

**MICHIGAN DEPARTMENT OF TRANSPORTATION
M•DOT**

INSPECTION AND REPAIR OF HIGH-MAST LUMINAIRES (HML)

Michael C. Isola, P.E.
R. L. McCrum

Research and Technology Section
Materials and Technology Division
Research Project 91 TI-1594
Research Report No. R-1342

Michigan Transportation Commission
Barton W. LaBelle, Chairman;
Richard T. White, Vice-Chairman;
Robert M. Andrews, Jack L. Gingrass
John C. Kennedy, Betty Jean Awrey
Robert A. Welke, Director
Lansing, August 1996

ACTION PLAN

1. Engineering Operations Committee
 - A. Approve Report

2. Maintenance Division
 - A. Inspect all HML statewide every two years using the *Procedure for the Inspection of High-mast Luminaires* as published by the Materials and Technology Division (Included in Appendix C).

 - B. Remove grout that is located under the base plate of HML so that adequate air circulation can be provided to the inside of the pole.

3. Design Division
 - A. Adhere to the following recommendations regarding the design and placement of high-mast luminaire structures:
 1. Tack welds used on anchor bolt nuts must no longer be used.
 2. Grout under the base plate of HML must no longer be used.
 3. Take the necessary steps in the geometric design of a roadway to avoid placing HML in a ditchline. High-mast luminaires should be placed at least 10 m (33 ft) from the roadway to minimize the amount of salt spray reaching the pole. This should not be a problem since the required clear zone is usually equal to or greater than this distance.

4. Traffic and Safety Division
 - A. Take the necessary steps in the geometric design of a roadway to avoid placing HML in a ditchline. High-mast luminaires should be placed at least 10 m (33 ft) from the roadway to minimize the amount of salt spray reaching the pole. This should not be a problem since the required clear zone is equal to or greater than this distance.

INTRODUCTION

In 1971, the M•DOT began to install high-mast lighting systems at high traffic volume interchanges and major bridges in an effort to improve nighttime visibility. High-mast lighting systems, commonly called high-mast luminaires (HML), provide a wide spread uniform distribution of light better defining interchange geometry resulting in improved capacity and reduced number of accidents. High-mast luminaires are 24.4 to 30.5 m (80 to 100 ft) tall lighting structures assembled by telescoping or transversely welding three to four individual sections. The cross-section of the poles are normally circular or 12-sided. Each HML pole is topped with a fixture ring containing four to eight individual lighting heads. The M•DOT maintains a population of 338 HML at 37 locations statewide (as of 1994) with over 71% of these installations in the Metro district. The 224 HML erected before 1981 were fabricated using A-588 weathering steel while the 103 HML erected after 1981 were fabricated using A-572 galvanized steel.

In late 1991, the Structural Research Unit initiated a project with the objective of determining the overall condition of Michigan's high-mast luminaire structures. Two hundred twenty-four of M•DOT's high-mast luminaire structures were made of A-588 weathering steel now ranging in age from 10 to 20 years old. This factor, combined with reports from the Maryland Department of Transportation concerning corrosion and cracking of their A-588 weathering steel HML poles, provided the basis for initiating this technical investigation. Subsequent reports from the states of Indiana and Illinois documenting their experiences with corrosion and cracking of A-588 weathering steel HML poles prompted the unit to refine and intensify its inspection.

1992 INSPECTION RESULTS

In 1992, the Structural Research Unit inspected a representative number of HML. This involved an extensive physical inspection of one HML per interchange and a visual inspection of every fifth HML. If any problems were discovered, every pole in the interchange was given visual inspections. We feel this procedure worked well to discover problem areas with our limited manpower. The inspections focused on several characteristics and problem areas. A complete summary of these areas is listed in Tables 1 through 5, which document all the locations, characteristics, and problem areas encountered during the inspection process. The following is a general overview of the tabulated information:

Table 1: A list of locations, job numbers, manufacturers and specific pole information throughout the state (last updated on 02/28/93).

Table 2: A summary of twelve sided high-mast luminaire characteristics.

Table 3: A summary of twelve sided high-mast luminaire problems that were documented in the field.

Table 4: A summary of Union Metal (circular) high-mast luminaire characteristics.

Table 5: A summary of Union Metal high-mast luminaire problems.

