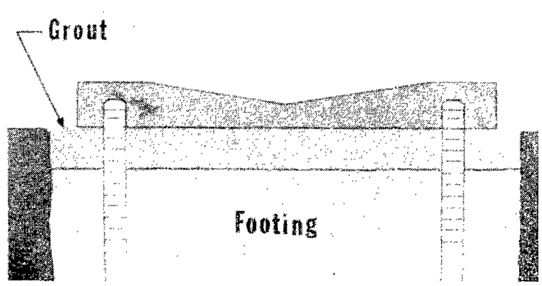
ASSEMBLY PROCEDURE



Installation of the New Jersey breakaway sign structure begins with construction of footings and installation of anchor bolts. Care should be taken to ensure that the anchor bolts are properly spaced, aligned and set to proper elevation. The concrete footing is poured to within 2 in of the top of the anchor bolts.

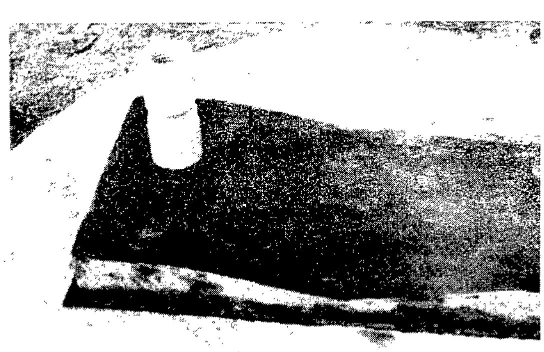


When the conrete sets, a leveling pan, is positioned on top of the footing so that about 1-1/8 in of anchor bolt protrudes into the pan.

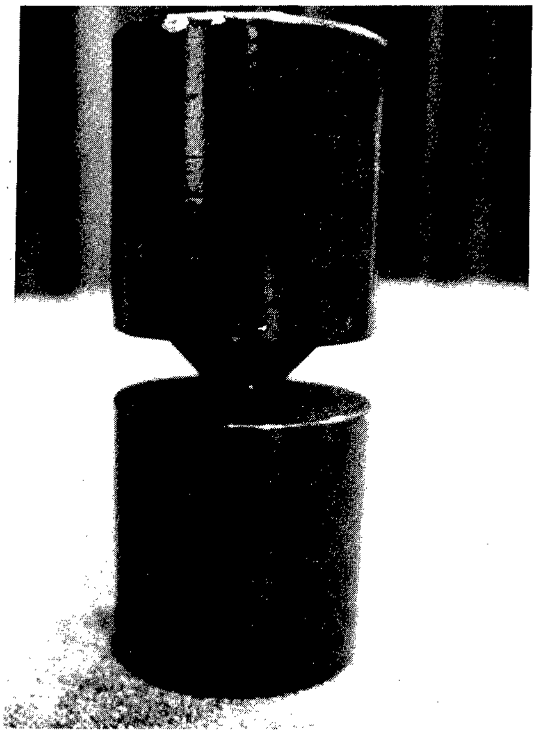


The remaining height between the top of the footing and the bottom of the pan is filled with grout to make the pan completely level.

If the anchor bolts and the leveling pan can be properly positioned simultaneously, such as with the aid of a jig, then the grout can be omitted and the concrete footing can be poured level with the bottom of the pan.

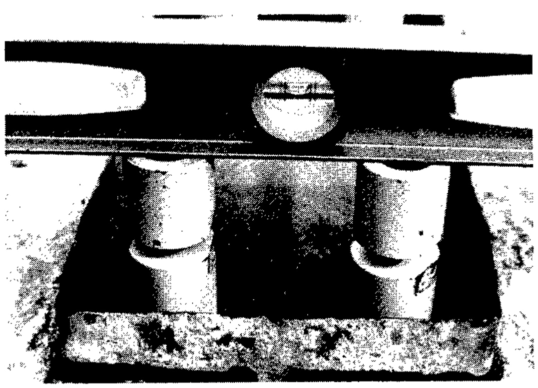


After the grout under the leveling pan has set, the breakaway couplings are screwed onto the anchor bolts. A lubricant (grease or silicone spray) should be applied to all threaded connections to facilitate installation and future removal.



The difference in hole sizes at each end of the breakaway coupling ensures that the coupling is installed on the anchor bolt with the smaller end of the taper pointing downward.

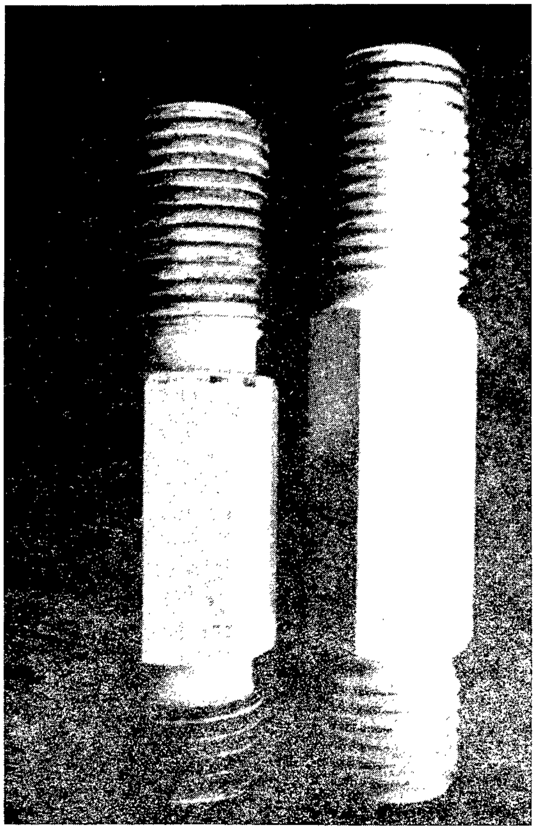
If a wrench is used to screw down the couplings make sure that only the lower wrenching flats of the coupling are grasped. This is done to prevent twisting of the coupling's tapered section.



The top of the couplings are leveled using a caprenter's level.

The level should be laid crosswise, lengthwise and diagonally over the couplings. Rotate each coupling until all four are perfectly leveled.

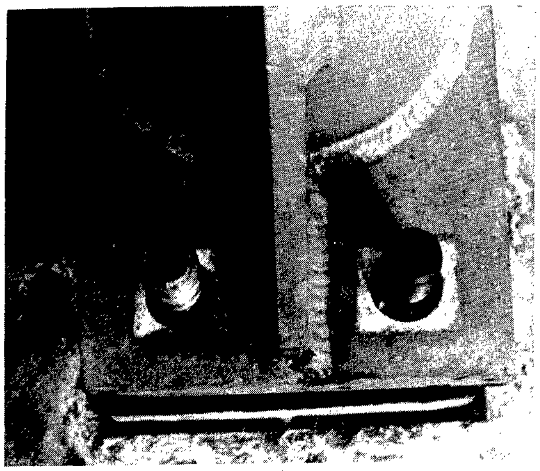
Hex studs are then screwed into the top of the coupling. Here, also, some lubricant is applied to facilitate installation and future removal.



Make sure the correct hex stud, as required per plans, is installed and that the shorter thread length is screwed into the top of each coupling.

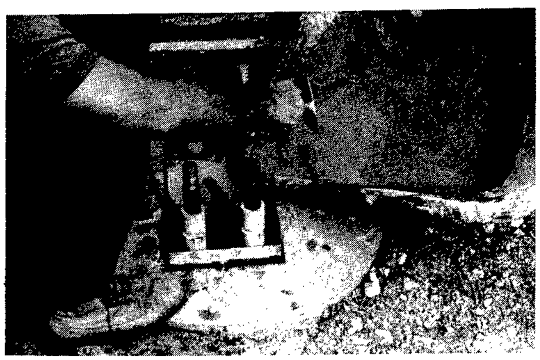
There are four sizes of hex studs used with the breakaway sign design, depending on the size of the sign support used. Each hex stud differs in overall length and upper thread length. Shown here for comparison are Sizes 3 and 4.

Before continuing with the installation, it is best at this time to confirm that the hex studs will fit loosely through the base plate holes by trying the post on the base.

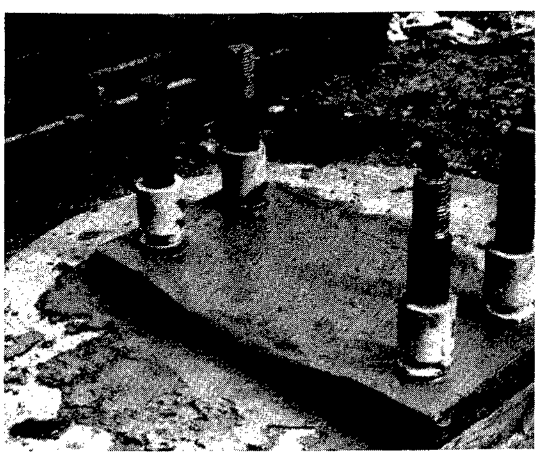


By design, the holes in the base plate are sufficiently oversized to ensure a loose fit even when the anchor bolts may not be perfectly aligned.

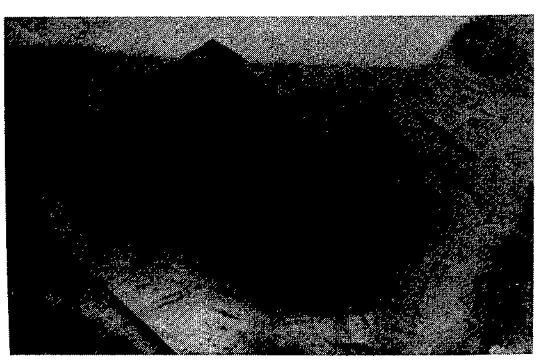
If any of the hex studs do not fit in loosely, it is a good indication that either the anchor bolt installation or the holes in the base plate do not conform to specifications. The problem must be identified and corrected before continuing with the installation.



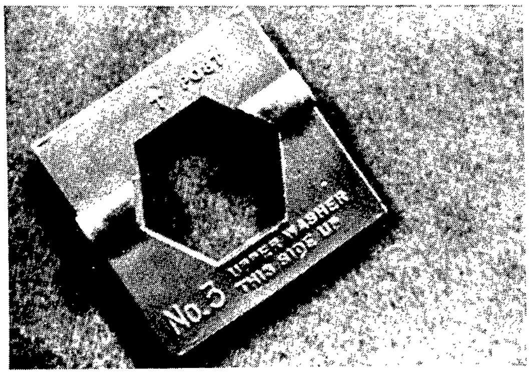
Once the fit is confirmed, the leveling pan can be filled with grout.



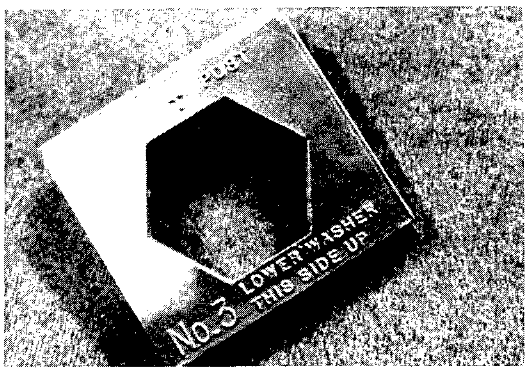
The surface of the grout should be finished smooth closely following the slope of the side of the pan. Care should be taken to keep the throat of the breakaway coupling free from grout.



The sloping surface of the grout is designed to provide a ramping surface for the post base during impact action. Scrape marks made by the broken coupling's upper half are clearly visible in this after-impact photo.

