Improved Breakaway Utility Pole, AD-IV

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Performance-tested breakaway utility poles have been available for almost a decade. The Texas Transportation Institute developed the Hawkins Breakaway System for FHWA under a contract completed in 1985. Design modifications to decrease the tolerance requirements of the upper hinge connection and the base connection have been completed by the Texas Transportation Institute. These modifications have reduced the amount of material used in the base connection, reduced the machining cost for the upper hinge straps, and significantly reduced the maintenance procedures for the upper connection. In turn initial costs and maintenance costs have been reduced. The new design, AD-IV, was subjected to three pendulum tests and was crash tested with a 1,800-lb automobile at 60 mph. AD-IV meets the test evaluation criteria of *NCHRP Report 230*. FHWA granted approval of the system on June 17, 1993.

The first practical structural system that can be used to convert a timber utility pole into a breakaway structure was developed by the Texas Transportation Institute for FHWA. This work was completed in 1985. The result, the FHWA Breakaway Pole System or the Hawkins Breakaway System (HBS), met both the requirements of *NCHRP Report 230* (*1*) and the requirements of utility companies (*2,3*).

With FHWA leadership, HBS has now been implemented in Kentucky and Massachusetts. Several other states, including Washington, Florida, and Texas, are planning further installations. Texas is now developing specifications to use AD-IV on 60 installations of wood poles to support luminaires and to carry the power supply for the temporary lighting in a construction zone in El Paso. The purpose of the field demonstration projects was not to verify the performance of HBS during collisions. That was clearly demonstrated by crash tests in the proving ground environment (*2*). The purpose was to evaluate the installation procedures and the performance of HBS under such environmental loads as wind and ice. The results of these field evaluations have been excellent (*4*). No serious problems have been encountered in installation or maintenance, and the modified poles have, as predicted, withstood winds up to 70 mph in Kentucky and up to 80 mph in Massachusetts.

Just as predicted by laboratory strength tests, the HBS installations are stronger than those without the breakaway modification. In the 80-mph wind event in Massachusetts, unmodified poles were broken down, whereas the HBS installations developed only small rotations in the upper parts of the poles, that part above the upper knee connections.

It was clear, however, that in spite of the excellent performance to date there are improvements in HBS that would be helpful to the utility companies and states where it will be used. In fact, it was never considered that HBS would be the final system design (*5*). Recognizing the value of developing an improved design, the Texas Transportation Institute continued to develop an improved breakaway pole system. The goals were simple: reduce cost and improve performance. The result is AD-IV (*6*). Costs are projected to be reduced significantly in the AD-IV design, and several other improvements have been demonstrated. The AD-IV design was approved by FHWA on June 17, 1993 (*7*). The following sections describe and illustrate these design improvements.

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DESCRIPTION OF BREAKAWAY POLES

This system consists of a lower connection (slip base), an upper connection (hinge mechanism), and structural support cables. The slip base and hinge mechanism activate on impact, reducing the effect of a semirigid pole on the errant vehicle while minimizing the effect on utility service. The slip base is designed to withstand the overturning moments imposed by in-service wind loads as well as to yield appropriately to the forces of an automobile collision. The upper hinge mechanism is sized so as to adequately transmit service loads while hinging during a collision to allow the bottom segment of the pole to rotate up and out of the way. This upper connection reduces the effective inertia of the pole and minimizes the effect of any variation in hardware attached to the upper portion of the pole during a collision. The overhead guys (one above the upper connection and one below the neutral conductor) stabilize the upper portion of the pole during a collision to ensure the development of the bending moment necessary to activate the hinge. If enough utility conductors are present, the upper guys may possibly be eliminated. The proper function of a breakaway utility pole is illustrated in Figure 1.

Approved breakaway designs consist of three basic modifications to existing (or new) timber poles. The modifications used are a slip base (lower connection), a plastic hinge (upper connection), and the overhead guys (structural support cables). These devices for the HBS system were previously described in detail (*3*).

DESIGN DISADVANTAGES OF HBS

Subsequent to completion of the original FHWA project (*2*), discussions were held with representatives of numerous utility companies and with several steel fabricators. The following characteristics of Federal Highway-Breakaway Pole were discussed:

1. The circular shape of the base plates along with the six machined bolt slots were considered cost factors. If these circular bases were fabricated from plate steel there would be considerable waste. A square base plate, if not a functional disadvantage, would be lower in cost, and if a four-bolt connection rather than the six-bolt connection could be designed, further cost reductions could be