PROBLEM AREAS

Five problem areas were noted during the Structural Research Unit inspections:

1. Cracks in the longitudinal weld:

It was found that 19 of 71 (27%) A-588 HML fabricated by the Union Metal Corporation have cracks in the longitudinal weld. One crack was found in the longitudinal weld away from the telescoping end. The crack, shown in Figure 1, was 430 mm (17 inches) long. Since we could not confidently locate the crack tip with a dye penetrant test or ultrasonic test, the pole was removed. Eighteen of the cracks are located in the weld at the telescoping joint. Each telescoping joint ranges between 600 mm and 900 mm (2 and 3 feet), depending on the height of the structure. Cracks were found at the first and/or second telescoping joint and were between 24 mm and 432 mm (1 and 12 inches) in length (See Figure 2). A repair procedure was developed for the 18 defective Union Metal HML and is discussed in detail later in this report.

The crack extensions are believed to be the result of stress corrosion cracking (SCC). Stress corrosion cracks occur when the existing stress intensity factor is greater than the materials SCC threshold stress intensity factor and a suitable with a corrosive median is present, a moist chloride environment in the case. The stress intensity factor is a measure of the magnitude of the elastic-stress field for a given applied stress, crack shape, size, orientation, and structural configuration. Tensile stresses are created by residual stresses, which result from the manufacturing process. Additional stress is applied by radial pressure in the telescoping joint from the weight of the pole and wind loads.

2. Non-full penetration weld in the telescoping joint area:

Partial penetration welds in the telescoping joint area were found at 16 interchanges (146 HML) where full penetration welds are currently specified. Telescoping joint weld areas are currently required to have a 100 percent (full) penetration weld according to the M•DOT specifications and the 1985 AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals. This problem was found with all 71 Union Metal HML as well as the other 75, A-588 weathering steel and A-572 galvanized steel, 12-sided structures that were produced by other manufacturers. Partial penetration welds were detected by ultrasonically testing a representative sample of HML at each interchange in the telescoping joint weld area. Partial penetration welding can contribute to increased local stresses and stress intensity factors in these critical areas, increasing the probability of cracking as discussed in problem area (1) above.

3. Corrosion:

Although some *minor* corrosion was found on nearly all of the A-588 weathering steel HML, particularly near the base, it was found that potentially corrosive situations exist on nearly all HML.

a. Internal corrosion:

High-mast luminaires were visually inspected on the inside of the base and ultrasonically tested at the outside of the base of the structure. Ultrasonic thickness measurements were taken to verify the remaining metal thickness at the base of each structure.

At eight interchanges, bases were found which were completely sealed, allowing water buildup on the inside of the structure (See Tables 3 and 5). This situation initiates corrosion from the inside of the pole due to moisture that condenses and collects at the base. Significant levels of corrosion may develop from inadequate air circulation to keep these bases dry. At seven of these interchanges (74 HML), grout was used to fill the area between the base plate of the structure (where the leveling nuts are located) and the foundation. It was discovered, however, that this grout can be easily removed with a small sledge hammer and will prevent water accumulation and promote air circulation (See Figures 3 and 4) when the grout is removed. At the eighth interchange (4 HML), leveling nuts were improperly placed above the top anchor nut, leaving the base plate flush with the concrete foundation (See Figure 5). It should be noted that all eight interchanges with sealed bases have HML that are fabricated of A-588 weathering steel that may be more susceptible to corrosion than A-572 galvanized steel in this environment.

b. External Corrosion:

Fifty-seven HML were found to have site specific conditions which could promote external corrosion (See Tables 3 and 5). The two most extreme conditions noted were: (1) HML located adjacent to the roadway and exposed to salt spray (See Figure 6) and (2) HML located in low-lying areas, such as ditchlines and median depressions, which are typically covered with soil and gravel (See Figure 7).

4. Anchor Bolt Nuts:

High-mast luminaires typically have a four or six anchor bolt pattern on a 381.0 to 736.6 mm (15 to 29 inch) bolt circle. Inspections included sounding the nuts for tightness as well as ultrasonic testing to determine if the anchor bolt was flawed. Although no anchor bolts were found to have flaws, twenty-nine HML (See Tables 3 and 5) were found with loose anchor nuts, and in one case, all of the nuts were loose. Instructional memorandums for tightening loose anchor nuts were sent to the districts 5 and 9 on February 20 and 21, 1992 regarding these structures. The bolt tightening procedure is shown in Appendix B.