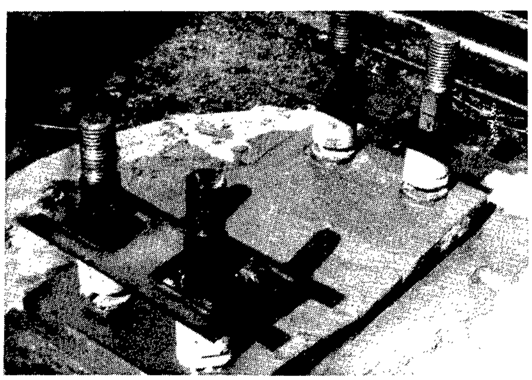


The lower set of load concentrating washers are next positioned over the hex studs. The L.C. washers are marked "LOWER WASHER THIS SIDE UP" on one side and "UPPER WASHER THIS SIDE UP" on the other.
When properly positioned, the lower washers will have the raised shim portion face down and in direct contact with the top of the coupling.
The arrow imprinted on the washer needs to be pointing toward the post.



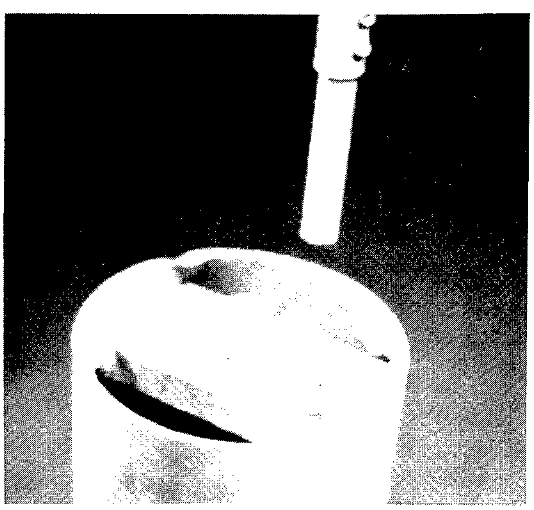
Make sure the correct washer is installed. There are four sizes of washers used in the breakaway design; each is identified by a number and a corresponding color code painted on its side.

All washers on a post will be the same. Washers on an adjacent post can differ, if that post is of a different length.



Washer retainers are placed in the grooves of the front and rear set of washers. It may be necessary to back off each hex stud a maximum of 30 degrees to allow the washer retainer to fit.

The base is now ready for the support post to be mounted, but first let's take a look at the assembly of the components.



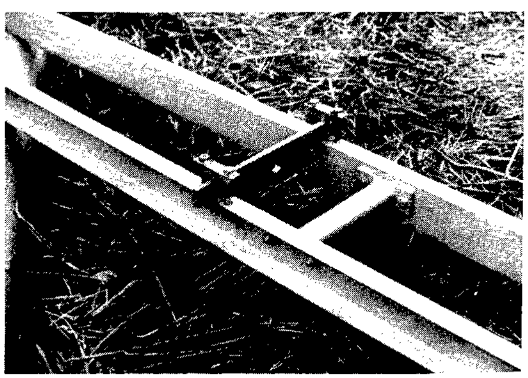
The shock absorbing device mentioned earlier is inserted through a slot in the bar welded across the top of the post and the threaded lower portion is pulled through a hole in the post base.

The shock absorber is secured to the base plate with a lock washer and nut. Initially, just turn the nut by hand about 3/4 of the way in. We'll get back to it later.

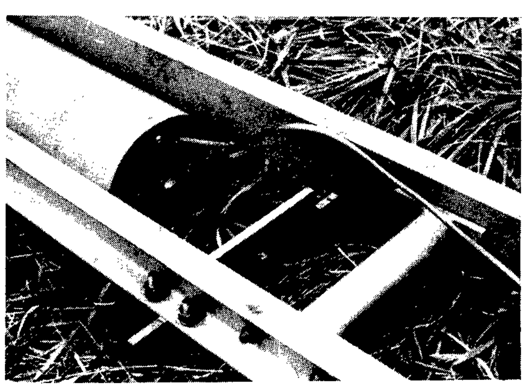
A cover plate is secured to the top of the post. Its purpose is to keep out rain, snow and debris.

About 2 ft of the shock absorber's wire rope cable extends above the post top.

Note that the post is rotated so that the cable is in the 12 o'clock position during assembly.



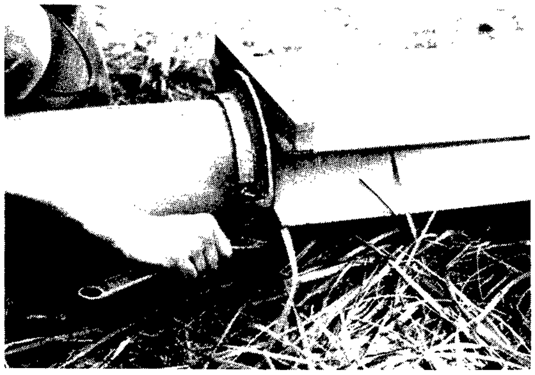
A post to panel connecting plate is secured to the channel frame assembly.



The channel frame is then positioned on the post.

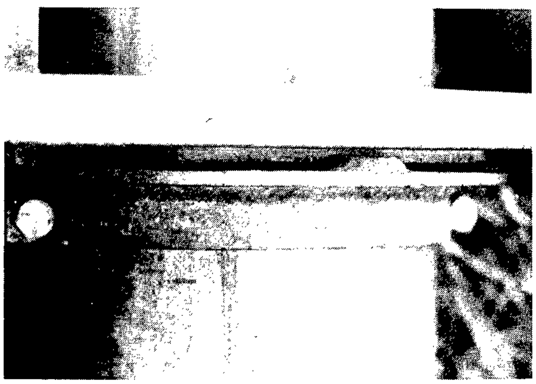
When properly aligned, the connecting plate will be positioned on the opposite side of the shock absorber cable.

The pin mounted at the top of the post fits into the hole in the connecting plate.



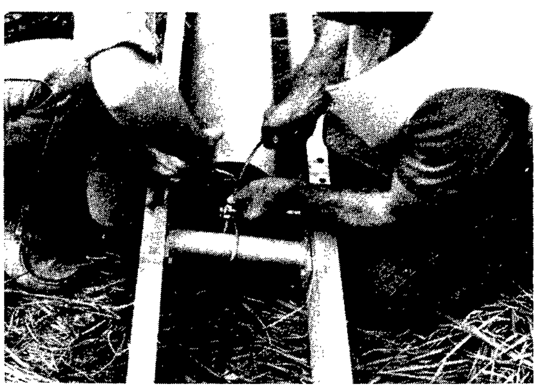
A two piece collar is bolted to the post tube just below the bottom of the channel frame.

Before securing the bolts, however, make sure that the collar is properly positioned.

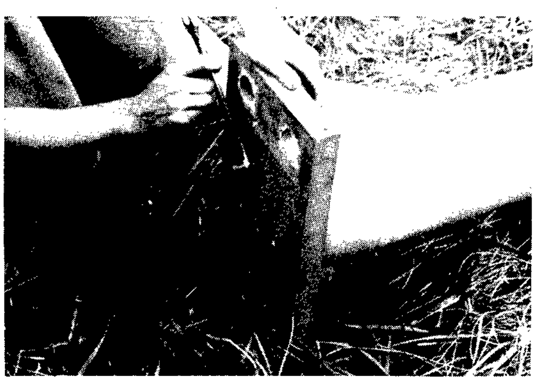


The small aluminum tab welded to the front half of the collar must be in front of a larger tab riveted to the bottom of the channel frame.

When positioned in this manner, these overlapping tabs will prevent the bottom of the sign panel from swinging forward by wind forces. The tabs do not interfere with the breakaway function during impact.



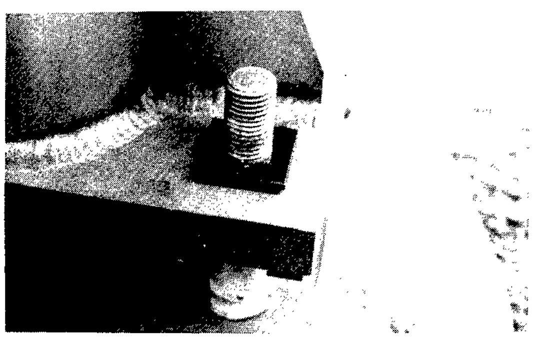
Once the channel frame bolts are tightened, the shock absorber cable is looped over the round tube bolted between each pair of channels. The cable is snugged as much as possible and secured with three wire rope clamps.



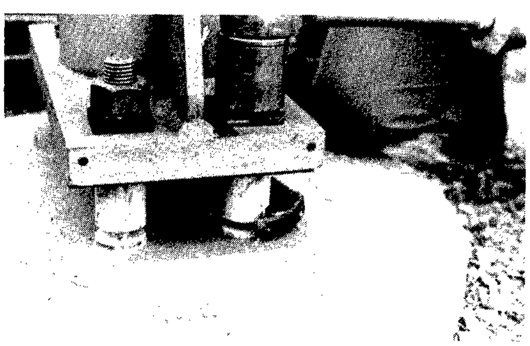
The nut at the bottom of the shock absorber is tightened using a wrench, further snugging the stiff wire rope loop on top. When the nut is fully seated against the base plate, the cable should be just snug enough to ensure that the pin at the top of the post and the post to panel connecting plate remain engaged, but not so tight as to initiate shock absorber slicing.

With the channel frame firmly assembled to the post, the post is lowered over the hex studs coming to rest on top of the lower washers.

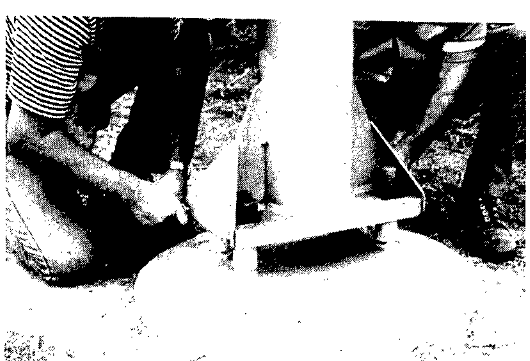
Care must be taken to ensure there is no lateral pressure put on the couplings.



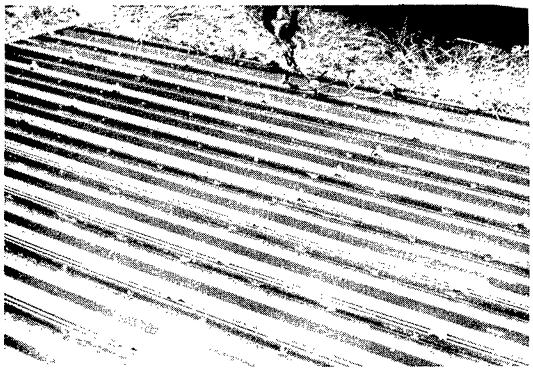
The upper set of washers are now positioned with the raised shim portion now facing upwards and the arrow still pointing toward the post.



Hex nuts are placed on the hex studs and tightened. The upper wrenching flats of the coupling are now held with a wrench. There is no torquing requirement, the nuts should be just snuggly tightened by the turn of the nut method.

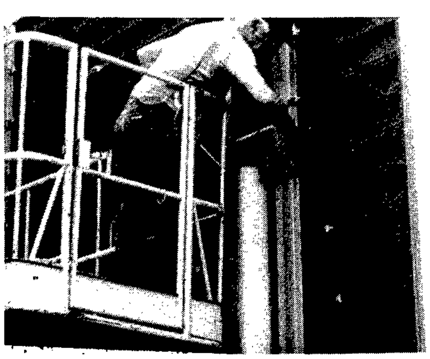


Post base shields are bolted to the front and back of the post base. The shields help protect the exposed hex stud threads in the event of an impact.