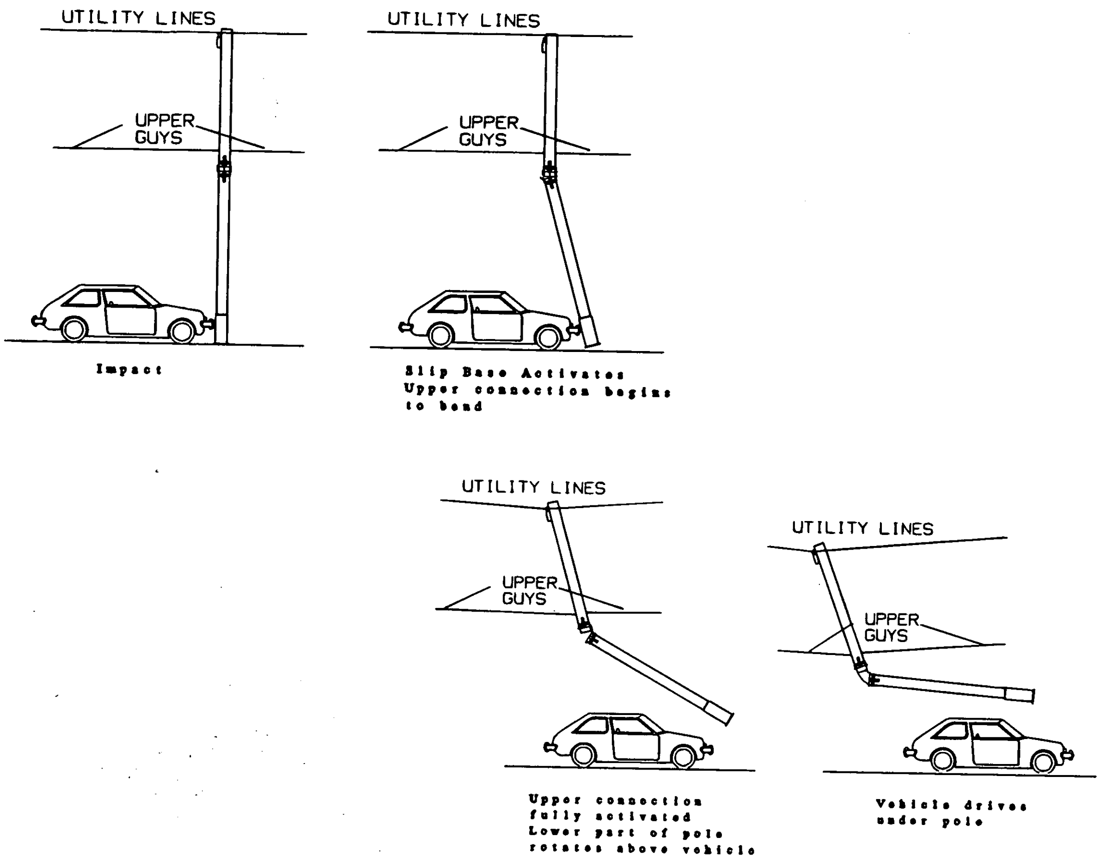


FIGURE 1 Proper function of breakaway utility pole.

achieved. Fortunately, the six-bolt connection had already been shown to be substantially overdesigned in static pullover tests (Figure 2).

2. The matching of a slot and four holes as the first yield mechanism of the steel straps in the upper connection would entail considerable fabrication costs. The tolerances of the margin between the holes needed to be accurate to within $\pm 1/1{,}000$ of an inch to achieve the proper yield strength. Designing the upper yielding connection to reduce these costs and make quality control less critical was considered important.

3. When an HBS modified timber pole is subjected to high repeated wind loads, an angular deflection of 5 to 10 degrees can develop in the upper pole segment. The HBS design required the upper pole to be straightened, usually by some piece of heavy equipment, and then all the bolts in at least one of the pole bands to be loosened, the bands adjusted, and the bolts retightened. A less labor- and equipment-intensive way to maintain poles in true alignment was considered of some importance.

DESCRIPTION OF AD-IV

It will be seen as AD-IV is described in detail that the three shortcomings of HBS have been overcome. AD-IV works precisely like HBS. Figure 3 shows the two components of AD-IV that are different from HBS. The overhead guys of HBS (Figure 1) are exactly the same in the AD-IV system.

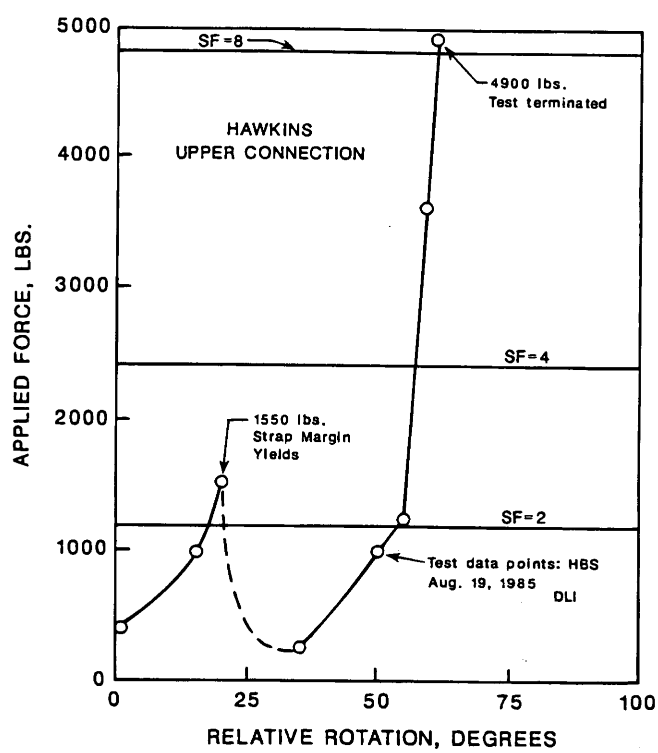


FIGURE 2 Load rotation characteristic of HBS upper connection (ultimate load safety factor is greater than eight).

