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# Evaluation of Traffic-Induced Light Pole Vibrations On the I-80 Le Claire Bridge

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Christopher Volkman, PE, and Christopher Hahin, MetE, PE

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**16. Abstract**


EXECUTIVE SUMMARY

The results obtained from accelerometers mounted on the luminaires of the I-80 Le Claire Bridge over the Mississippi River, near East Moline, IL, indicated peak acceleration forces of approximately 5 g. Due to hazards posed by luminaries falling onto traffic or the bridge deck, District 2 removed the lighting until a safe solution is tested and approved.

It was found that the acceleration in the longitudinal direction of the bridge was found to be only about 2.0 g. The largest g forces were sustained at 45°, averaging 4.73 g ± 0.17g with an internal plastic pipe, and 4.82 g ± 0.22g with only a Fabreeka® vibration attenuation pad and washers bolted in between the pole base and parapet. Transverse accelerations, which are perpendicular to the long axis of the bridge, were only slightly less at 3.99 g ± 0.45g with an internal HDPE plastic pipe, and 4.06 g ± 0.33g with only a Fabreeka® pad.

These results indicate that the deck is deflecting inward as trucks pass by, pitching the pole in a vector close to 45° away from the transverse axis. The peak accelerations occur as point pulses derived from axle loads as trucks pass by, resulting in sharp downward deflections and accelerations of the luminaire. At 55 mph, the average rise time for these pulses is about 8 milliseconds. Acceleration of the luminaire is a direct function of axle load and truck speed. Further testing is required to determine the effects of: (a) changing the pole material from aluminum to hot-dip galvanized steel or polymer composites; (b) adding sufficient mass for the luminaire counterbalance and precise direction for best vibration attenuation; and (c) increasing luminaire resistance to vibration at 5-g acceleration or more. Before any pole lighting is re-installed, it is imperative that luminaires be tested and approved by their manufacturers and the Illinois DOT to verify their resistance to 5-g vibration at a cyclic range of 1-10 Hz.


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## Background

Since 1995, aluminum light poles on the Le Claire Bridge, where Interstate-80 crosses the Mississippi River near East Moline, IL, have been experiencing severe deflections and vibrations, causing luminaires to fail on numerous poles. This investigation was undertaken at the request of District 2, and the Electrical and Mechanical Unit of the Bureau of Design and Environment to determine the causes of the lighting failures, which constitute a hazard to traffic on Interstate-80.

## General Description of the Bridge

The LeClaire Bridge is a long, multi-span bridge, carrying passenger cars, light trucks and heavy commercial truck traffic over the Mississippi River near East Moline, IL. The bridge has an average daily traffic (ADT) of 30,000 vehicles per day, with an average daily truck traffic (ADTT) of 9,400 trucks per day. Its overall length is 3,483 ft between the abutment bearings, and its superstructure is supported by 26 piers.

### *Piers and Superstructure*

As shown in *Figure 1*, the approaches are multi-stringer beams which support a total of four lanes of traffic. The remainder of the bridge is supported by two deep constant-depth girders, which are connected by cantilevered floor beams, also shown in *Figure 1*. In the main spans between piers 12 and 15, the two haunched girders supporting the span have two web plates, providing some redundancy, as shown in *Figure 2*. The remainder of the superstructure is supported by two single-web girders for 2,320 ft, which is approximately 67% of the length of the bridge. In turn, floor beams connect these deep plate girders, and support the stringers, deck and parapets.

*Figure 1.* Photograph of the LeClaire Bridge over the Mississippi River, taken from the western approach, showing beam stringers of piers 8 and 9. The superstructures of the intermediate spans consist of two deep plate girders which support cantilevered floor beams. An 8-in thick reinforced slab deck, composite in the positive moment areas, rests on 24-in deep wide flange stringers.