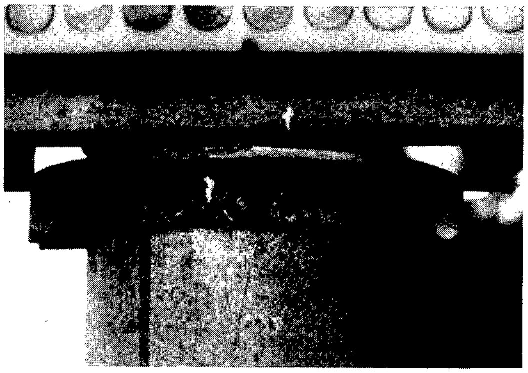


The sign panel is now readied for installation. Sign panel clips are inserted into each panel groove and staggered between each side of the channel frame, as detailed on the plan sheets.

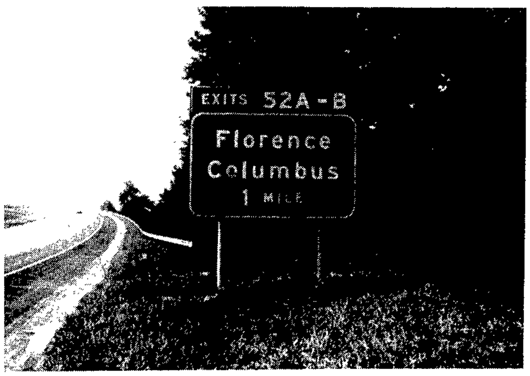
The entire sign panel is lifted, centered against the channel frames and lowered until it rests on the bottom lip of the channel frames.



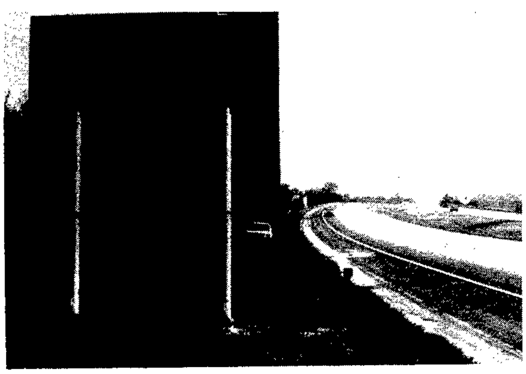
The sign panel clips are pushed against the edge of the channel and tightened with a socket wrench.



Once the sign panel has been secured to the frames, a hole is drilled through each post collar and a blind rivet is inserted to keep the collar in place.



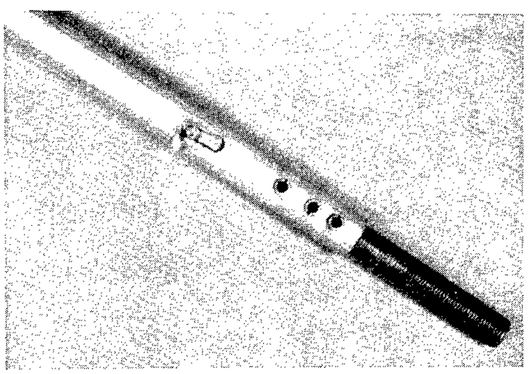
The installation is now complete.



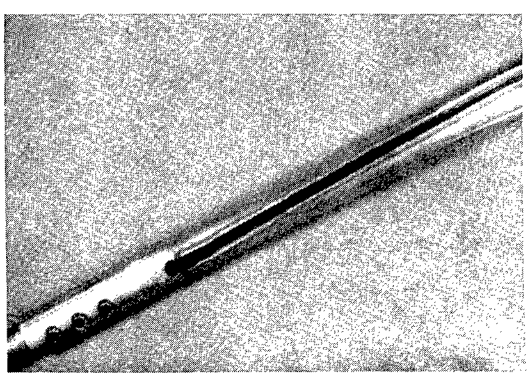
No regular maintenance will be required until the sign structure is knocked down by an errant vehicle.

A typical after impact maintenance of a NJ breakaway sign consists mainly of replacement of the breakaway couplings and shock absorber(s).

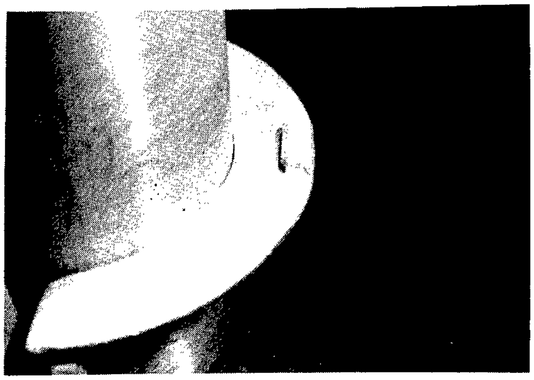
Intact couplings from the unimpacted post(s) are also replaced as a precaution in case small cracks, invisible to the naked eye, may have developed due to the forces of the impact.



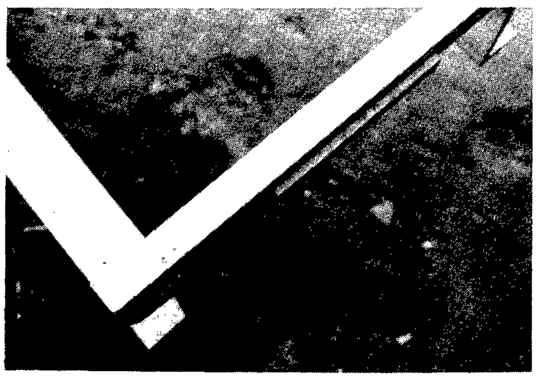
After each impact, the shock absorbing device should be removed from each post and inspected for slicing.



Generally, the shock absorber in the unimpacted post will remain intact while the shock absorber in the impacted post may be sliced anywhere from 1/4 in to as much as 3 ft. Sliced shock absorbers must be replaced.



The post collar/channel frame connection may at times also require repair after an impact.



Occasionally, either the small tab welded to the collar or the larger tab riveted to the bottom of the channel frame or both may break off during impact action.

Down time can be minimized by having spare collars on hand. A damaged collar can later be repaired in the shop and reused in the future.

In addition to ensuring that the hardware is properly assembled, maintenance personnel should also inspect the site and make sure any deep ruts created by the errant vehicle are regraded and that the footing/base stub of the sign (as shown on sheet No. 1 of the construction plans) does not project more than 4 in above the ground. Other obstructions, such as trees which may have grown near the sign, should also be removed so that the area in front and behind the sign is clear.

CONCLUDING REMARKS

After 17 years of actual roadside experience, at least 68 of the estimated 500-700 breakaway signs installed on New Jersey roads since circa 1972 are known to have been impacted by errant vehicles. About half of the incidents have been documented by police reports; the others are suspected of being hit and runs with little known about the circumstances. The police documented incidents indicate only eight instances of injury, consisting mainly of complaints of pain and scratches. Based on the results of full scale crash tests of the modified design as presented in this report, it is anticipated the modified design will result in an even greater level of safety for the motoring public and function with less hardware damage, consequently, resulting in expedited re-erection.

Although construction and maintenance personnel were not charged with the responsibility of upgrading the design, several of the recent improvements are a direct result of their recommendations. Construction and maintenance personnel are commended for their contributions and are encouraged to continue to make suggestions to improve the safety to the motoring public.

Appendix A

NJ Breakaway Sign
Typical Wind and Impact Analysis

Wind and impact forces applied to the New Jersey breakaway support produce a bending moment at the critical section of the couplings. During wind loading, the eccentric load concentrating washers produce a counteracting moment which cancels the wind induced bending moment at the coupling's critical section. However, when a vehicle impacts one of the sign's support posts (18 in above the ground), the L.C. washers are not effective in cancelling the vehicle induced bending moment due to the reduced moment arm (about 1/10th the wind induced moment). As a result, the post and its base are moved in the direction of impact causing the couplings to bend and break at the critical section.

As a numerical example, a wind load of 2,000 lb, as calculated per AASHTO Standard Specifications for Structural Supports for Highway Signs, is applied to the center of the sign panel at a height (L_1) of 14 ft above the critical section of the couplings. This results in a bending moment, M_b, at the base of the support (figure 3.)

M_b = Wind load x L_1

M_b = 2,000 lb x 14 ft = 28,000 ft-lb

As the support post bends due to the load, tensile (T) and compressive (C) forces are applied to the couplings. Assuming the distance (ℓ) of two feet between the front (under tension) and rear (under compression) couplings, the reaction force on each coupling is calculated. (Calculations shown for tensile side.)

T = M_b/ℓ x number of couplings under tension)

T = 28,000 ft-lb/2 ft x 2 = 7,000 lb

The reaction forces are applied through the L.C. washers' eccentric shim causing a rotational bending moment at each coupling. Assume a shim eccentricity (e) of 0.0208 ft.

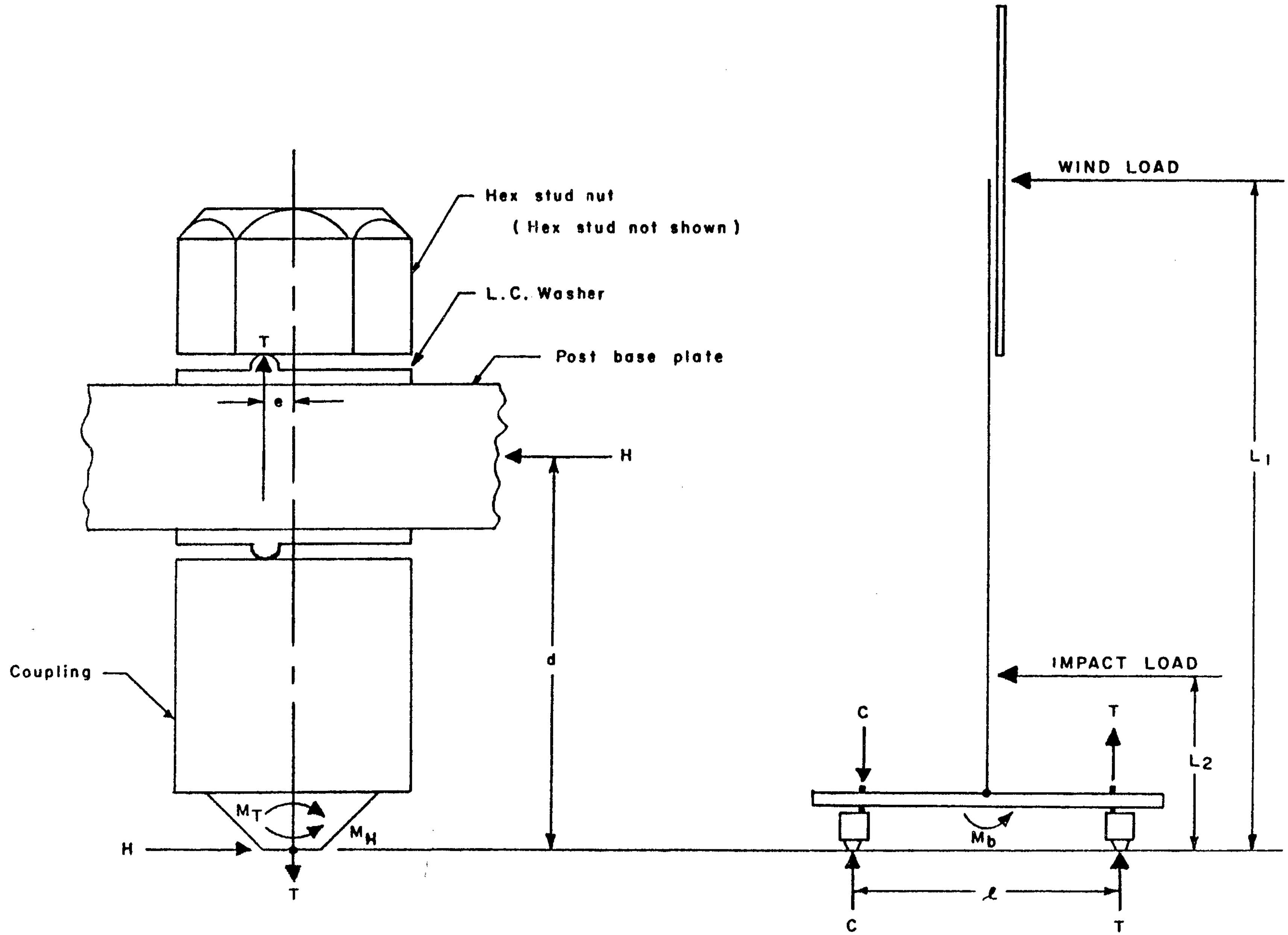


Figure 3. Breakaway Base Loading Forces

$M_T = T \times e$

$M_T = 7{,}000 \text{ lb} \times 0.0208 \text{ ft} = 146 \text{ ft-lb}$ (clockwise)

The applied horizontal wind load (H) is distributed equally to all four couplings through the center of the base plate.