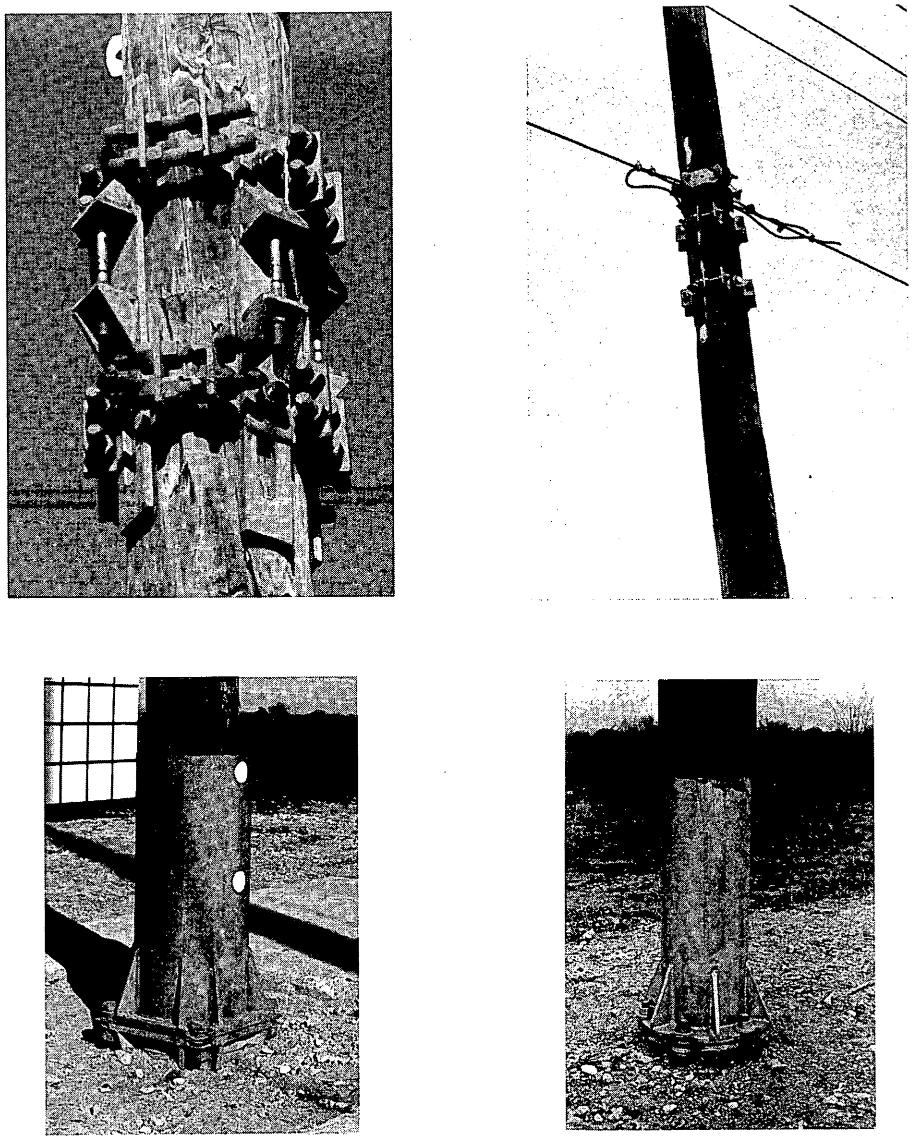


FIGURE 3 Upper and lower connections of AD-IV utility pole modification (*left*) compared with HBS (*right*).

LOWER CONNECTION: SLIP BASE

Just as in HBS, a lower shear plane is created by AD-IV through installation of a slip base at an elevation of 3 in. above grade. This shear plane consists of two $\frac{3}{4}$-in.-thick plates separated by a 26-gage keeper plate intended to maintain the bolts in the recessed corners of the 1 ft $3\frac{3}{4}$ in. square base plate and by $2\frac{1}{2}$-in.-diameter $\times$ $\frac{1}{8}$-in. washers. The base plates are connected to each other by four $1\frac{1}{8}$-in.-diameter high-strength bolts, with $2\frac{1}{2}$-in. $\times$ $\frac{1}{4}$-in. washers. These bolts are torqued to 200 ft-lb. Connection of the wooden utility pole to the slip base is through a steel pipe (Figures 3 and 4). These tubes are nominally 12 in. in diameter and 30 in. in length and are welded to the base plates. In addition, the base plates are braced by $\frac{1}{2}$-in.-thick stiffeners that are welded to both the base plate and the steel tube.

UPPER CONNECTION

Similar in basic structure, this connection consists of a pair of pole bands installed above and below a saw cut through the pole. The straps connecting the pole bands are detailed in Figure 5. The pole bands (and straps) are further secured to the pole by means of 1-in.-diameter through bolts as shown in Figure 6. At the bottom pole band, the bolt pass through the upper end of a $5\frac{3}{4}$-in. slot. Initial bending resistance is provided by the strength of four $\frac{5}{8}$-in. gal-