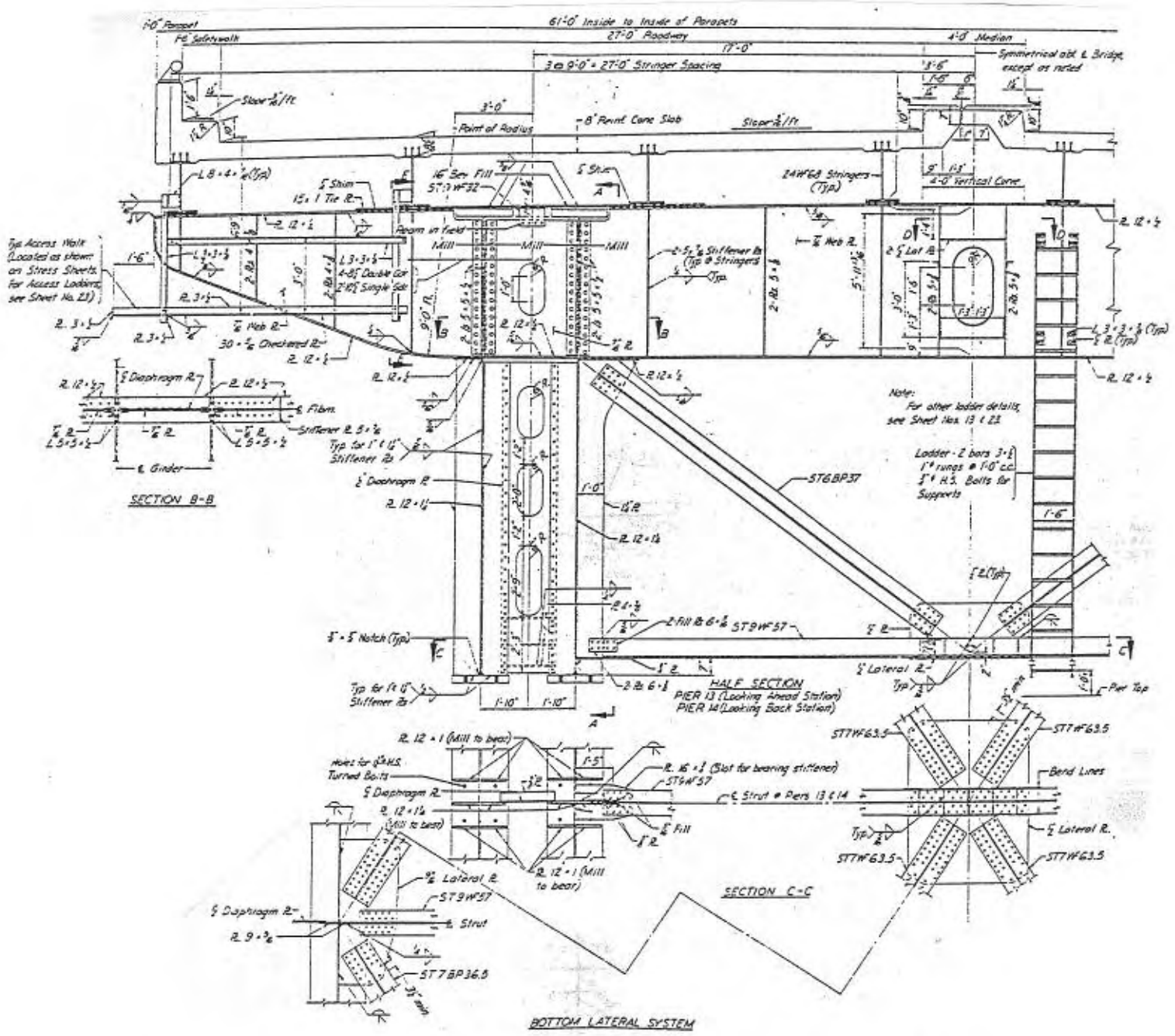


*Figure 2.* Floor beam cross section at piers 13 and 14 over the main channel where there is composite action with the deck.