$H = \text{Wind load/number of couplings}$

$H = 2{,}000 \text{ lb}/4 = 500 \text{ lb/coupling}$

Assuming a distance (d) of .2917 ft from the center of the base plate to the critical cross-section of the coupling, the horizontal load (H) produces a rotational moment at the critical section.

$M_H = H \times d$

$M_H = 500 \text{ lb} \times 0.2917 \text{ ft} = 146 \text{ ft-lb}$ (counterclockwise)

Since the rotational moments produced by the bending at the base, M_T, and by the horizontal wind force, M_H, are equal in magnitude but act in opposite directions, they cancel out resulting in no bending at the critical section of the coupling.

For a typical vehicle impact analysis, a vehicle impact load of 10,000 lb is assumed to be a typical force developed by a 1,800 lb vehicle impacting at low speed. The load required to fracture the couplings should, however, be considerably smaller since the low toughness property of the coupling material will allow breaking to occur at very low energy levels. The impact load is assumed applied at a height (L_2) of 18 in above the ground. The impact load results in a bending moment (M_b) at the base.

$M_b = \text{Impact load} \times L_2$

$M_b = 10{,}000 \text{ lb} \times 1.5 \text{ ft} = 15{,}000 \text{ ft-lb}$

The support bends under the load applying tensile (T) and compressive (C) forces to the couplings. (A 2-ft spacing between the front and rear couplings is assumed.)

$T = M_b/\ell$ x number of couplings under tension)

$T = 15{,}000$ ft-lb/2 ft x 2 = 3,750 lb

The tensile force is applied through the L.C. washer's eccentric shim causing a rotational bending moment at the critical section of the coupling. (A shim eccentricity (e) of 0.0208 ft is assumed.)

$M_T = T \times e$

$M_T = 3{,}750$ lb x 0.0208 ft = 78 ft-lb (clockwise)

The applied horizontal impact load (H) is distributed equally to all four couplings through the center of the base plate.

H = Impact load/number of couplings

H = 10,000 lb/4 = 2,500 lb/coupling

Assuming a distance (d) of 0.2917 ft from the center of the base plate to the critical section, the horizontal force (H) produces a rotational moment at the critical section.

$M_H = H \times d$

$M_H = 2{,}500$ lb x 0.2917 ft = 730 ft-lb (counterclockwise)

The rotational bending moments produced by the bending at the base, M_T, and by the horizontal force, M_H, result in a moment imbalance at the coupling's critical section.

$M_H - M_T$ = Rotational moment imbalance

730 ft-lb (ccw) - 78 ft-lb (cw) = 652 ft-lb (cw)

Since there is now a rotational moment imbalance at the critical section, the coupling's tensile stress (F_t) is checked.

$F_t = M/Z + P/A$

Where:

P = Axial load on each coupling

M = Resultant bending moment

A = Area of critical section

Z = Plastic section modulus

$$F_t = \frac{652 \text{ ft-lb } (12 \text{ in/ft})}{0.0334 \text{ in}^3} + \frac{7{,}500 \text{ lb}}{0.269 \text{ in}^2}$$

$$F_t = 234{,}252 + 27{,}881$$

$$F_t = 262{,}133 \text{ psi}$$

Since the resultant tensile stress (F_t = 262,133 psi) is in excess of the coupling's tensile strength range of 195,000 to 225,000 psi, the coupling will break at the critical section upon impact.

It should be noted that the coupling's critical section design (neck/notch shape) results in a neck strengthening effect of about 20 percent. Hence, the ultimate tensile strength range of about 195,000 to 225,000 psi is used for the above computation in lieu of the steel's ultimate tensile range of 165,000 to 185,000 psi.

Appendix B

NJ Breakaway Coupling
Steel Specification

1. CHEMICAL REQUIREMENTS - The steel shall conform with A.I.S.I. chemical composition requirements for Grade 4150 alloy steel and shall include the addition of Tellurium (0.01 percent min.) or Sellenium (0.035 percent min.) to improve machinability. If Tellurium is used, the Sulfur limit shall be 0.06 percent maximum.

2. MECHANICAL REQUIREMENTS - The steel shall be drawn at elevated temperature* to conform to the mechanical test requirements specified below:

Tensile Strength	165,000-185,000 psi
Yield Strength	155,000 psi min.
Elongation	13% max.
Reduction of Area	40% max.
Hardness	36-40 Rockwell-c
Toughness (Charpy V-Notch)	10 ft-lb max. at 70 ^{o}F.

3. DIMENSIONAL REQUIREMENTS - The steel shall be finished into two-inch (+0 in/-0.006 in) diameter bars and cut to 11 to 13 ft lengths prior to shipment. The steel bars from which test samples will be taken are exempted from the length requirement and will be accepted in less than 11 ft lengths.

4. INSPECTION - A New Jersey Department of Transportation engineer or representative shall have access to the facility concerned with the manufacture of the above-specified steel, at all times while the manufacturing of this steel is being performed. The manufacturer shall afford said engineer all reasonable facilities necessary to satisfy him that the steel is being

*Elevated temperature drawing is a process by which a heated bar stock, drawn through a die, achieves the required high strength and low toughness.

furnished in accordance with this specification. All tests and inspection shall be made at the place of manufacture prior to shipment and shall be so conducted as not to interfere unnecessarily with the operation of the plant.

The following New Jersey Department of Transportation representative shall be notified at least three (3) days prior to production and testing of this steel:

Chief, Bureau of Materials
New Jersey Department of Transportation
999 Parkway Avenue
Trenton, NJ 08625

Telephone: (609) 530-2308

5. SAMPLING - Each required sample bar and the location on the bar from which test samples will be taken shall be randomly selected from the steel lot by the NJDOT engineer. The steel lot shall consist of all steel from the same heat sequentially processed under the same conditions.

6. TEST METHODS - The manufacturer shall perform tensile (including yield, elongation and reduction of area), hardness and Charpy impact tests in accordance with procedures established in the latest issue of ASTM Methods A-370. The manufacturer shall also perform chemical analysis in accordance with procedures established in the latest issue of ASTM Methods A-751.

7. NUMBER OF TESTS - Five each of tensile, hardness and impact tests and five chemical analyses on samples taken from the five tensile specimens shall be required to satisfy the acceptance criteria.

8. ACCEPTANCE CRITERIA - The steel shall be considered in compliance when all of the above requirements are satisfied. If any test specimen fails because of mechanical reasons such as failure of testing equipment or improper specimen preparation, it may be discarded and another specimen taken.

9. CERTIFICATION - A manufacturer's certification that the steel was produced, tested and complies with this specification, together with the test results shall be furnished at the time of shipment.

10. SHIPMENT AND DELIVERY - Shipment of the steel will be FOB to the following address:

    Chief, Bureau of Purchase and Stores
    New Jersey Department of Transportation
    Fernwood Shops (Building #24)
    999 Parkway Avenue
    Trenton, NJ 08625

    The Supervisor of Materials at the New Jersey Department of Transportation offices located at 12 Farrell Avenue, Trenton, NJ 08625, Telephone No. (609) 530-2308 shall be notified at least 48 hours in advance of any shipment. Deliveries must be arranged to be made on a state business day between the hours of 8:00 a.m. and 3:00 p.m. The steel bars shall be securely bundled for shipment and identified with the heat number. Each bundle shall not exceed 1,000 lb.

11. PAYMENT - The price for the steel shall include manufacturing, testing, packaging and identification, loading, trucking expense, all labor and all else necessary to ensure delivery of the required material to the designated location. Payment for the steel quantity ordered will be the price quoted and as indicated on the purchase order.

Appendix C

Mechanical and Chemical Properties For "e.t.d." 4150-X* Steel

Chemistry:

Carbon:	0.48% Minimum
Manganese:	0.75/1.00%
Phosphorus:	0.035% Maximum
Sulfur:	0.040% Maximum**
Silicon:	0.15/0.35%
Chromium:	0.80/1.10%
Molybdenum:	0.15/0.25%
Tellurium:	0.01% or Selenium 0.035%

**When tellurium is added, sulfur may be 0.04/0.06%.

Mechanical Properties:

Tensile Strength:	165,000-185,000 psi
Yield Strength:	155,000 psi (Minimum)
Elongation:	9% Mean (13% Maximum)
Reduction of Area:	34% Mean (40% Maximum)
Machinability:	56% of C-1212
Toughness:	10 ft-lb (maximum at 70 ^{o}F)

*"e.t.d." 4150-X is a product of the LaSalle Steel Company, Hammond, Indiana.

Appendix D

NJ Breakaway Coupling
Fabrication Specification

DESCRIPTION - The breakaway coupling specified under this contract shall be fabricated in accordance with the detail included as part of this specification (figure 4.)

MATERIAL - The breakaway coupling shall be machined from a special low toughness-high tensile alloy steel to be supplied by the New Jersey Department of Transportation. The steel shall be two-inch diameter bar approximately 12 feet long.

The required number of steel bars shall be made available to the fabricator at the following location:

Chief, Bureau of Equipment
New Jersey Department of Transportation
Fernwood Shops (Building #1)
999 Parkway Avenue
Trenton, NJ 08625

Pick-up of the steel must be made on a state business day between the hours of 8:00 a.m. and 3:00 p.m. The fabricator shall notify the Supervisor of Materials, at NJDOT's offices located at: 12 Farrell Avenue, Trenton, NJ 08625, Telephone: 609-530-2218, at least 48 hours in advance of pick-up.

FABRICATION - The fabricator shall ensure that couplings are machined only from the special steel supplied by NJDOT. This steel has been selected because of its unique low toughness/high tensile property which allows a support post on a breakaway highway sign system to breakaway when impacted by an errant vehicle. Use of any other steel for the couplings could cause the system to malfunction.

The fabricator shall exercise care in machining couplings to ensure good workmanship. The fabricator is required to drill and tap the coupling ends prior to cutting the reduced section located midway. A skin cut of no more than 0.030 in should be taken from the outside diameter of the bar before machining the coupling. The surface of the finished coupling shall be clean, dry and free from any foreign material.