Tack-welded anchor bolt nuts, for the purpose of locking the nut to the anchor rod and base, were also found on most of the HML (see Figure 8; Tables 3 and 5). Tack welds create high stress concentrations between the anchor nut and base and eventually break loose, therefore, tack welds must no longer be used.

5. Bending:

Although nearly all HML inspected did exhibit some minor bending creating out-of-vertical alignment (typically 0.30 to 0.61 meters (1 to 2 feet) near the top of the pole, four HML were found to have bending in excess of 1.22 meters (4 feet) (See Figure 9). These structures were the first installed by M•DOT and have a significantly smaller cross-section at the top of the structure than the remaining HML population. This bending is not critical at this time, however, these HML may be more susceptible to weld cracks due to high tensile stress in the telescoping joint areas and should be closely monitored.

1994 INSPECTION RESULTS

In 1994, M&T's Structural Services Unit also performed an inspection of all HML in Michigan. Their inspection centered on the base of the HML and highlighted many of the problem areas found during the Structural Research Unit's inspection in 1992.

The Structural Services Unit inspection revealed the following areas of concern:

1. Gaps between the leveling nut and high-mast luminaire base plate.
2. Loose leveling and top nuts. Several nuts were found to be loose and manual tightening was conducted in each case. However, some nuts would not turn.
3. Anchor bolts out of plumb.
4. Anchor bolts not fully engaged into nut, leaving the bolt's top below the top surface of the nut.
5. Washers missing.
6. Nuts and washers tack welded to the base plate (many tack welds were cracked).
7. Rodent screens missing or badly damaged.
8. Grout under the base plate inhibiting inspection of leveling nuts and holding moisture.

9. Anchor bolts and nuts were noted with little or no galvanizing remaining.

These findings were sent to the Maintenance Division's Statewide Operations Engineer on August 24, 1994, (see Appendix A).

RETROFIT OF UNION METAL HML TELESCOPING WELD AREA CRACKS

As a result of the cracks found in Union Metal HML at the telescoping joint area, a repair procedure was developed. The decision was made to repair the defective Union Metal HML based on cost estimates of replacement as well as their remaining service life (approximately 10 to 15 years). If these structures had not been repaired, the replacement of a defective HML with a new A-572 galvanized steel HML would have cost approximately \$35,000 per pole for a total cost of \$595,000 for 17 cracked poles.

The initial repair of each defective Union Metal HML consisted of the following steps:

1. The area around the crack region was ground to remove A-588 steel "pitting" and create a smooth surface. Surface preparation is essential to make accurate ultrasonic test results (See Figure 10).

2. The crack extension in the weld area was found by ultrasonic inspection. That is, the length of the crack on the inside of the pole was found (See Figure 11).

3. A 38.1 mm (1-1/2 inch) diameter hole was drilled at the crack tip as determined by the ultrasonic inspection. The hole relieved the residual tensile stresses that were present at the crack tip and precluded further extension of the crack (See Figure 12).

4. A dye penetrant test was performed to confirm that the crack did not extend beyond the upper end of the hole (See Figure 13).

5. The hole area and weld area around the hole were painted with a zinc based paint to prevent further corrosion of the HML. Finally, the hole was plugged with a rubber stopper (See Figure 14).

The *cores* that were removed from the hole in the cracked region were further examined in the laboratory (See Figure 15). After the discs were polished and etched, it was found that all cracks were contained in the weld itself or in the adjacent heat affected zone.

FRACTURE MECHANICS ANALYSIS AND RETROFIT

METHODOLOGY

Fracture Mechanics Summary

The cracking is apparently the result of major defects in the longitudinal welds combined with a high residual stress field that allows stress corrosion cracking (SCC) to occur. Such cracking is not normally a problem for weathering steels since the stress necessary for initiation do not normally occur. Stress studies performed by the Illinois Department of transportation indicate that the material used in making some of the poles was cold worked to the point that higher than normal residual stresses have been left adjacent to the weld area. This in turn allows smaller defects (than would otherwise have been the case) to create the effectively greater stress intensity factors necessary for SCC.

The stress intensity factor necessary for SCC is of roughly the same magnitude as that necessary for unstable crack growth in weathering steel sections that are most susceptible to fracture (i.e., thicker sections with higher constraint, more dynamic loading rates, etc). Understandably there was some concern about the potential for unstable fracture of our own structures.