The stringer beams which support the 8-inch reinforced concrete slab deck consist of 24 in deep ASTM A36 hot-rolled steel wide flanges at 68 lbs/ft. These 24 WF 68 stringers are non-composite in their negative moment areas. They are made composite with studs in their positive moment areas. Four stringer beams support two lanes of traffic. A typical cross-section for a cantilever floor beam is shown in *Figure 3.* The bridge is relatively narrow, with a small shoulder separated by a NJ-shaped central barrier median. The parapets are 12 in thick, and 28 in high, with an 18 in safety cross walk. Each lane is 12 ft wide, with 3 ft wide shoulders. No guard rail is presently installed on top of the parapet.

***Installation of the Lighting***

Lighting poles were originally installed on a spacing which provided optimal light coverage, based on luminaire beam spread. As a result, lighting pole positions do not correspond with pier positions, and have remained unchanged since original construction. Lighting placement is shown in *Figure 4.* However, the original poles were 27½ ft tall, made of tapered aluminum alloy tubes, with 0.250-in wall thickness. The luminaires were attached to the pole by an extension davit arm at 45°. The davit arm was attached to the pole with a wrap-around compression fitting. The luminaire was an IES Type III mercury vapor high-intensity light, operating at 480 V with 400 W of power. Design details are shown in *Figure 5.*

In 1995, 32 ft high HAPCO aluminum poles, with curved style davit arms, were installed. Fixtures were Crouse-Hinds OVF style, which continually sustained lens and lighting failures due to vibration. In 1999, lighting was modified by adding a vibration damper clamp assembly, which was mounted on the davit arm behind the slip fitter. It was anticipated in 1999 that vibration would be attenuated by installing counter-weights, but the weights proved to be ineffective.