The following NJDOT representative shall be contacted to resolve any questions concerning fabrication of breakaway couplings. Said representative shall be notified at least three (3) days prior to start of fabrication of couplings:

Chief, Bureau of Materials
New Jersey Department of Transportation
999 Parkway Avenue
Trenton, NJ 08625

Telephone: 609-530-2308

INSPECTION - A NJDOT engineer shall have access to the fabricator's facility concerned with the fabrication of the breakaway couplings at all times while the machining of said couplings is being performed.

The fabricator shall afford said engineer all reasonable facilities necessary to satisfy him that the couplings are being fabricated in accordance with this specification.

Couplings shall be considered in compliance with specifications when all the dimensional requirements are within the prescribed limits.

Couplings which exhibit any cracking or which are deformed shall be rejected.

IDENTIFICATION - All couplings under this contract shall be identified with an identifiable mark, such as a letter, number or company logo so that each coupling can be readily identified with the producer when sampled, distributed and installed. The mark shall be permanently stamped to one of the wrench flats on the 1¼ in threaded portion of the coupling. The identification mark must be approved by the Chief, Bureau of Materials prior to application on couplings.

COATING - Couplings shall be inspected and approved for coating by the NJDOT engineer. A primer coat shall be applied which will be fully compatible with the coating. A red coating ground from fully homogenized Cellulose Acetate Butyrate plastic and appropriate coloring agents shall be applied to the couplings by the electrostatic spray process.

The coating may be fused to the coupling by exposure to temperatures not exceeding 450 $^{\circ}$F for a maximum of eight minutes duration. The coating shall have a minimum thickness of three mils.

Chipped areas on the coating surface shall be repaired. All threaded surfaces, after coating, shall be cleaned, if necessary, to allow them to function properly.

PACKAGING - The breakaway couplings shall be packaged securely in cartons so as to prevent direct contact between the couplings. Each carton shall contain twenty-four (24) couplings and shall be properly sealed to prohibit the infiltration of dirt. Clearly stamped on the exterior of each carton shall be the count and net weight of the contents.

Cartons shall be protected to ensure they will remain dry. Any cartons which are delivered wet or exhibit evidence of water damage will be rejected and will be returned to the sender at his expense.

SHIPMENT AND DELIVERIES - The total quantity of breakaway couplings stated in the proposal must be delivered within the six (6) month period immediately following the contract award date.

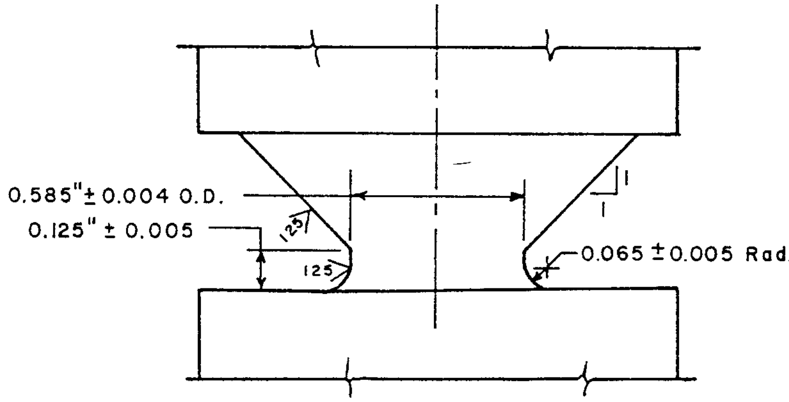
The vendor shall notify the Supervisor of Materials, at the New Jersey Department of Transportation offices located at 12 Farrell Avenue, Trenton, NJ 08625, Telephone: 609-530-2218, a minimum of 48 hours in advance of any shipment. Deliveries must be arranged to be made on a state business day between the hours of 8:00 a.m. and 3:00 p.m.

Shipments will be required to be made to the following address:

Chief, Bureau of Purchase and Stores
New Jersey Department of Transportation
Fernwood Shops (Building 24)
999 Parkway Avenue
Trenton, NJ 08625

Whenever a shipment is comprised of more than six (6) cartons, the cartons shall be properly stacked on wooden pallets to permit safe unloading with mechanical forklift equipment.

QUANTITY AND PAYMENT - The price for the coupling quantity ordered shall include pick-up of steel, fabrication, packaging, loading, delivery expense, labor and all else necessary therefore and incidental to ensure delivery to the designated location. Payment for the coupling quantity ordered will be the price quoted and as indicated on the purchase order.



BREAKAWAY COUPLING
THROAT DETAIL

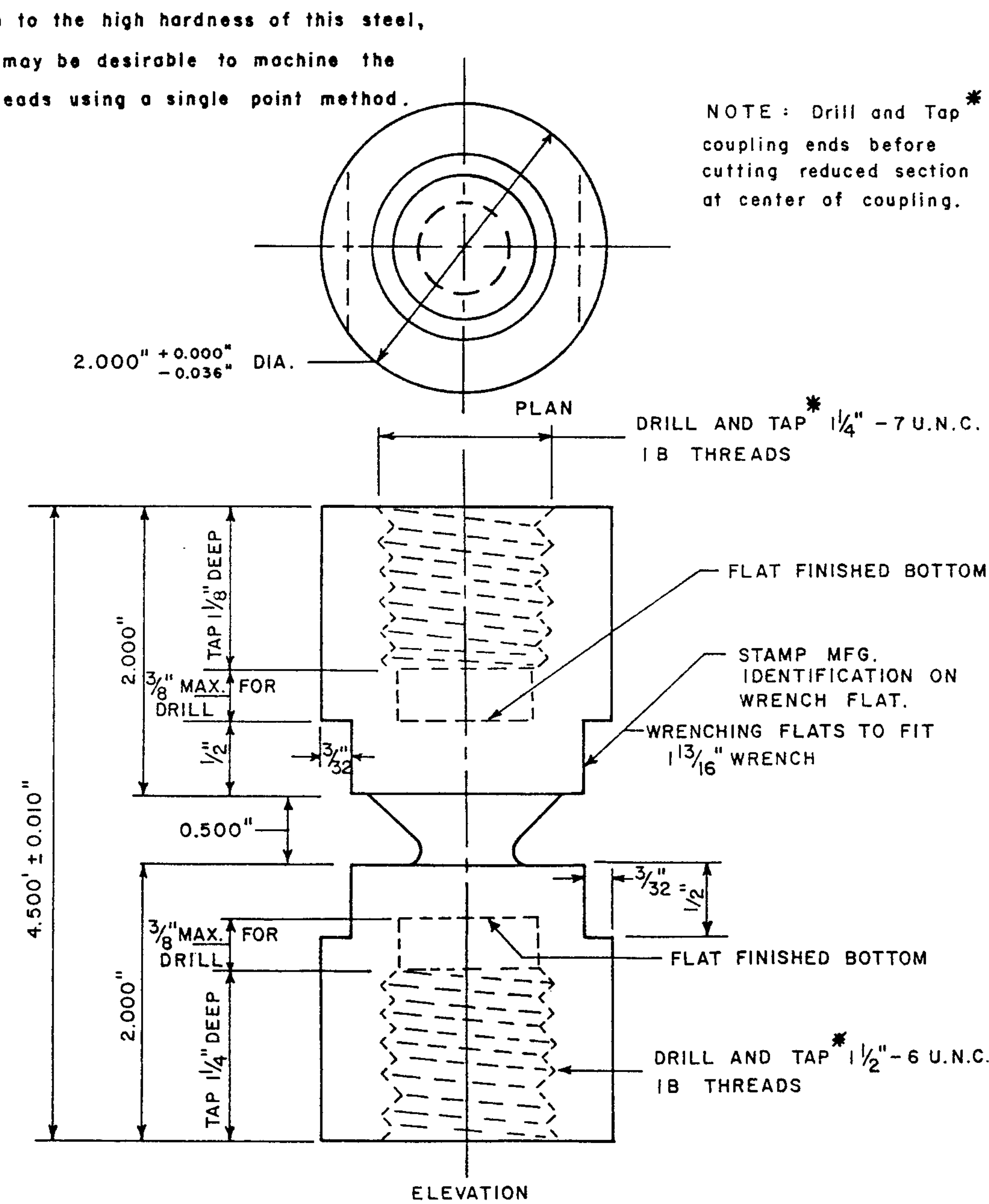


Figure 4. Breakaway Coupling

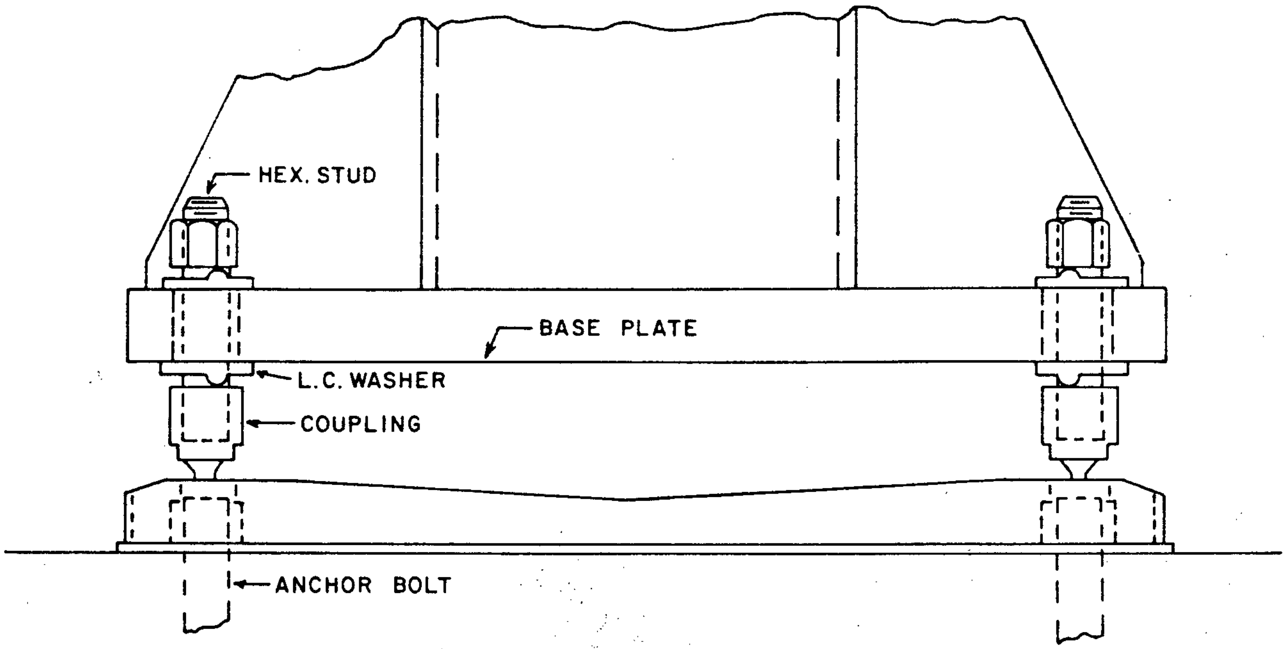
Appendix E

Background for NJ Breakaway Coupling Steel and Coupling Fabrication Specifications

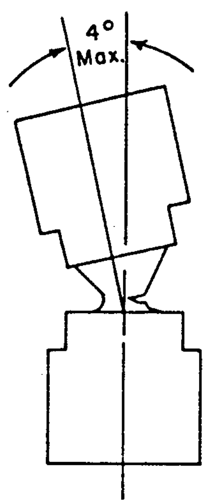
The NJ Breakaway Sign concept is based on two basic components: the breakaway coupling and the load concentrating (L.C.) washer. The L.C. washers are designed to cancel wind induced bending moments at the coupling's necked-down section. However, when a vehicle impacts a support post about 18 in above the ground, the post and its base are moved (forward) in the direction of the impact. The L.C. washer's built in eccentric shims act as pivots allowing the coupling's upper section to bend about the critical section. The degree of bending is limited to about 4 degrees by the clearance built into the base plate's hex stud holes (figure 5).