We decided to provide clamps to go around the poles at the cracked areas to compensate for the material lost. This action would also reduce the stress in the *blunted* crack tip area since the tensile force applied with the clamps imposes a compensating compressive field in the underlying pole material. The stress reduction will reduce the stress intensity at the repaired crack tip and, therefore, the likelihood of future cracking. The clamps also effectively reduce the seriousness of any reoccurrence of cracking by effectively changing the existing edge cracks to a configuration more like a center or through thickness crack. A center crack requires roughly twice the crack extension, at the same stress level, to achieve the same stress intensity factor as an edge crack. This means that any reoccurrence of cracking, must progress almost twice as far before possessing the same possible danger (from a fracture mechanics viewpoint) as the original cracks. Fracture mechanics and existing field experience suggest that a crack on a repaired lap joint might grow up to as much as 305 mm (12 inches) (beyond the repair clamps) before becoming a potential fracture risk.

Collar Design and Installation

The Structural Research Unit designed a 100 mm (4 inch) wide by 6 mm (0.25 inch) thick *collar* that wrapped around the area of the crack to replace lost cross section, as well as, reduce the stress intensity in the area of the blunted crack. The collar was constructed of A-588 weathering steel to maintain compatibility with the existing structure and help eliminate the need for future maintenance. The collar's 25 mm (1 inch) diameter A325 Type 3 bolts and high strength connection lugs allowed us to tighten the bolts to 133 kN (30,000 pounds), thus applying a circumferential or *hoop* stress of approximately 207 Mpa (30 ksi) into the pole. This load was chosen because it provides a desired amount of compressive stress across the crack, minimizes the

future corrosion between the collar and HML, and still allows reserve capacity for any wind loads. The A325 Type 3 Bolts used were first strength tested in a 10° and 20° wedge test according to ASTM F606 then additional bolts were calibrated in a skidmore for the desired tension. We positioned the bolts perpendicular to the crack surface as near as possible (see Figures 16 and 17).

All eighteen of the defective Union Metal HML were repaired by the Structural Research Unit. Tension in bolts of several initial installations were checked and found to be sustaining the desired load. Site specific information for each repair is listed in Table 6.

CONCLUSIONS

Because of the problems shown in this report and resulting repairs, an inspection program has been developed to ensure the integrity of both the repaired and unrepaired HML for their remaining service life. An inspection procedure was developed and is shown in Appendix C. The procedure details the necessary steps that must be taken to prevent or recognize future problems with the HML population. To help provide consistent inspections, an evaluation form is also provided in Appendix D.

RECOMMENDATIONS

Based on the inspection of these poles, we recommend the following:

1. Maintenance Division

A. Inspect all HML statewide every two years using the *Procedure for the Inspection of High-mast Luminaires* as published by the Materials and Technology Division (Included in Appendix C).

B. Remove grout that is located under the base plate of HML so that adequate air circulation can be provided to the inside of the pole.

2. Design Division

A. Adhere to the following recommendations regarding the design and placement of high-mast luminaire structures:

1. Tack welds used on anchor bolt nuts must no longer be used.

2. Grout under the base plate of HML must no longer be used.

3. Take the necessary steps in the geometric design of a roadway to avoid placing HML in a ditch line. High-mast luminaires should be placed at least 10 m (33 ft) from the roadway to minimize the amount of salt spray reaching the pole.

This should not be a problem since the required clear zone is usually equal to or greater than this distance.

3. Traffic and Safety Division

A. Take the necessary steps in the geometric design of a roadway to avoid placing HML in a ditch line. High-mast luminaires should be placed at least 10 m (33 ft) from the roadway to minimize the amount of salt spray reaching the pole. This should not be a problem since the required clear zone is equal to or greater than this distance.

TABLES

FIGURES

APPENDIX A

APPENDIX B

HIGH-MAST LUMINAIRE ANCHOR BOLT TIGHTENING PROCEDURE

The tightening shall be accomplished using a multiple pass procedure, including separate passes for snugging and tightening. Full tightening shall not be done all at one time. No more than one nut shall be removed at any one time. Anchor bolts must have full thread engagement on the nut to accomplish the tightening. Any bolts that do not have full thread engagement on the nut shall be tightened to a *snug* tight condition only.