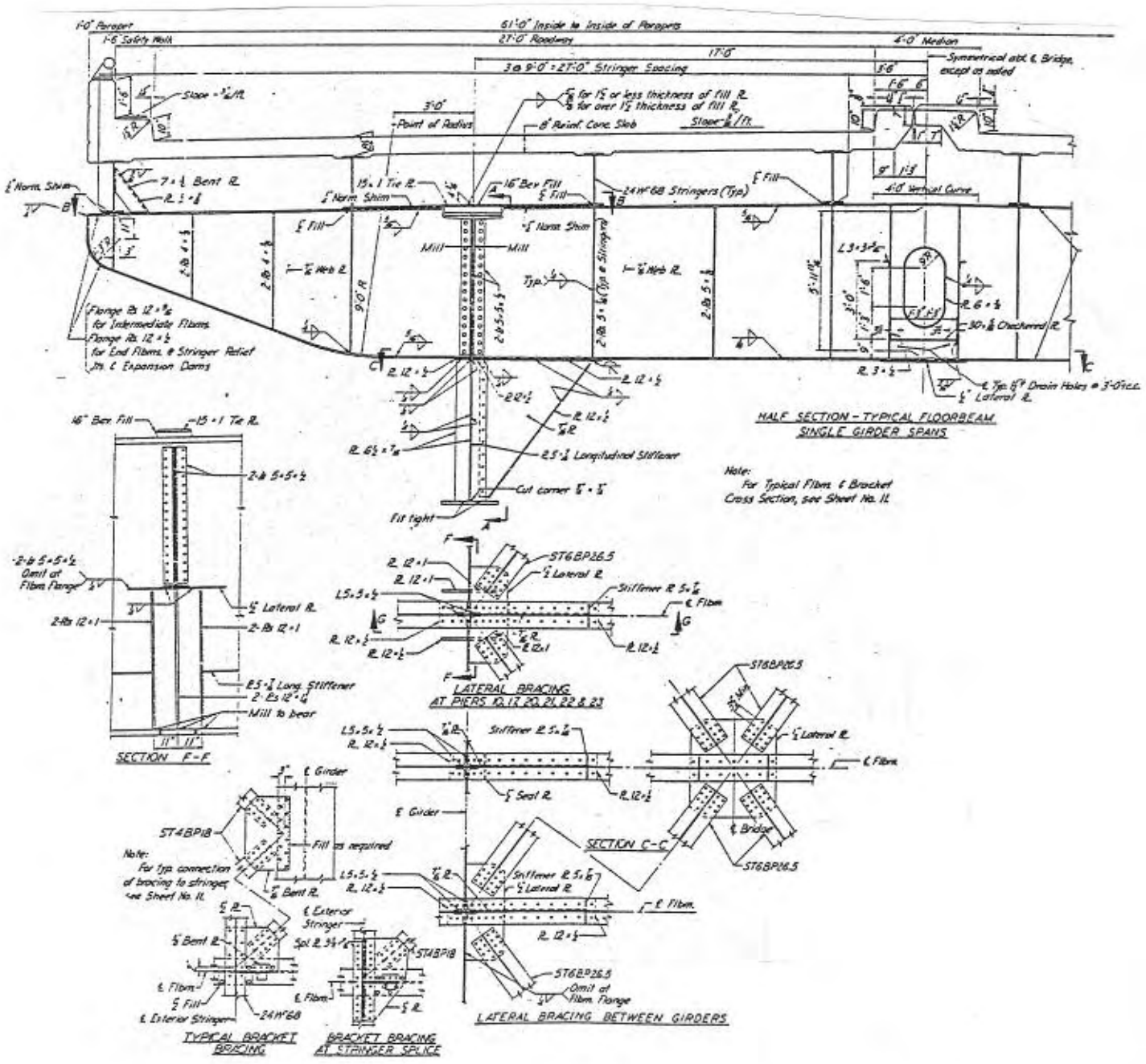


*Figure 3.* Typical cross section for cantilever floor beams which support the deck.