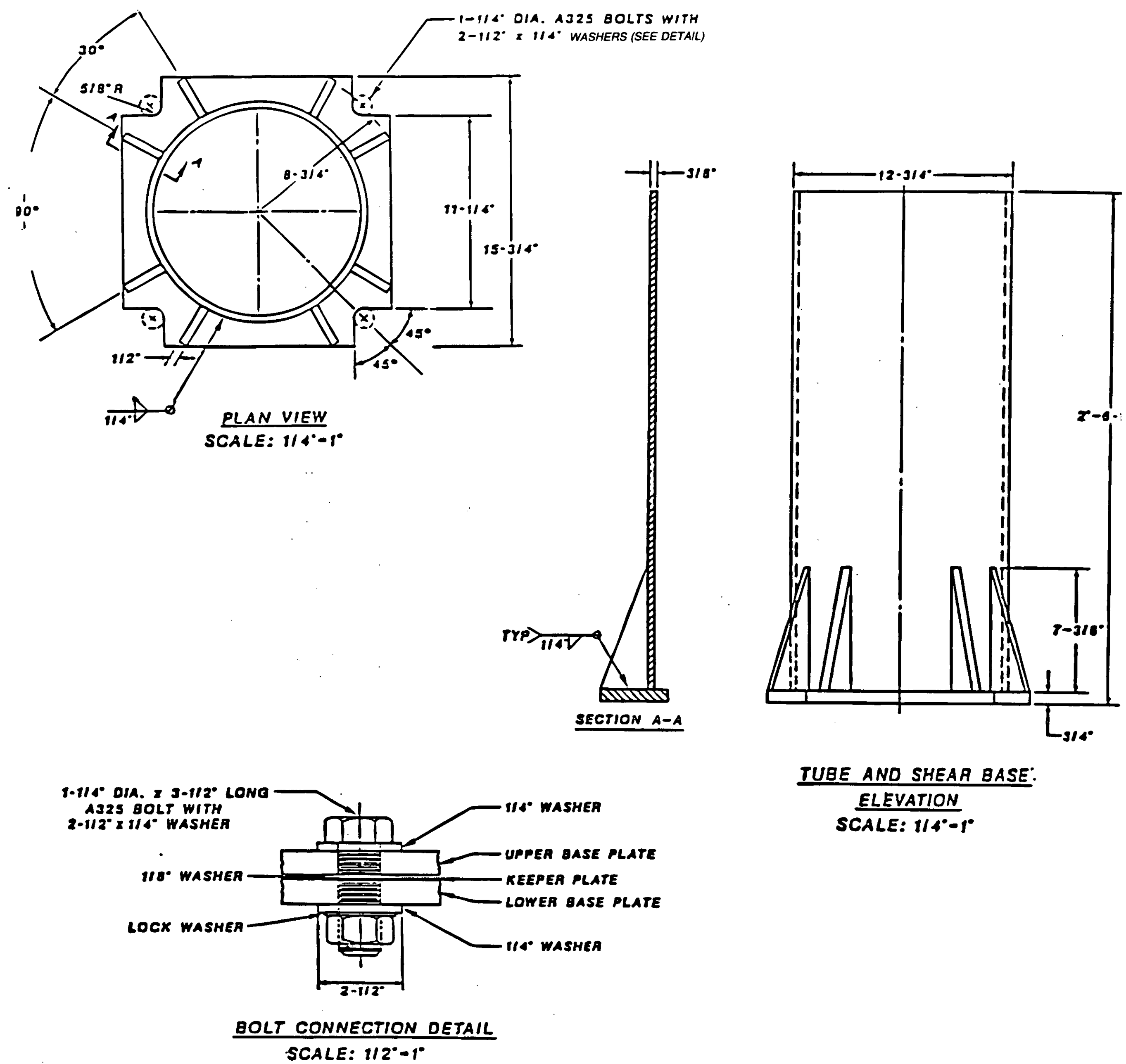


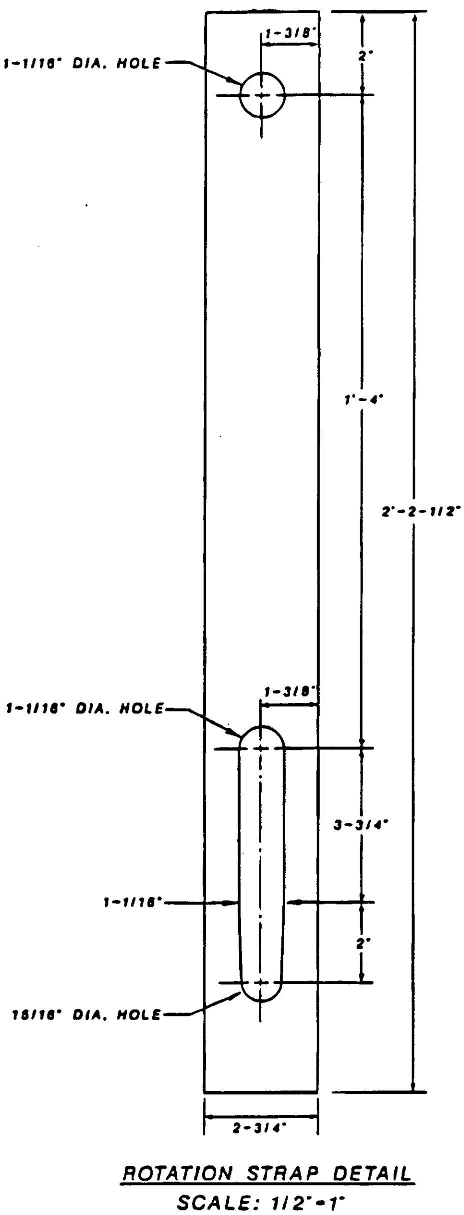
FIGURE 4 AD-IV slip base (lower connection).

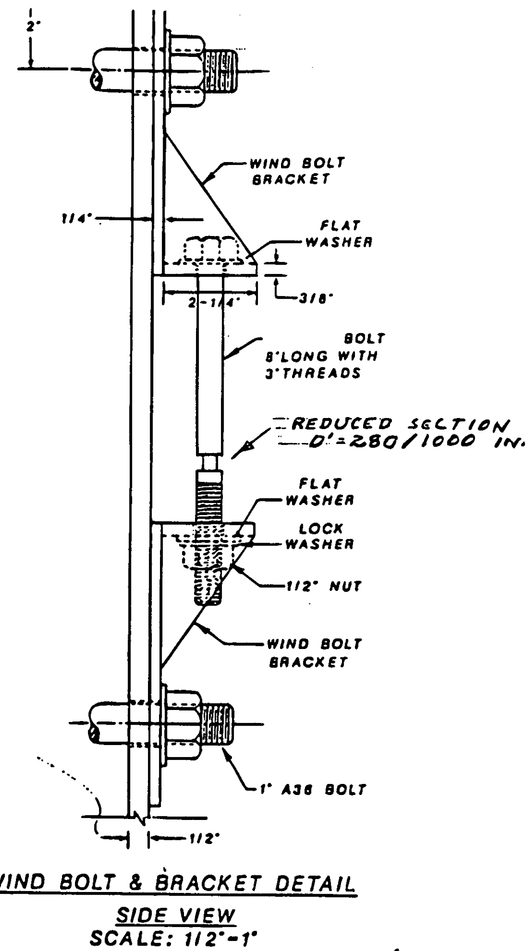
vanized bolts that connect the brackets shown in Figure 6. These bolts have a turned stress riser groove 1 in. above the point where the threads start. The groove is ¼-in. wide and of sufficient depth that the remaining bolt diameter is 280/1,000 ± 5/1,000 in. Once two of the bolts fail in tension at a predetermined bending moment of 18,000 ft-lb, resistance is offered by friction between the straps and through bolts and by bending of the straps. Once significant rotation has occurred, the bolts bear on the end of the slot, thereby providing the required ultimate bending strength represented by a horizontal force approaching 4,800 lb, a safety factor of 4 for Class 4 poles. A completed installation is shown in Figure 7.

The load versus rotation curve is presented in Figure 8. This curve is similar to that of the HBS upper connection (shown in Figure 2) and achieves the same safety factors at the appropriate angular rotation levels.

MEETING *NCHRP REPORT 230* REQUIREMENTS

Use of the AD-IV upper connection does not result in any significant performance differences during automobile collisions. The advantages of the AD-IV are twofold. First, the costly machining of