Since the couplings break mainly in bending when a sign structure is impacted by an errant vehicle, the ductility of steel selected for the couplings is low enough to ensure that the ultimate stress in the tensile fibers is reached prior to the coupling bending the maximum of 4 degrees. Under stress, the outside fibers begin to break, forming minute cracks which reduce the cross-sectional area and lead to a rapid progressive failure of the entire cross-section.

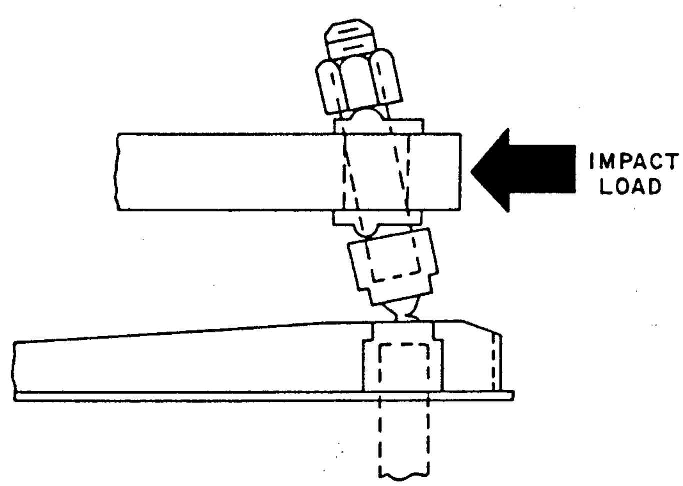
The energy exhausted in fracturing a steel is measurable and is defined as the "toughness" of the steel. This property is typically measured by a V-notch Charpy impact test (ASTM A-370) and is reported in terms of ft-lb. Ductile steels fracture in sheer and with appreciable absorption of energy while non-ductile steels fracture rapidly in cleavage and with low energy absorption. The mid-range between sheer and cleavage fractures is frequently defined in the range of 10 to 20 ft-lb. Hence, to ensure the rapid, low energy fractures under impact, a maximum toughness limit of 10 ft-lb was selected for the breakaway coupling.



BREAKAWAY POST BASE ASSEMBLY



MAXIMUM COUPLING BENDING



"DURING IMPACT" DETAIL

Figure 5. Coupling Position/bending detail

The "e.t.d." 4150-X steel (specified in appendix C) is the sole product identified to possess the desired characteristics. The steel is produced by "elevated temperature drawing," a proprietary process of the LaSalle Steel Company of Hammond, Indiana. The "etd" process is similar to cold drawing, except that the bar stock is heated (600-1,000^{o}F) prior to being drawn through the die. The die, being of smaller diameter (1/16 to 1/8 in smaller), "squeezes" the heated bar stock as it is drawn through. This process yields an increase in the steel's tensile, yield and hardness properties and a decrease in the ductility and toughness. This steel is produced to a mean ultimate tensile strength of 177,000 psi and a Charpy V-notch toughness of about 4 ft-lb. Results of tests conducted on samples of a 13,000 lb lot of the steel, purchased in 1983, are summarized in table 1.

Breakaway couplings fabricated from this steel were found to have an average tensile strength of about 215,000 psi, 15 to 20 percent higher than the steel's tensile strength. This increase in tensile strength is a result of the coupling's critical section design. The hourglass shape acts as a mild notch under tension, producing radial and transverse stresses which raise the value of the longitudinal stress required to cause failure. The resulting coupling breaking strength averaged about 58,000 lb (ranging from about 54,000 to 61,000 lb). This more than sufficiently satisfies the minimum tensile strength limit of 47,000 lb which has been previously established as a safe limit to ensure that even the largest of breakaway signs does not collapse when subjected to design wind loads (80 mi/h + 30 percent gust).

It should also be noted that the coupling's ultimate breaking strength is affected by thickness of the section under the neck. A 1/16 in reduction in the 3/8 in minimum thickness (figure 6) was found to lower the coupling's breaking strength by as much as 7,000 lb. It is theorized that as the thickness is reduced the amount of deflection (buckling up) that occurs under an axial load is increased. As this low ductility steel buckles up under a tensile load, hairline cracking initiates along the circumference of the neck, where the outside fibers are being stressed to their ultimate strength, leading to premature failure of the cross-section. However, increasing the thickness under the neck by 1/8 in was found to increase the coupling's breaking strength by only 3,000 lb. It was also noted that an irregular finish on the surface of the lower bottom tapped and drilled fitting will also have a negative effect on the tensile breaking strength. It is, hence, necessary that this surface be finished flat after drilling and that the minimum thickness of 3/8 in be maintained to ensure proper coupling function.

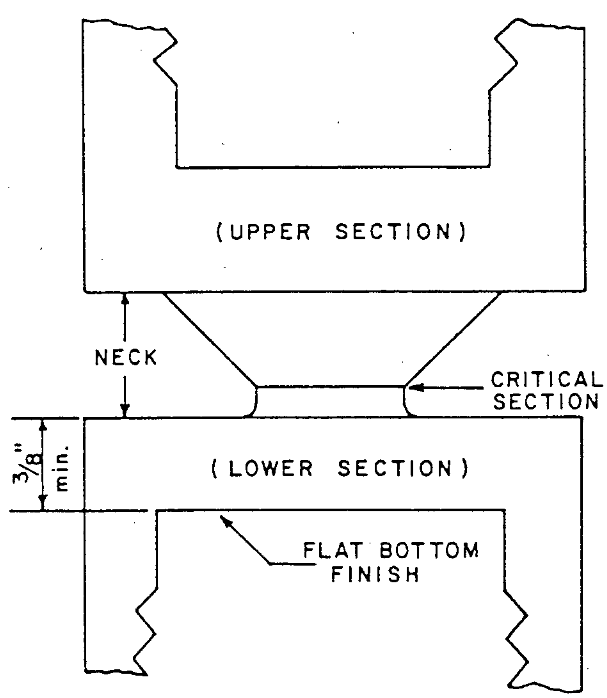


Figure 6. Coupling Detail

"e.t.d." 4150-X Steel

SUMMARY OF PHYSICAL TESTS

	QUANTITY SAMPLED	DATE TESTED	TENSILE STRENGHT	YIELD STRENGHT	PERCENT ELONGAT.	REDUCTION OF AREA	HARDNESS	THOUGHNESS	COMMENTS
			165-185 ksi	155 ksi (min)	13% max.	40% max.	---	10 Ft-Lbs (max)	SPECIFICATION LIMITS
x-1	8530 lb	----	176.2 ksi	162.6 ksi	9.9	30.5	38 Rc	-------	See note 1.
1		8-2-83	178.6 ksi	165.9 ksi	11.1	26.9	39 Rc	4-4-4	See note 2 & 3.
2			175.7	163.0	8.6	30.2	39	4-6-5	
3			175.9	162.4	7.7	31.2	38	6-5-3	
4			178.3	165.0	8.5	26.9	39	5-3-5	
5			168.5	147.6	10.5	33.7	38	6-5-5	
R-5		8-5-83	177.6	163.2	11.0	32.1	39	-------	See note 4.
x-2	5220 lb	----	179.0 ksi	165.3 ksi	9.1	29.9	38	-------	See note 1.
11		8-11-83	179.3	163.5	11.0	34.3	----	4-2.5-4	See note 5.
12			180.8	166.4	11.0	34.0	----	5-5-5	
13			178.8	163.5	11.0	32.7	----	4-3.5-5	
N11		8-19-83	181.8	173.2	---	----	38	6-5	See note 6.
N12			181.3	176.2	10.0	----	38	3-3.5-4	
N13			178.8	171.6	10.0	----	38	3.5-6-6	

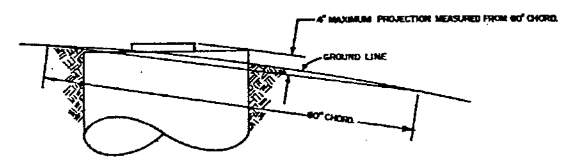
NOTES:
1. LaSalle routinely performs one Tensile test per each 5,000 Lbs of steel.
2. Tests 1-5 sampled and tested under supervision of an NJDOT inspector present at plant.
3. Test 5 rejected since its results were substantially outside the normal distribution.
4. Retest of test 5. A sample was cut from the same bar and adjacent to test 5 section.
5. Tests conducted by LaSalle with no NJDOT supervision.
6. Tests conducted by NJDOT on samples made from the same bar sections as tests 11-13 which were tested by LaSalle.

SIGN SUPPORT DATA TABLE

IDENTIFICATION		OFFSET	SIGN SIZE			C.G. SIGN	NO. OF	TUBE SIZE		POST HEIGHT			BASE	DIMENSIONS TO TOP OF FOOTING			FOOTING DIMENSIONS		REINF. STEEL	L.C. WASHER NUMBER		
NO.	STATION	X_1	A_1	B_1	A_2	Y_1	POSTS	O.D.	THK.	C_1	D_1	E_1	TYPE	F_1	G_1	H_1	K_1	L_1	M_1	Post #1	Post #2	Post #3

NOTE:

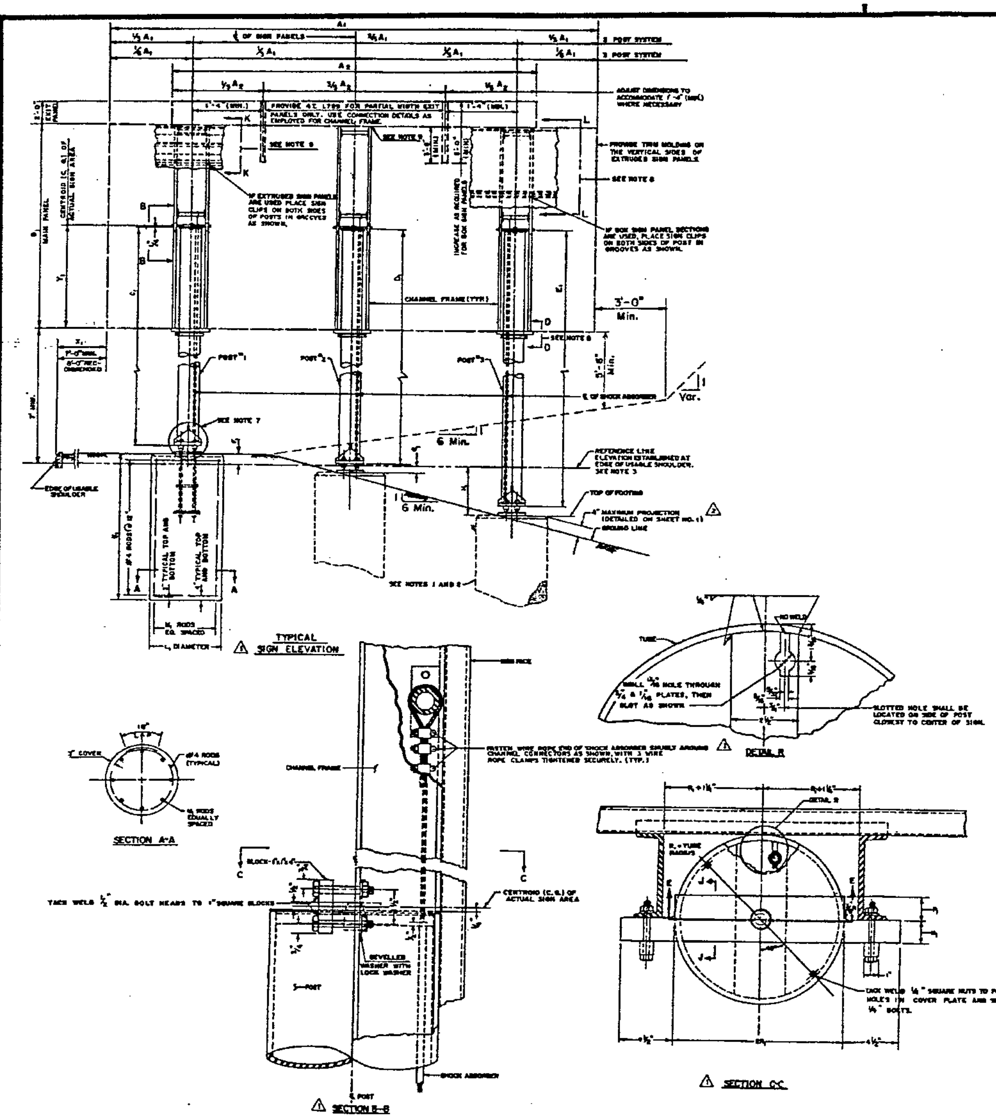
2. LOAD CONCENTRATING WASHER FACE COLOR CODE SHALL BE AS FOLLOWS. L.C. WASHER #1 ORANGE, L.C. WASHER #2 YELLOW, L.C. WASHER #3 BLUE, L.C. WASHER #4 GREEN.
3. FOR IDENTIFICATION OF TABULAR ITEMS, AND DETAILS RELATING THERETO, REFER TO BREAKAWAY SIGN SUPPORTS FOR GROUND MOUNTED SIGNS