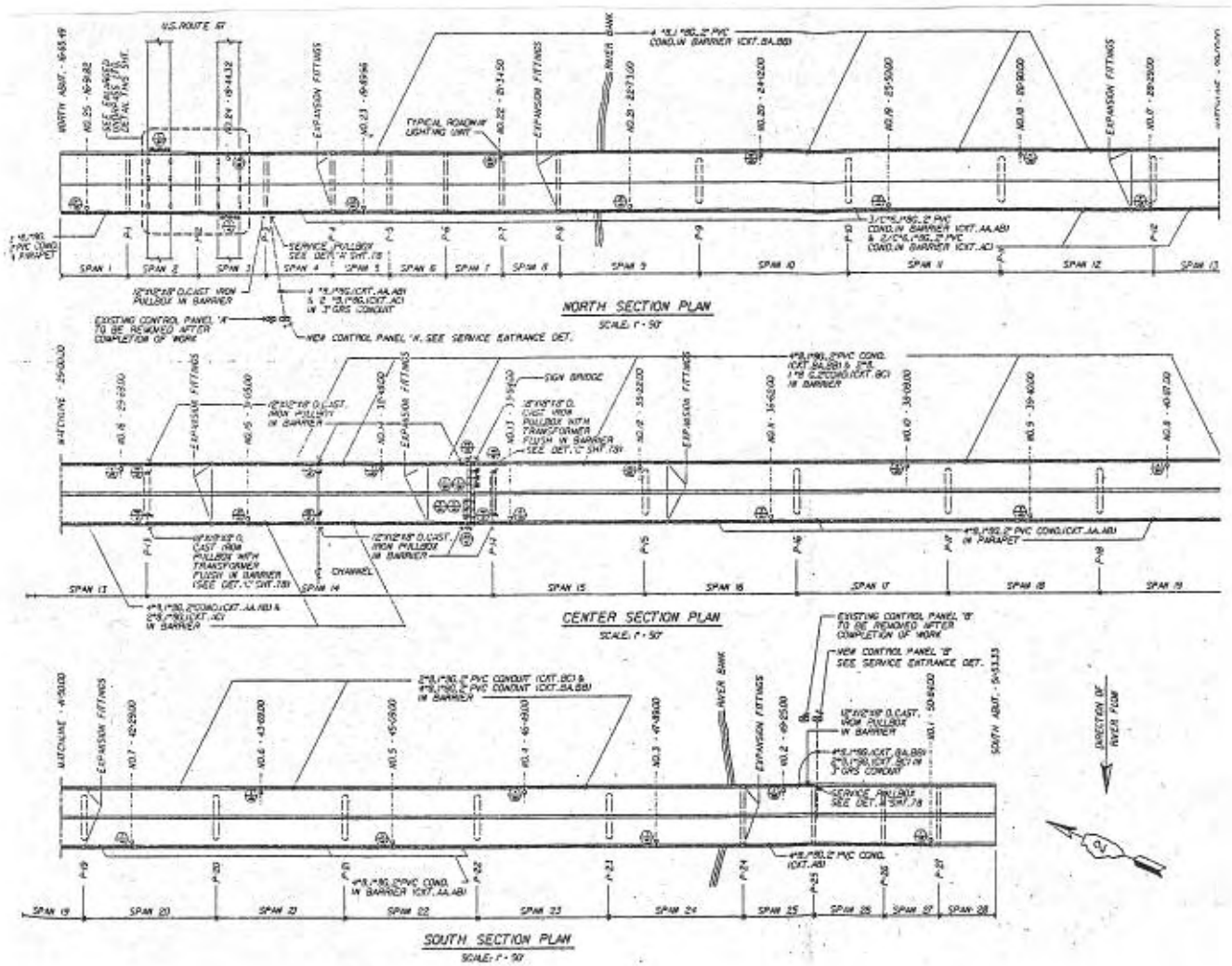


*Figure 4.* Distribution of the lighting along the bridge. Spacing is determined by lighting coverage and inherent luminaire beam spread. Lighting placement is independent of the location of main piers and floorbeams.