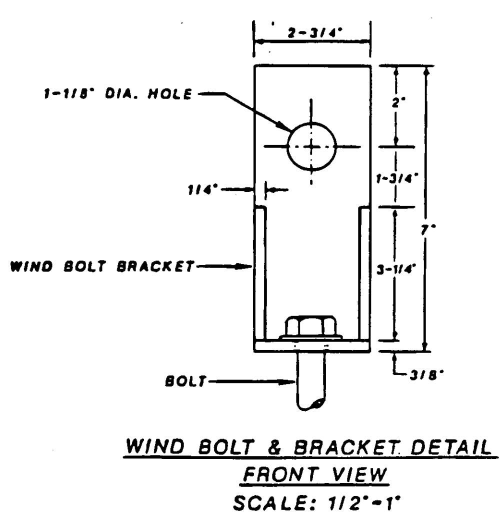
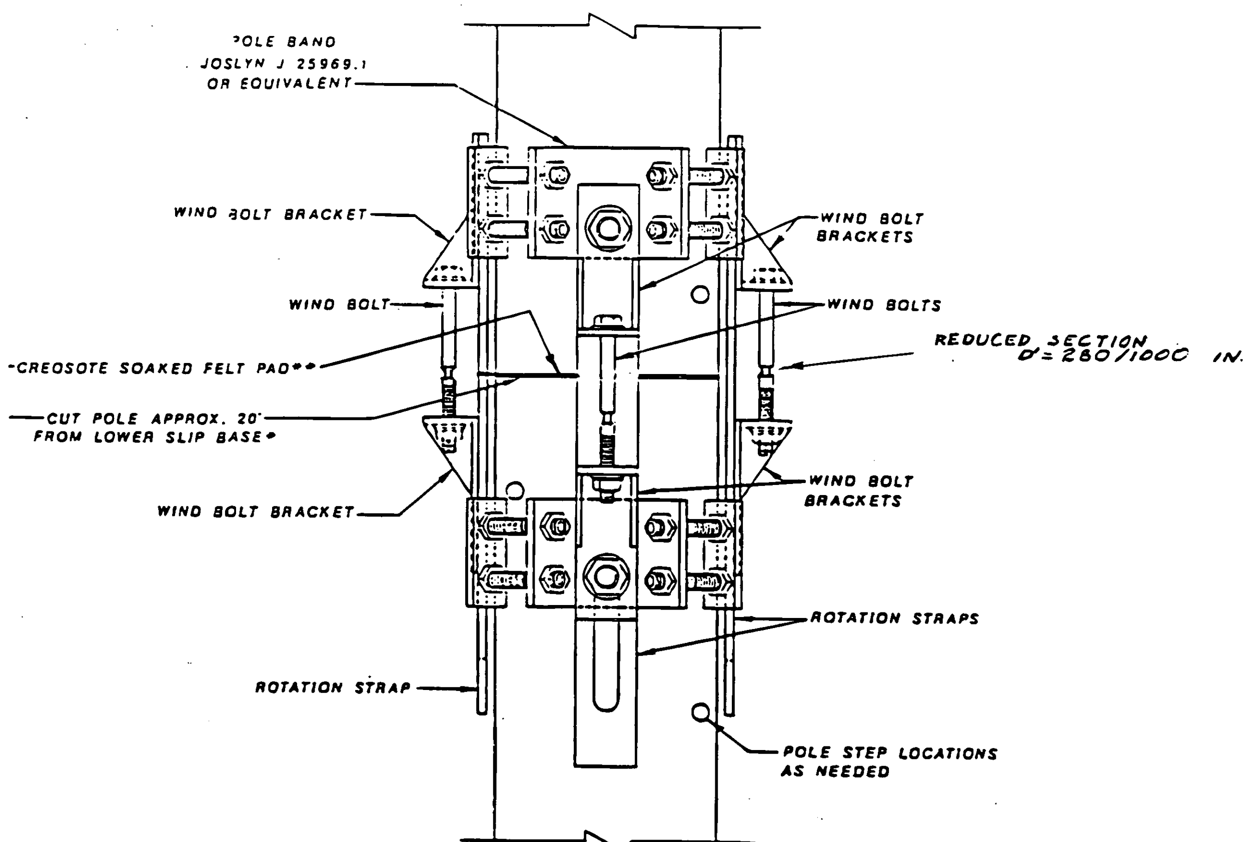


FIGURE 5 Detail of rotation strap, wind bolt, and bracket.



WIND BOLT & BRACKET OPTION
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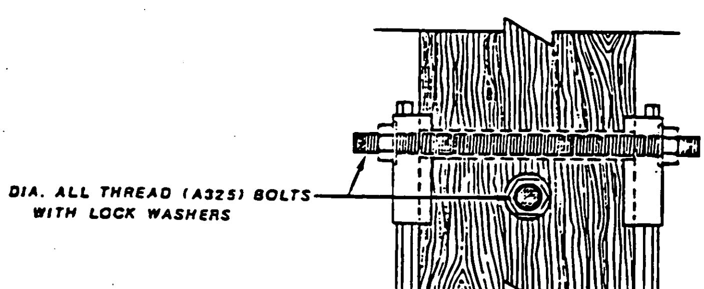
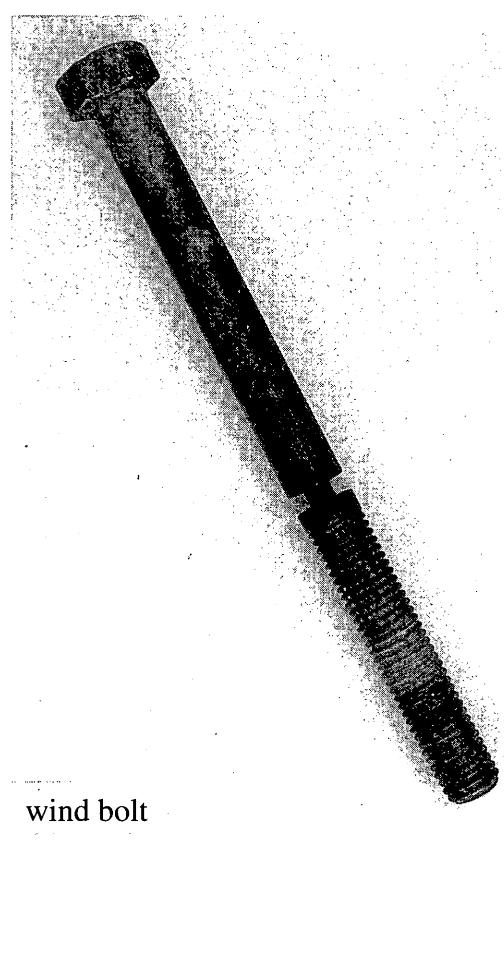


SECTION A–A
SCALE: 1/4"=1"



wind bolt

FIGURE 6 **AD-IV hinge (upper connection).**

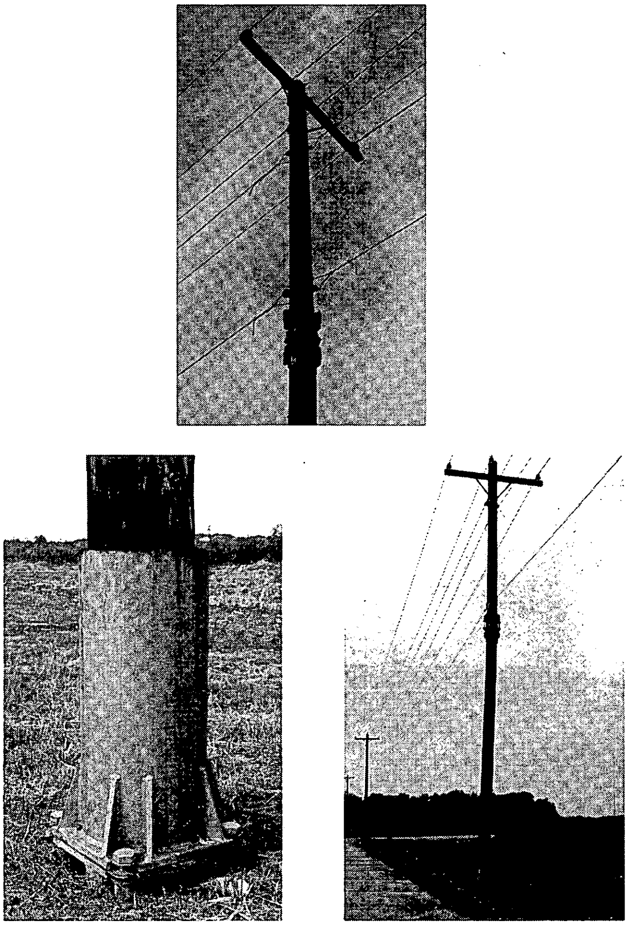


FIGURE 7 Slip base utility pole before Test 6018A-1.