Procedure:

1. Determine the anchor bolt diameter and the number of threads per inch to compute the thread pitch.

2. Lightly wire brush the exposed threads to remove grit and debris that would interfere with removal of the nut.

3. All top nuts and leveling nuts (bottom nuts) shall be brought to a *snug* tight condition before removing the first nut. Some nuts are tack welded to the base plate. Remove the tack weld by grinding and avoid damaging the base plate and nut. Spray the ground surface with cold galvanizing after the tightening operation is complete. A *snug* tight condition is defined as the tightness attained by the full effort of a person using a wrench with a length equal to 14 times the diameter of the anchor bolt. The full effort required to achieve a *snug* tight condition, must be applied as close to the end of the wrench as possible. Pull firmly, by leaning back and using your entire body weight (brace your feet to prevent slipping) on the end of the wrench until the nut stops rotating. Check tightness with repeated passes. Use a minimum wrench length of 450 mm (18 inches).

4. Remove the top nut and washer of one bolt (some structures will not have washers). If a washer is missing under the top nut, install new flat washer according to the material type stated in step 5. Wire brush off any additional grit or debris on the anchor bolt. (See Table 1 for maximum torque values).

5. Generously apply beeswax or the equivalent to the top nut bearing face and the top nut internal threads prior to replacement on the anchor bolt. Tighten the top nut to a *snug* tight condition as defined in step 3 above. If any gaps exist between the top nut and the base plate, a beveled washer shall be added between the nut washer and the base plate to eliminate the gap. If the structure is galvanized steel, the beveled washer shall be stainless steel Type 304. If the structure is A588 weathering steel, the beveled washer shall be made from material according to ASTM F436 Type 3.

6. Repeat steps 4 and 5 until all bolts and nuts have been lubricated and tightened to a *snug* tight condition. The sequence of snugging shall be such that the

opposite side nut, to the extent possible, shall be subsequently tightened until all the nuts in the pass have been snugged.

7. Check to make sure all of the leveling nuts are in contact with the base after all the top nuts have been *snug* tightened. If any gap exists between any leveling nut and the base plate, bring the nut into full bearing with the base plate. This may require the removal of a rodent screen. If a rodent screen does exist, it must be reinstalled after the tightening procedure is complete and reattached with galvanized steel ties.

8. Mark each nut and anchor bolt combination with a felt pen in order to visually verify the proper amount of rotation needed.

9. Using a hydraulic wrench, rotate all top nuts an additional portion of a turn in accordance with Table 1. The total additional turning of the nuts shall be accomplished by tightening all nuts in two separate passes of equal incremental turns (i.e., 1/16 or 1/12 turn each pass). The sequence of nut tightening in each pass shall be such that the opposite side nut, to the extent possible, shall be subsequently tightened until all the nuts in that pass have been turned. There shall be no rotation of the leveling nut during top nut tightening. See Table 1 for maximum permissible torque values.

TABLE 1 (English Unit Bolts Shown Only)

Bolt Diameter inch	Thread Pitch	Total Turn Required	*Maximum Permissible Torque (ft/lb)	*Maximum Permissible Torque (N*M) Joules
1	-8 UN	1/3	500	680
1	-8 UNC	1/3	500	680
1 1/4	-8 UN	1/3	900	1220
1 1/4	-7 UNC	1/3	900	1220
1 1/2	-8 UN	1/3	1600	2170
1 1/2	-6 UNC	1/6	1600	2170
1 3/4	-8 UN	1/3	2600	3530
1 3/4	-5 UNC	1/6	2600	3530
2	-8 UN	1/3	4000	5420
2	-4 1/2 UNC	1/6	4000	5420
2 1/2	-8 UN	1/3	7800	10580
2 1/2	-4 UNC	1/6	7800	10580

*This is the maximum permissible torque to be applied for nut removal and nut tightening. Maximum torque is established in order to prevent anchor bolt and/or nut damage from occurring. If this maximum torque is reached before the nut is removed or is fully tightened, record this information and omit this particular anchor bolt from the remaining tightening process.

APPENDIX C

**MICHIGAN DEPARTMENT OF TRANSPORTATION
MATERIALS AND TECHNOLOGY DIVISION
PROCEDURE FOR THE INSPECTION OF HIGH-MAST LUMINAIRES**

Establish Structure Location: Location information should include district number, MDOT structure inventory number, county name, route number, control section, and description of structure location using visible reference (ramps, overpasses, intersections, buildings) to facilitate future inspections. Also, reference to stationing or mile markers should be used if available. Structures must be stenciled with inventory number for future reference.