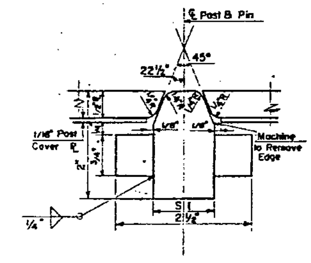


FOOTING/STUB PROJECTION DETAIL

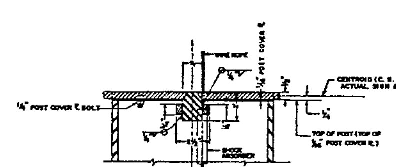
BREAKAWAY SIGN SUPPORTS
FOR GROUND MOUNTED SIGNS - SHEET NO. 1

Appendix F
Standard construction details



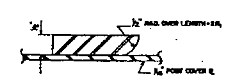


PIN DETAIL
N.T.S.



SECTION E-E

BASE TYPE	ALL DIMENSIONS IN INCHES N_1	P_1	S_1
2	1-1/8	1-1/8	1
3	1-1/2	1-1/2	1-1/4
4	1-7/8	1-3/4	1-3/8
5	2	2-1/4	1-1/2



SECTION J-J

GENERAL NOTES:

1. USE CLASS B CONCRETE IN ALL FOOTINGS, ULTIMATE COMPRESSIVE STRENGTH f'_c = 3,000 p.s.i.

2. ALL FOOTINGS SHALL BE PLACED AGAINST UNDISTURBED EARTH, EXCEPT FOR FOOTING TOPS WHICH SHALL BE FORMED TO A DEPTH OF 3" BELOW GROUND LINE.

3. TOPS OF FOOTINGS ABOVE REFERENCE LINE ARE INDICATED BY PLUS (+) VALUE, IF BELOW BY MINUS (-) VALUE.

4. ALL MATERIAL SHALL BE ALUMINUM ALLOY 6061-T6 UNLESS OTHERWISE NOTED.

5. NUTS, BOLTS AND FLAT WASHERS SHALL BE MADE FROM ALUMINUM ALLOY ALCLAD 2024-T4. SPRING LOCK WASHERS SHALL BE MADE FROM ALUMINUM ALLOY 7075-T6.

6. ALL WELDS SHALL CONFORM TO A.W.S. STANDARDS. FILLER ALLOYS SHALL BE ER 3556 OR ER 5356.

7. FOR DETAIL OF POST BASE AND INSTALLATION REFER TO "BREAKAWAY SIGN SUPPORTS FOR GROUND MOUNTED SIGNS - SHEET NO. 3

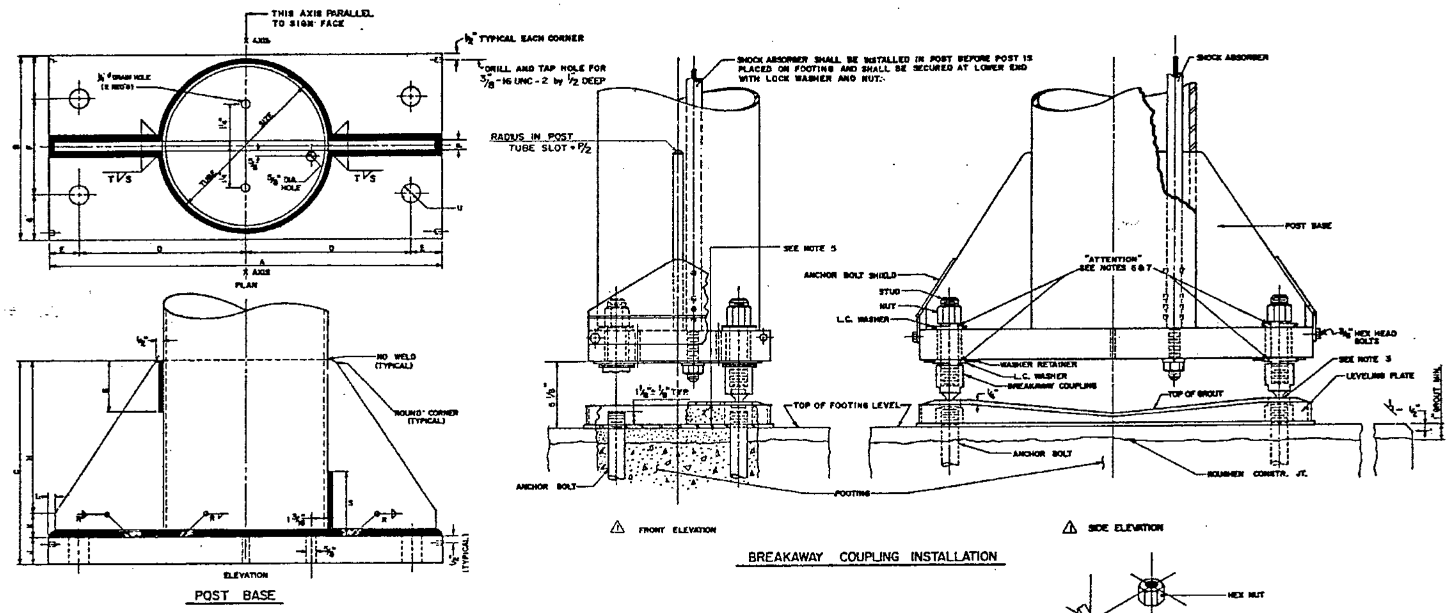
8. FOR DETAILS OF SECTIONS "D-D", "K-K" AND "L-L" REFER TO "BREAKAWAY SIGN SUPPORTS FOR GROUND MOUNTED SIGNS - SHEET NO. 4

9. SIGNS WITHOUT EXIT PANELS OR SIGNS WITH PARTIAL WIDTH EXIT PANELS SHALL BE PROVIDED WITH CHANNEL FRAMES EXTENDING TO THE TOP OF THE MAIN PANEL AS SHOWN. CHANNEL FRAMES SHALL BE EXTENDED TO THE TOP OF THE EXIT PANEL WHEN FULL WIDTH EXIT PANELS ARE EMPLOYED.

10. UNUSUAL FOUNDATION CONDITIONS MAY REQUIRE REDESIGN OF FOOTINGS AND SUCH CONDITIONS SHALL BE BROUGHT TO THE ATTENTION OF THE ENGINEER.

BREAKAWAY SIGN SUPPORTS
FOR GROUND MOUNTED SIGNS-SHEET NO.2

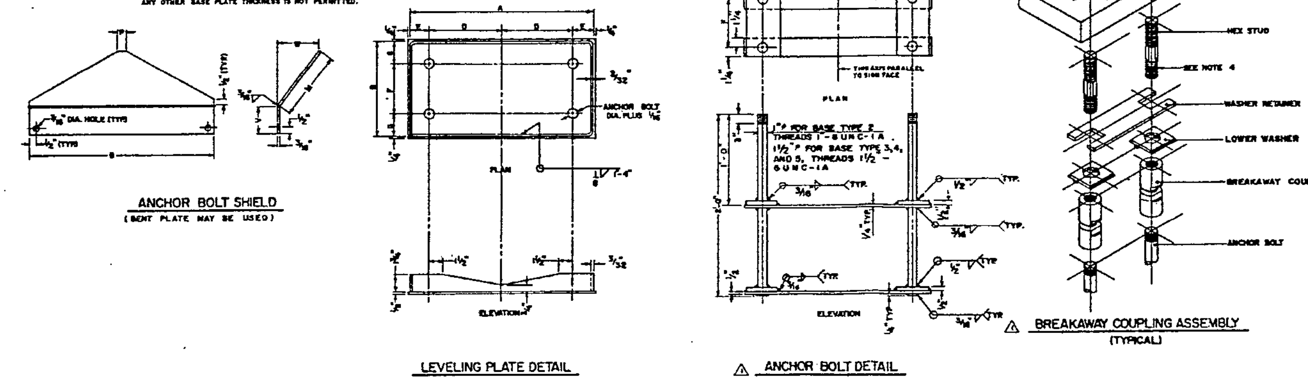
REVISION	BY	CK'D	DATE
			3-9-87
			3-1-86
			11-21-74



POST BASE

POST BASE DATA																			
DIMENSIONS INCHES																			
BASE TYPE	A	B	C	D	E	F	G	H	*J	K	L	M	P	R	S	T	U	V	W
2	13 1/8	7 1/2	9 1/8	5	1 5/8	4	1 3/4	7	1 1/4	1	1/8	5 1/2	7/8	3/8	3 1/2	3/8	1 1/8	1	1 7/8
3	16	9 1/2	12	7	2	5	2 1/2	9 5/8	1 1/2	1 3/8	1/2	6 1/2	5/8	1/2	4 3/4	1/2	1 3/4	1 1/2	2 5/8
4	22	11 1/2	12 3/4	9	2	6	2 3/4	9 1/2	1 3/4	1 1/2	1/2	5	7/8	5/8	10 3/4	5/8	1 3/4	1 5/8	2 1/2
5	26	13 1/2	15	12	2	7	3 1/8	11 1/2	2	1 3/4	1/2	8	15/16	1/2	12 1/2	5/8	1 3/4	2	3 1/2

* THE BASE PLATE THICKNESS "J" MUST CORRESPOND EXACTLY WITH THE BASE TYPE AS SHOWN IN THE TABLE ABOVE. SUBSTITUTION OF ANY OTHER BASE PLATE THICKNESS IS NOT PERMITTED.



ANCHOR BOLT SHIELD

LEVELING PLATE DETAIL

ANCHOR BOLT DETAIL

BREAKAWAY COUPLING ASSEMBLY (TYPICAL)

GENERAL NOTES

1. ANCHOR BOLT ASSEMBLY & LEVELING PLATE SHALL BE STRUCTURAL STEEL TYPE A36 OR EQUIVALENT WITH MIN. YIELD STRENGTH OF 36,000 PSI.. NUTS, WASHERS AND TOP 6" OF BOLTS SHALL BE ZINC COATED BY THE HOT DIP PROCESS. TOP 3" OF ALL ANCHOR BOLTS SHALL BE THREADED.