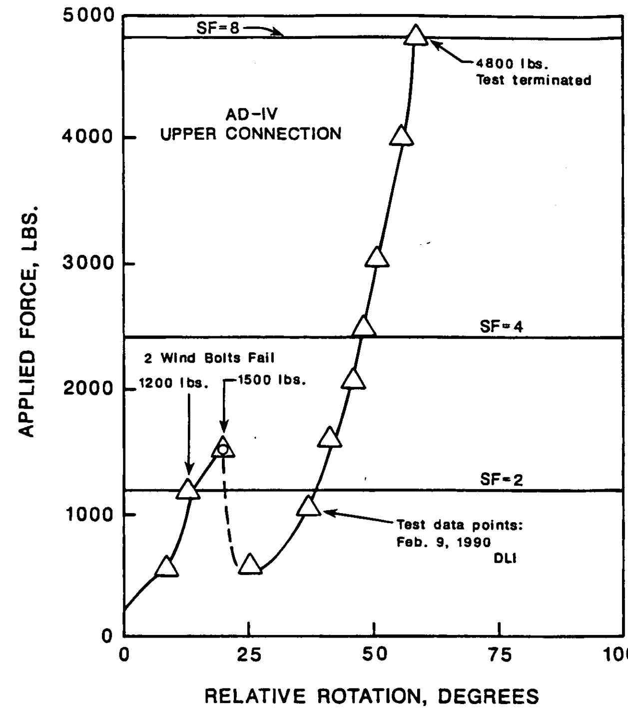


FIGURE 8 Load-rotation characteristic of AD-IV upper connection (ultimate load safety factor is greater than eight).

the wind straps for HBS has been eliminated. Second, if the AD-IV upper connection allows the upper part of the pole to lean during high winds or excessive ice, the pole can easily be straightened by simply loosening the large through bolts that clamp the wind straps, tightening or loosening the wind bolts to change the slope of the upper pole segment, and then retightening the through bolts. No heavy equipment would be required.

Use of the AD-IV lower connection should result in a slight reduction of energy absorbed in activating the slip base (*6*) owing to three factors: (*a*) the weight of the square plate is reduced, (*b*) the friction to be overcome using four bolts is approximately two-thirds the friction associated with the six-bolt HBS connection, and (*c*) the orientation of the slots in the corners of the AD-IV base is optimum for release if it is impacted from the primary traffic direction. In the case of HBS, the two bolts with slots located 90 degrees out of phase with the traffic direction must be moved laterally to allow the slip base to activate. Thus, AD-IV should perform somewhat better than HBS. Since HBS meets the requirements of *NCHRP Report 230* (*1*), AD-IV will also meet those same requirements with a slightly greater margin of safety. Although it was not considered necessary to perform all NCHRP full-scale compliance tests on AD-IV, the most critical test was run with an 1,800-lb automobile at 60 mph.

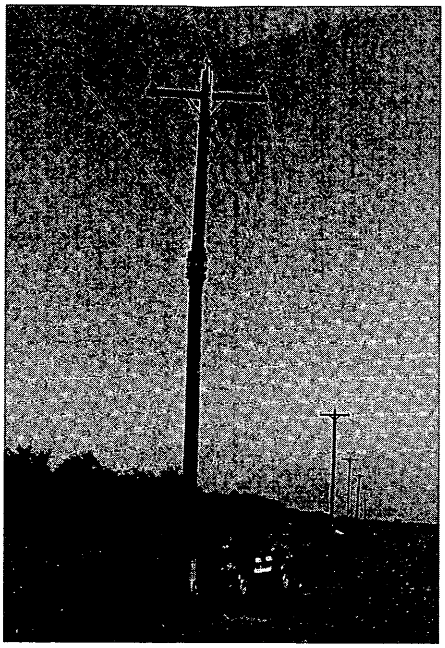
CRASH TEST ANALYSIS

A 1980 Honda Civic (Figure 9) was used for the full scale crash test. The inertial mass of the test vehicle was 1,800 lb (816 kg), and its gross static mass was 2,130 lb (966 kg). The vehicle was directed into the utility pole by the cable reverse tow and guidance system and was released to be freewheeling and unrestrained just before impact. The vehicle impacted the pole at a speed of 59.6 mph (95.9 km/hr), and the angle of impact was 15.0 degrees relative to the strung wires.

With time zero being the point of first contact with the pole, the hinge began to flex at 0.027 sec, and there was visible space between the upper and lower sections of the pole at 0.047 sec. The hinge reached maximum extension at 0.131 sec. Contact between the pole base and vehicle was lost at 0.181 sec, and the vehicle separation speed was 42.8 mph (68.9 km/hr).

As can be seen in Figure 10, the pole received minor damage at the top cross members, the hinge deflected, and the upper guy wire broke at its connection at 0.377 sec after impact. This guy wire break would not be the normal case in a field installation because it was found that a 3/8-in. wire rope was used; it should have been 1/2 in. The normal field installation after being impacted in the August 24, 1990, hit in Grafton, Massachusetts, is shown in Figure 11. The lower section of the pole and the slip base were undamaged. Brakes were applied at 1.13 sec, and the vehicle came to rest 165.0 ft (50.3 m) from the point of first contact.