General Structure Inspection: Record the condition of the galvanized coating on the structure. Many structures are A588 without coating. In all cases, note the general condition (heavy corrosive areas, bleed rust, etc.) of the structure. Inspect the condition of any visible welds (base plate to upright, hand hole, longitudinal seam welds, etc.). Count the number of sections that make up the high-mast luminaire and visually examine the longitudinal welded lap splice and/or transverse splice welds with binoculars. Most of the HML are 20 to 30 meters (60 to 100 feet) tall and have at least one lap splice. Some poles have collars retrofitted over the splice; visually inspect the condition of the collars with binoculars. Also inspect for cracks in the longitudinal weld directly above the collars. Record any tilt or lean the high-mast luminaire may have (north, south, east, or west and approximate horizontal distance of tilt from center of concrete foundation).

All of the above information must be recorded on the inspection form with any additional comments noted.

Inspection of the Pole at the Base Plate: The portion of the pole from the base plate up 75 mm (3 inches) shall be ultrasonically inspected for corrosion losses. The individual performing the ultrasonic testing (UT) must be certified at ASNT LEVEL II, on recommended practice No. SNT-TC-1A.

To determine the nominal thickness of the pole, average 4 thickness measurements in the pole 400 mm (16 inches) up from the base plate (follow the procedure below).

To inspect for corrosion loss in the pole, grind the perimeter of the pole from the base plate up 75 mm (3 inches) being sure to remove all corrosion. Care must be taken to prevent gouging of the base plate during the grinding process. Only grind the pole enough to remove any corrosion and smooth the surface. Some small pits will remain visible after grinding which should not affect the UT inspection.

The inspection may be done using either of the following methods. (1) an ultrasonic inspection unit calibrated to a 25 mm (1 inch) screen and using a 5 Hz, 13 mm (1/2 inch) diameter, straight beam probe. Calibration is done using DSC block and a step block. (2) an ultrasonic thickness gage.

Care must be taken to insure that the backer ring inside of the pole is not included in the thickness measured. Standard straight beam probe techniques shall be used during the inspection process.

The average thickness and minimum thickness will be recorded on the inspection form.

Inspection of Base: Determine the bolt pattern for the anchor base. With a plastic tie, attach a plastic tag to the number one bolt (this can be any bolt if not already tagged). This tag should be placed between the base plate and the concrete foundation tied to the anchor bolt. Using a permanent marker, mark the corresponding bolt numbers on the vertical support in a clockwise pattern from the number one or tagged anchor bolt for future reference. Measure and record the anchor bolt diameter. Look for missing or damaged anchor bolts or nuts (gouges, corrosion, etc.). Note any bolt ends that have been bent to align with the holes in the base plate or anchor bolts that are not plumb. Note any bolt ends that are lower than the top of the top nut. If the bolt is lower than one or two threads, measure the depth and mark it on the inspection form in the box corresponding to the bolt number. Note any nuts that are tack welded to the base plate. Visually inspect any welds in the base (gussets, vertical support to base plate connection), looking for cracks or unusual welds. Also, note any damage (corrosion, cracks, gouges, dents) to the base, gussets, and vertical support.

Inspect the condition of the concrete foundation, noting any spalling, cracks, and general deterioration.

Using a 750 gram (24 ounce) ball-peen hammer, hit the side of both, the top nuts and leveling nuts and hit the top of the bolts. This is done to check for loose nuts (leveling and top) and/or cracked or broken bolts. If the nuts are tight, there is a sharp ringing sound; if the nuts are loose, there is a dull sound. Check all nuts (leveling and top) on all bolts before proceeding with tightening of the loose nuts. Inspection of leveling nut and washer may require the removal of a rodent screen between the base plate and the foundation. Rodent screens are steel mesh wrapped around the base plate with the ends wire tied together. After removing the rodent screen, visually check for any gaps between the leveling nut and the base plate. Physically grasp the washer and try to move it to determine the leveling nut tightness. If the leveling nut is loose, tighten it after tightening the corresponding top nut. If the leveling nuts and washers have been inspected, tag the number one bolt, as stated above, and reinstall the rodent screen tying the ends together with new galvanized tie wire. Be sure the rodent screen is securely in place and tightly tied at the ends.