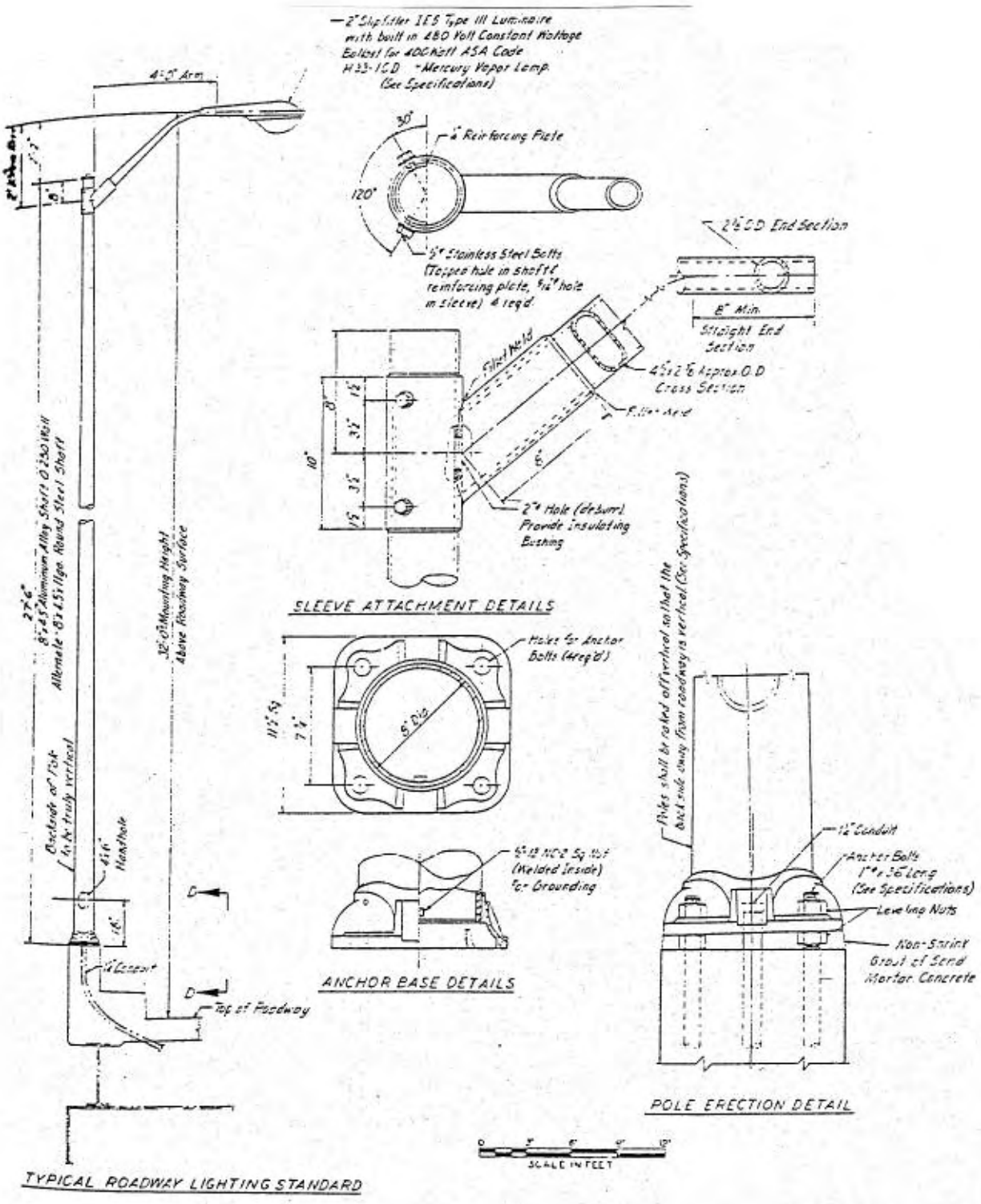


*Figure 5.* Original light fixture installed on the LeClaire Bridge. Successive luminaire heights have increased from 27½ ft to 40 ft.

In 2002, tapered aluminum poles of 40 ft height manufactured by Valmont, of Valley City, NE, were installed. The lighting elements were subsequently upgraded by contract specifications to a Crouse–Hinds OVF 3G fixture, capable of sustaining vibrations up to 3 g. Fabreeka SA-47 vibration pads were also installed at the pole bases. These poles were straight tenon-top poles, with tilted luminaries facing toward the bridge decking. Unfortunately, Crouse-Hinds ORL luminaires were mounted instead of the specified OVF 3G fixtures. The ORL fixture is a 480 V high pressure sodium vapor lamp, with a swing-down ballast tray, and weighs 45 lbs. Both ORL and OVF 3G luminaires are directly attached to the top of the pole, reducing the free-end moment associated with an extended davit arm. However, vibration problems continued to plague the luminaires mounted on the replacement tenon top poles.

## Compression and Acceleration Tests

In the first phase of the investigation, a series of compression tests were completed to determine the elastic characteristics of the vibration isolation pads and washers used on the pole bases. In the second phase of the study, the accelerations of the luminaires were recorded. Because acceleration measurements were taken on a calm day with no appreciable wind, the accelerations were solely caused by the deflection and vibration of the bridge and deck induced by the frequent heavy truck traffic that passes over the Le Claire Bridge.

### *Characteristics of Vibration Isolators*

The base vibration isolation pad and its isolation washers which interface between the anchor bolt nuts and steel washers are manufactured by Fabreeka, Inc. of Stoughton, MA. The base material pad and washers initially installed during construction were composed of SA-47, a random, ostensibly isotropic dispersion of synthetic fibers in a synthetic rubber matrix. The rated Durometer of SA-47 composite is 80 ±10 Shore A. Originally, SA-47 washers were

inserted between the anchor bolt nut and the pole base top. However, after torquing, the SA-47 exhibited considerable deformation because of its lower modulus of elasticity, as compared to the harder Fabreeka® material. No ft-lb value for bolt torque was apparently supplied to the contractor.