The vehicle sustained damage as shown in Figure 12. Maximum crush at the center front bumper height was 17.0 in. (43.2 cm), and



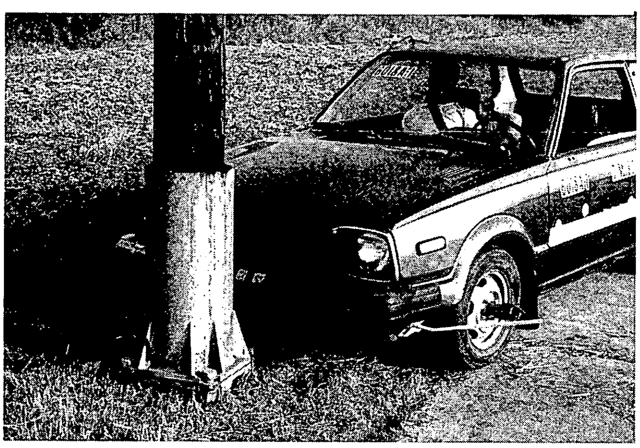


FIGURE 9 Vehicle and utility pole geometrics for Test 6018A-1.

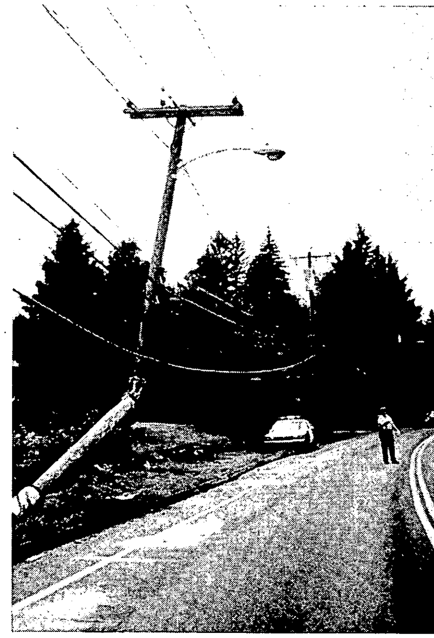


FIGURE 10 Field installation after collision.

both the left and right front corners were pulled inward approximately 2.0 in. (5.1 cm).

Data from the accelerometer located at the center of gravity were digitized for evaluation, and occupant risk factors were computed as follows. In the longitudinal direction, occupant impact velocity was 19.7 ft/sec (6.0 m/sec) at 0.122 sec, the highest 0.010-sec average ridedown acceleration was −2.4 *g* between 0.144 and 0.154 sec, and the maximum 0.050-sec average acceleration was −13.6 *g* between 0.0 and 0.050 sec. In the lateral direction, occupant impact velocity was −3.1 ft/sec (−0.94 m/sec) at 0.944 sec, the highest 0.010-sec average ridedown acceleration was 1.4 *g* between 0.969 and 0.979 sec, and the maximum 0.050-sec average acceleration was −2.0 *g* between 0.024 and 0.074 sec. These data and other pertinent information from the test are summarized in Figure 13. Note the occupant impact velocity and the ridedown acceleration are well below the limits preferred by *NCHRP Report 230* (*1*).

The data in Table 1 indicate that the results of the test met *NCHRP Report 230* criteria. This test had not been run on the HBS during the original project for FHWA. Data are compared with data from tests with vehicles traveling at 20 and 40 mph, which were reported previously. Pendulum tests were conducted during the development process for AD-IV to verify breakaway characteristics. Accelerations from the final test, which complied with *NCHRP Report 230* guidelines, are compared with earlier pendulum tests on the HBS in Figure 14.

CONCLUSIONS

Engineers at FHWA have played a major role in conducting field trials of breakaway utility poles, and the FHWA-sponsored research was the turning point in developing practical, strong, and collision-safe utility poles. Table 2, by Buser and Buser (*4*), documents colli-

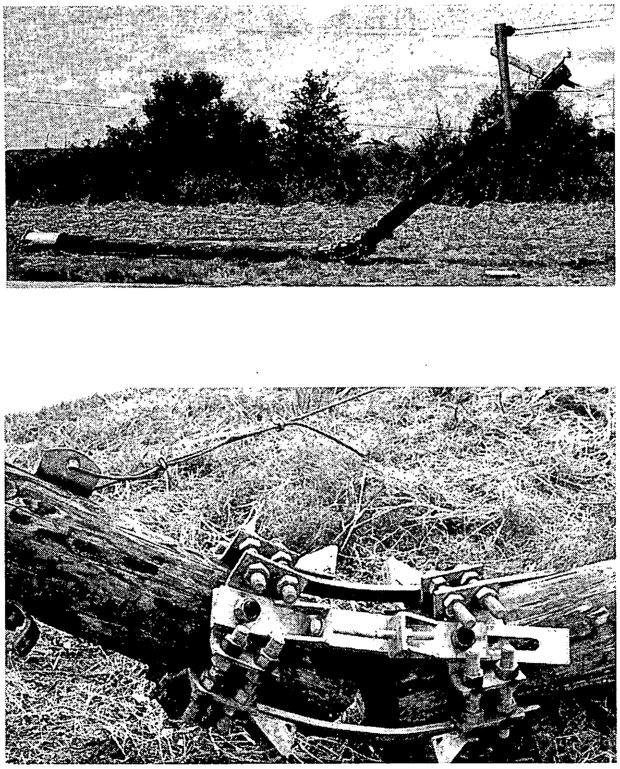
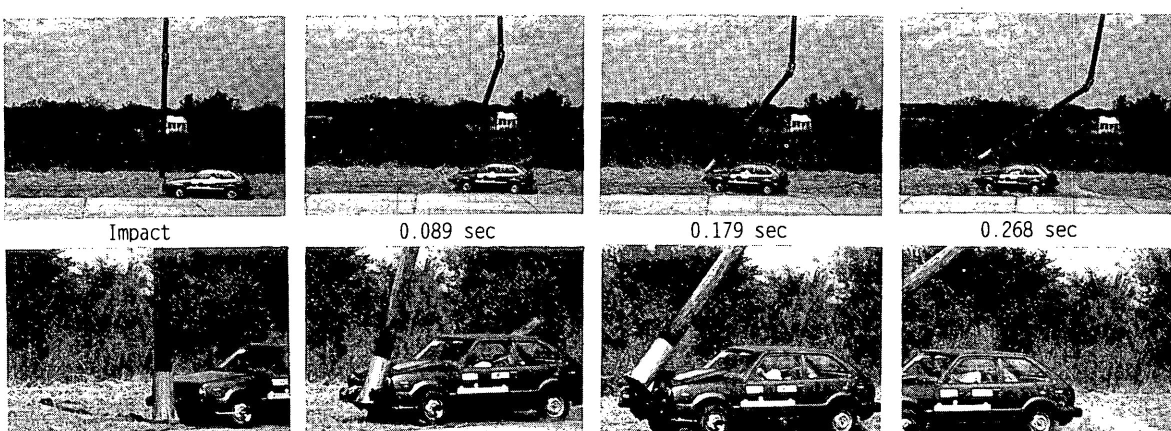


FIGURE 11 Utility pole after Test 6018A-1.