2. THE CONCRETE FOOTINGS FOR BREAKAWAY SIGNS SHALL BE POURED TO WITHIN APPOXIMATELY 1 INCH OF THE BOTTOM OF THE LEVELING PLATE, THE REMAINING HEIGHT BEING FILLED WITH GROUT. THE LEVELING PLATE SHALL BE PLACED ON TOP, SET TO THE PROPER ELEVATION, AND MADE COMPLETELY LEVEL. THE GROUT MAY BE OMITTED IF THE ANCHOR-BOLTS AND LEVELING PLATE CAN BE PROPERLY POSITIONED.

3. AFTER THE GROUT UNDER THE LEVELING PLATE HAS SET, THE BREAKAWAY COUPLINGS SHALL BE SCREWED TO THE ANCHOR BOLTS, WITH CARE TAKEN THAT THE SMALLER END OF THE TAPER POINTS DOWNWARD. WHILE TIGHTENING THE THE COUPLINGS TO THE ANCHOR BOLTS, ONLY THE LOWER SET OF WRENCHING FLATS SHALL BE USED.

4. THE HEX STUD END WITH THE SMALLER THREAD DEPTH (1 1/8") SHALL BE SCREWED INTO TOP OF BREAKAWAY COUPLING.

5. THE ENTIRE LEVELING PLATE SHALL BE FILLED WITH GROUT, WITH CARE TAKEN TO KEEP THE TAPERED SECTION OF THE COUPLING FREE FROM GROUT.

6. THE PROPER WASHER NUMBER (Stamped on washer) MUST BE USED FOR EACH POST AS INDICATED IN THE TABLE ON "GROUND MOUNTED SIGN SUPPORT SHEET No. 1".

7. RAISED PORTION OF L.C. WASHERS MUST BE POSITIONED AS INDICATED. CENTER OF RAISED PORTION MUST BE TOWARD ℄ OF POST.

8. WASHER RETAINERS SHALL BE PLACED IN THE GROOVES OF THE L.C. WASHERS, AS SHOWN. IT MAY BE NECESSARY TO BACK-OFF ON EACH STUD A MAXIMUM OF 30 DEGREES TO ALLOW THE WASHER RETAINER TO FIT.

9. THE POST BASE SHALL BE PLACED OVER THE STUDS ON TOP OF THE WASHER RETAINERS, AFTER WHICH THE TOP WASHER SHALL BE PLACED OVER EACH HEX STUD. AGAIN, IT IS IMPORTANT THAT THE RAISED PORTION OF THE WASHER CONTACT THE LOWER-SURFACE OF THE NUT WHEN IT IS TIGHTENED ON THE STUD AND THAT THE ARROW, APPEARING ON THE TOP SURFACE OF THE WASHER, POINT TOWARD THE CENTER LINE OF THE POST.

10. THE HEAVY HEX NUT SHALL BE PLACED ON EACH HEX STUD AND TIGHTENED HOLDING THE UPPER WRENCHING FLATS OF THE COUPLING. THESE NUTS SHALL BE TIGHTENED BY THE TURN OF NUT METHOD.

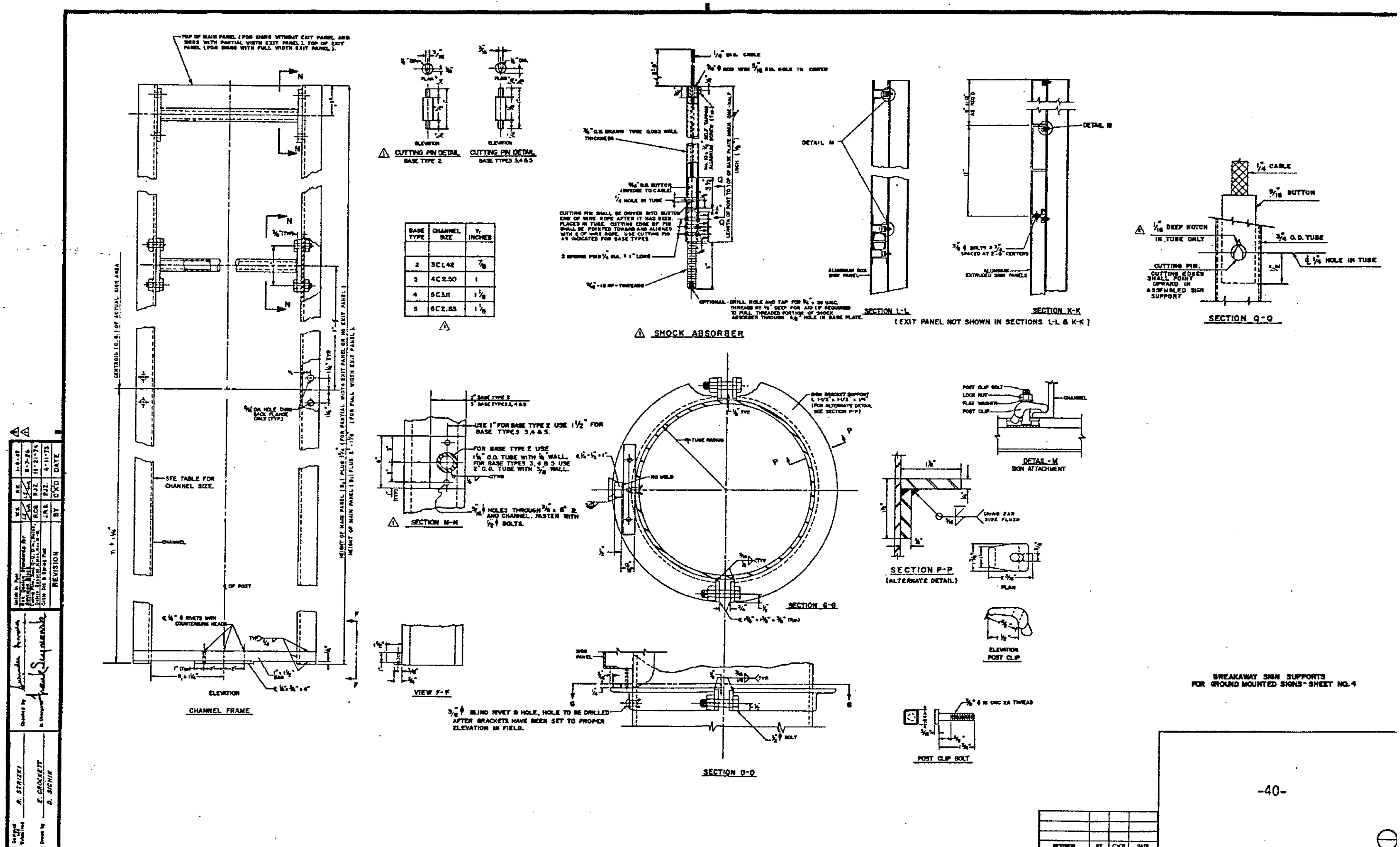
BREAKAWAY SIGN SUPPORTS
FOR GROUND MOUNTED SIGNS-SHEET NO. 3

-39-

REVISION	BY	CK'D	DATE

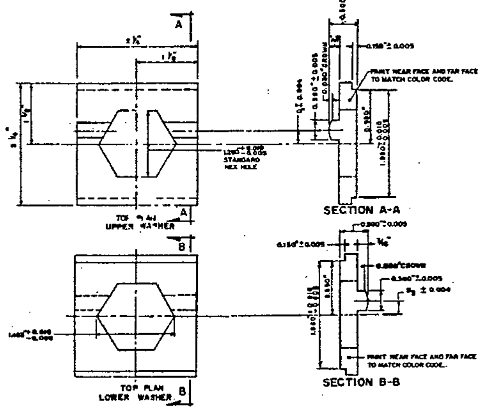
Designed: P. STRIZKI
Drawn by: E. CROCKETT, D. SICHIK

REVISION	BY	CK'D	DATE
	JRR	RJZ	4-11-73
	RCG	RJZ	11-21-74
			8-7-76
			1-8-87



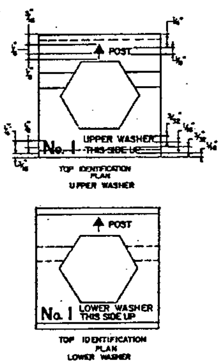
BASE TYPE	CHANNEL SIZE	Y_1 INCHES
2	3C1.42	7/8
3	4C2.50	1
4	5C3.11	1 1/8
5	6C2.83	1 1/8

BREAKAWAY SIGN SUPPORTS FOR GROUND MOUNTED SIGNS-SHEET NO.4



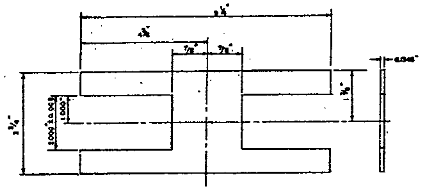
LOAD CONCENTRATING WASHER DETAILS

WASHER NUMBER	"C" INCHES	FACE COLOR CODE
1	0.100	ORANGE
2	0.150	YELLOW
3	0.200	BLUE
4	0.250	GREEN

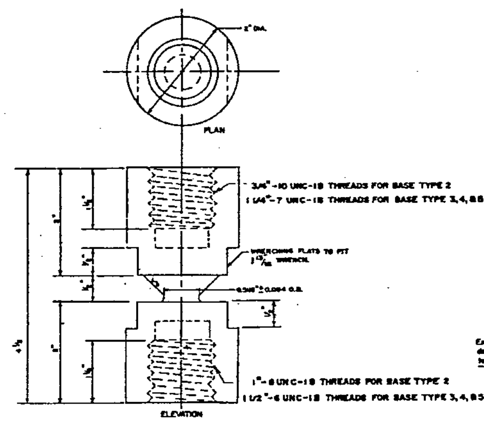


LOAD CONCENTRATING WASHER IDENTIFICATION DETAIL

NOTE: ALL LOAD CONCENTRATING WASHERS SHALL BE PERMANENTLY LABELED WITH APPROPRIATE WASHER NUMBER AND IDENTIFICATION AS SHOWN.

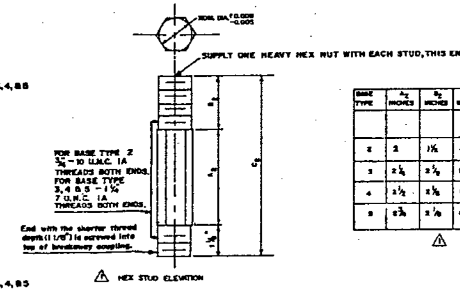


WASHER RETAINER



BREAKAWAY COUPLING *

* SHOWN FOR INFORMATION ONLY. COUPLINGS SHALL BE SUPPLIED BY N. J. D. O. T.



BASE TYPE	A_2 INCHES	B_2 INCHES	C_2 INCHES	HEX SIZE
2	2	1 1/2	4 5/8	3/4
3	2 1/4	2 1/8	5 1/2	1 1/4
4	2 1/2	2 1/8	5 3/4	1 1/4
5	2 3/4	2 1/8	6	1 1/4

HEX STUD LENGTHS & SIZES

BREAKAWAY SIGN SUPPORTS
FOR GROUND MOUNTED SIGNS - SHEET NO.5

-41-

REVISION	BY	CK'D	DATE

Designed and Detailed	R. STAIZKI
Drawn by	E. CROCKETT / D. SICHIK

REVISION	BY	CK'D	DATE
Use Design Standards for Breakaway Block; Delete Hex Nuts			3-7-84
	RCQ	PJZ	11-21-74
Coupling Tower Bin	JRS	PJZ	4-11-73