To prevent this deformation, the electrical contractor inserted a Fabreeka® washer instead, which is a series of tightly woven layers of fibers impregnated with synthetic rubber. It has greater tensile and shear strength than an SA-47 washer, and has a substantially higher modulus of elasticity. Fabreeka® pads are rated at 90 ± 5 Shore A Durometer hardness.

Airloc, of Franklin, MA, another manufacturer of vibration isolation devices, also submitted samples for testing. The Airloc 30 washers are composed of a synthetic polymer with layers of granulated cork and random fibers in a polymer matrix. The elasticity of each washer was tested experimentally by application of known loads, and measuring actual deformation upon compression.

Three different vibration isolators, Fabreeka®, SA-47, and Airloc 30, were tested in an Instron Model 4206 tensile machine. This instrument has a load range of 0 to 44,480 N [0 to 10,000 lbs]. Load cells are able to resolve loads to the nearest 0.1 N [0.022 lbs]. Column screw resolution is 0.001 mm [0.000039 in]. Compressive displacement was further confirmed by use of an Ono Sokki digital linear gage, with an accuracy of 0.00005 in.

The load-deformation elasticity values for SA-47, Fabreeka®, and Airloc 30 washers are plotted in *Figure 6*. Close-ups of the internal cross-sections of SA-47, Fabreeka® and Airloc 30 styles of washers are shown in *Figure 7*. The Fabreeka® washer is approximately 10 times as stiff as the Airloc washer, and 3 times stiffer than the SA-47 washer. Because of the appreciable

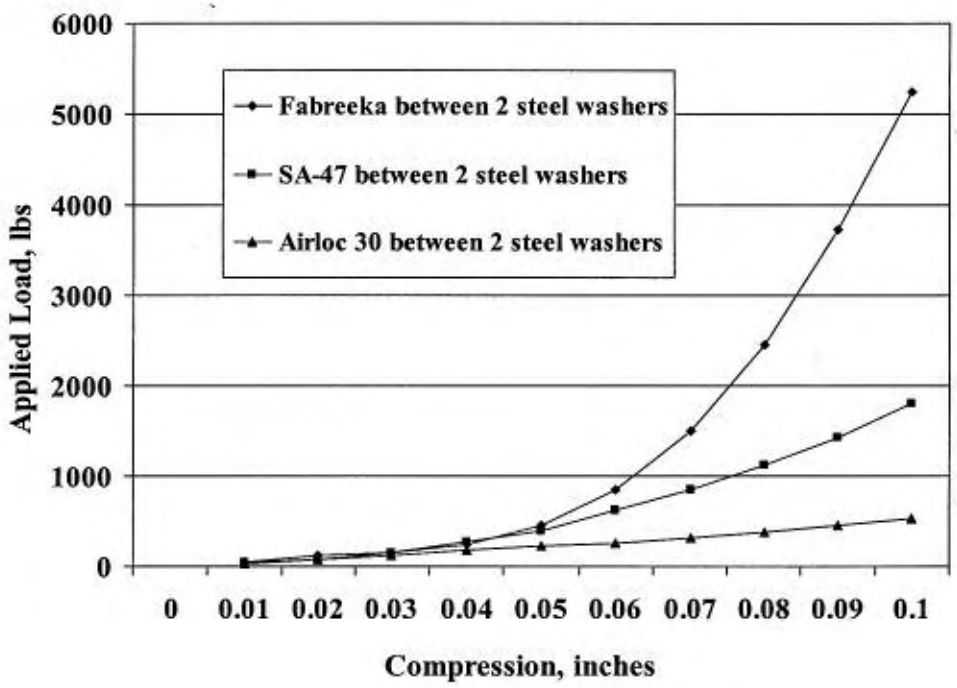


*Figure 6.* Compression testing of the Fabreeka®, SA-47, and Airloc 30 washers. Washers had the same dimensions, and were compressed under identical conditions. All washers have dimensions of 3-in OD, 1¼-in ID, and are ½-in thick. In order to achieve 0.100-in compression, the stiff Fabreeka washer requires about 5000 lbs of load, compared with the soft SA-47 at 1800 lbs, and 500 lbs for the even softer Airloc 30 washers.