FIGURE 12 Vehicle after Test 6018A-1.



Test No.	6018A-1
Date	09/02/92
Test Installation	Slip-base Utility Pole
Installation Length	N/A
Max. Dynamic Movement	Not Obtained
Max. Perm. Movement	27.25 ft (8.31 m)
Test Vehicle	1980 Honda Civic
Vehicle Weight	
Test Inertia	1,800 lb (816 kg)
Gross Static	2,130 lb (966 kg)
Vehicle Damage Classification	
TAD	12FC4
CDC	12FCEW2
Maximum Vehicle Crush	17.0 in (43.2 cm)

Impact Speed	59.6 mi/h (95.9 km/h)
Impact Angle	15.0 deg
Speed at Parallel	N/A
Exit Speed	42.9 mi/h (69.0 km/h)
Exit Trajectory	Not Obtained
Vehicle Accelerations at center-of-gravity (Max. 0.050-sec Average)	
Longitudinal	-13.6 g
Lateral	- 2.0 g
Occupant Impact Velocity at true c.g.	
Longitudinal	19.7 ft/s (6.0 m/s)
Lateral	-3.1 ft/s (0.9 m/s)
Occupant Ridedown Accelerations	
Longitudinal	-2.4 g
Lateral	1.4 g

FIGURE 13 Summary of results for Test 6018A-1.

TABLE 1 Selected Test Results (*7*).

	Occupant Velocity Change ft/s	Ride Down Acceleration 10ms max g's	Highest Vehicle Acceleration 50ms max g's
Test 6018A-1 (AD-IV) 60 mph	19.7	2.4	13.6
Test 4859-16 (FHWA) 40 mph	12.0	1.0	8.0
Test 4859-12 (FHWA) 20 mph	10.1	2.1	6.7
NCHRP 230 (Guidelines)	30	15	---
FHWA Suggested Value	22*	---	---

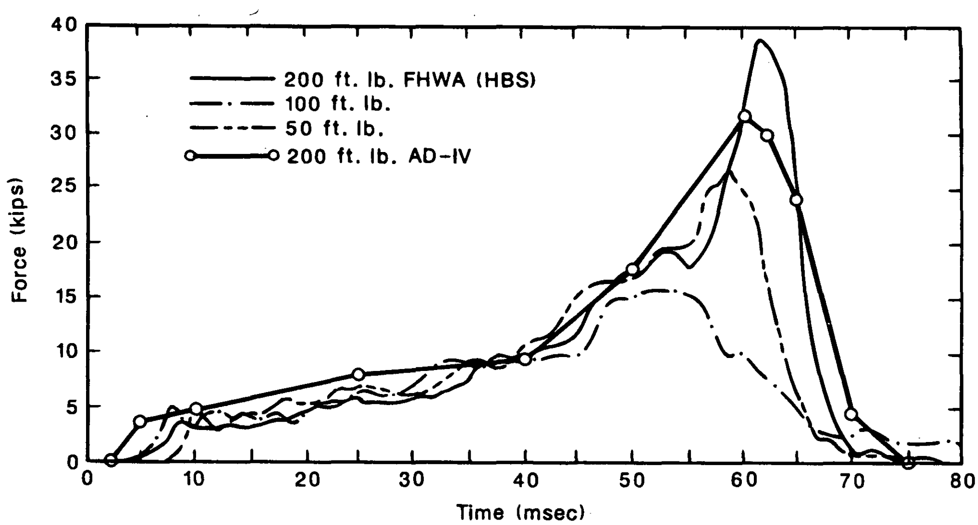


FIGURE 14 Impulse curve comparing AD-IV with original design (HBS).

TABLE 2 Breakaway Utility Pole Collisions.

DATE	PLACE	TIME TO RESTORE POLE
August 24, 1990	Grafton	3 Hours
December 12, 1990	Oxford	4 Hours
April 21, 1991	Oxford	2 Hours
May 12, 1991	Methuen	1/2 Hour
September 25, 1991	Oxford	1 Hour

- **THERE WERE NO INJURIES IN ANY COLLISION.**
- **THERE WAS NO SERVICE LOST IN ANY COLLISION.**

sions with breakaway utility poles in field installations. There were no injuries and no service was lost in any of the collisions. Table 3 summarizes the differences between HBS and AD-IV and suggests that AD-IV is the next preferred step in the evolution of practical, low-cost, high-performance structural systems that can be used to modify timber utility poles. AD-IV systems were scheduled for implementation in Fort Worth, Texas, during 1994. It may be appropriate to include AD-IV installations at new locations as other states continue or begin the implementation process. The precedents for improving roadside safety through modification of selected timber utility poles are well established (*8,9*). Additionally, noninterruption of service and short repair times enhance cost considerations. On September 15, 1993, William Quirk of Boston Edison stated, "These poles [breakaway] save money on maintenance." AD-IV joins HBS, crash cushions, and guardrail designs as one more method of treating those poles found to be a hazard to the public (*10*).

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TABLE 3 Specific Points of Difference Between FHWA Breakaway Pole and AD-IV

	HBS	AD-IV
1.	Upper Connection	Upper Connection
	* 4 strap connectors between upper and lower pole bands.	* 4 strap/4 bolt connection between upper and lower pole bands.
	* Complicated arrangements of slots and holes machined to rigorous tolerances.	* Connection requires no precision machining.
	* No practical means of correcting misalignment of upper and middle pole segment without heavy construction equipment.	* Connection (4 strap/4 bolt) can easily be adjusted by individual maintenance workers to replace fractured elements and correct misalignment.
2.	Lower Connection	Lower Connection
	* 6 bolt circular slip base.	* 4 bolt square slip base
	* Circular base produces much waste when fabricated from steel plate.	* Square base reduces waste to negligible amounts and reduces weight of the resultant plate. (This is a significant safety advantage in reducing inertia of pole structure.)
	* Bolt/slot geometric arrangement is not optimum relative to energy absorbed when vehicle strikes the structure.	* Bolt/slot geometric arrangement reduces activation energy to lowest feasible level for most probable impact angles. (This is a significant safety advance and is found on no other multi-directional slip base.)

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