Tightening either of the anchor bolts nuts (leveling or top) can be done using an appropriately sized spud wrench, spanner wrench or socket wrench. A 1 to 1.2 meter (maximum 1.2 meter length) (3 ft to 4 ft) (maximum of 4 ft length) pipe is added to the wrench to increase leverage. The nut is tightened until no further movement takes place. Any broken rods should be easily identified as both the nut and the bolt **will** continue to twist with little applied torque. If only the nut rotates under the applied

torque, complete the tightening and resound the side of the nut and the bolt with the hammer. Note all the nuts that require tightening on the inspection form.

Ultrasonic Inspection: The individual performing the UT must be certified at ASNT LEVEL II, on recommended practice No. SNT-TC-1A.

Grind all anchor bolt ends flat (perpendicular to the shank of the bolt), being sure to remove all galvanizing, paint, dirt, and debris. Because deep 2 mm (1/16 inch) or greater surface imperfections (gouges, cuts) can affect the UT results, make the ground surface as smooth as possible. Some bolts have been marked with an X for use as bench marks. It is not necessary to grind the bolt until the indentions are completely removed, as these are usually shallow and should not affect the UT inspection. Only grind the bolt a sufficient amount to remove any paint or rust and smooth the surface. There are some bolt ends that have extreme slant and cannot be ground to a flat, perpendicular surface. Note any bolts that have this problem on the inspection form. At some future date, these bolts should be corrected with a flat, perpendicular surface to allow for inspection.

Calibrate the ultrasonic unit for straight beam probe method using a 250 mm (10 inch) screen with a 25 mm (1 inch) diameter straight beam probe. The probe is placed on a 25 mm (1 inch) thick calibration block (DSC block or section of anchor bolt), and the indications on the screen are adjusted so that a reflection is positioned at each inch mark. Next, place the probe on a 230 mm (9 inch) long test bar that has a 3 mm (1/8 inch) deep saw cut at a set distance 80 to 100 mm (3 to 4 inches) from the end in the threaded portion of the rod. Peak the back reflection from the 3 mm (1/8 inch) deep saw cut until the indication is at 50% or 80% of screen height. The dB reading is recorded to establish the REFERENCE LEVEL. The SCANNING LEVEL is set by adding 14 to 30 dB over the reference level. Calibration should be checked at each location before inspecting any bolts.

Apply couplant (glycerin) to the ends of the bolts. Ultrasonically test the anchor bolts using a circular motion inspection pattern and record the results. When scanning the anchor bolts, there should be no indications on the CRT screen between the Main Bang (zero depth) and the end of the screen 250 mm (10 inches) depth. Any indication that is displayed after the Main Bang is a possible flaw. Record the depth of the discontinuity observed and the amount of dB required to bring the indication to the REFERENCE LEVEL on screen. This is recorded as the INDICATION RATING.

After the inspection is complete, wipe off all the couplant (glycerin), then wash off bolt end with water and follow with an ethanol rinse. Allow the surface to dry thoroughly and spray the bolt end with cold galvanizing or zinc-rich paint.

Reporting Procedure: All written reports (obtain form #1018 for High-Mast Luminaire Inspection from MDOT's M&T Division) shall be legible, accurate, and detailed. These documents will be used as evidence of work performed (pay item). Payment for work will not be made if data gathered is illegible or undecipherable.

Any unusual or potentially dangerous findings shall be reported immediately to the Michigan Department of Transportation, Materials and Technology Division at 517-322-5709 or 517-322-1235.

Safety: High-mast luminaire inspections and related work (hammering and grinding) shall follow MIOSHA safety standards (use of safety apparel and equipment safety guards). Safety apparel and equipment (hard hats, leather gloves, safety glasses, safety shoes, safety vest) shall be worn by all workers.

Equipment Tool List:

- Complete ultrasonic unit with straight beam probe
- Portable generator to operate ultrasonic unit and grinder
- 30 mm (100 foot) electric power cord
- 750 gram (24 ounce) ball-peen hammer
- 1.2 m (4 ft) level
- Container of couplant (glycerin)
- Box of rags for cleaning
- Cans of cold galvanizing or zinc-rich paint
- L-head grinder with grinding disks
- 20 liter (5 gallon) gas can, must be safety type
- 4 m (12 ft) tape measure
- Round point shovel
- Wrenches (spud, spanner, or socket) and 1.2 m (4 ft) pipe extension
- Report forms: #1018 for High-Mast Luminaire Inspection
- Binoculars
- Stencil pad with numbers and letters
- Black and white spray paint

APPENDIX D