*Figure 7.* Close-ups of the cross sections of the Fabreeka®, Airloc 30 and SA-47 vibration attenuating material.

[A] The Fabreeka® washer is composed of 0.007-in thick layers of tightly-woven canvas duck fiber, which reinforces the elastomeric matrix which binds the layers together.

[B] The Airloc 30 pads and washers consist of layers of randomly oriented fibers, along with granulated cork, bound together by a polymer matrix. The irregular, elongated cork particles are roughly circular when transversely cut, with an average diameter of 0.030-in to 0.040-in.

[C] The SA-47 pads and washers are composed of cotton fibers randomly distributed in an elastomer, and compressed during curing for binding purposes.

volume of cork distributed throughout the polymer matrix of the Airloc washers, it has markedly less stiffness than the tightly woven Fabreeka® composite.

***Measuring Luminaire Accelerations***

In the second phase of the investigation, the accelerations of the luminaires were measured as truck traffic passed over the bridge. The tests were conducted without barricades and no traffic slow-downs, permitting trucks to pass over the bridge at typical speeds for at least 15 minutes. Because of the high percentage of trucks passing over during sampling, it was considered that this was a representative sampling of typical peak conditions for this bridge. Even when the barriers were erected to install gages, trucks traveling at 25-30 mph caused deflections of static barrier trucks of at least 2 to 3-in.

Four accelerometers were mounted on the luminaires, and were oriented 45° apart from each other, as shown in *Figure 8*. One of the accelerometers was oriented transverse to the bridge, and another was oriented longitudinal to the bridge. The acceleration data was recorded on a sensitive oscillographic Astro-Med Dash IV chart recorder. Detailed testing and safety procedures were as follows:

1. Station energy-attenuating crash barrier truck & transition cones on shoulder about 100 ft before work site to protect instrument installation crew.
2. Using bucket truck, install accelerometer(s) at luminaire-pole interface; attach wires to pole with nylon cinch straps.
3. Install adhesive strain gages at hand hole & about ¾-in above base weld.
4. Assure that data acquisition equipment is functioning.
5. Installation crew leaves site, followed by removal of cones & crash-barrier truck.
6. Vibration of existing pole monitored for 15 minutes.
7. Crash barrier truck returns to site.
8. Instrument crew backs off pole base nuts; nominal thickness, ½-in; any elastic recovery of prior compression on existing SA-47 Fabreeka pad should be noted.

9. Bolts re-torqued to finger-tight, then ½ turn; double-nutting used, with second nut a jam nut.
10. Assure that data acquisition equipment is functioning.
11. Installation crew leaves site, followed by crash-barrier truck.
12. Vibration of existing pole monitored for 15 minutes.
13. Crash barrier truck returns to site, accompanied by crane and new MIL-C-882 Fabreeka pad.
14. Choker attached to pole to lift it; base nuts removed; MIL-C-882 Fabreeka pad installed, and nuts torqued to manufacturer's recommendations.
15. Installation crew & crane leaves site, followed by crash-barrier truck.
16. Vibration of existing pole monitored for 1 hour.
17. Crash barrier truck returns to site.
18. Data acquisition equipment removed; instrument crew departs.
19. Crash barrier truck and cones removed.
20. Data of (a) existing pole, (b) pole with lessened torque on existing pad, and (c) pole with Fabreeka pad compared to note any significant differences in vibration at various points on pole.

***Pole Removal***

For safety reasons, the subject light poles were taken down by District 2 before tests could be conducted to note if there were any differences in attenuation of luminaire g-forces with the Airloc 30 base pads and washers.

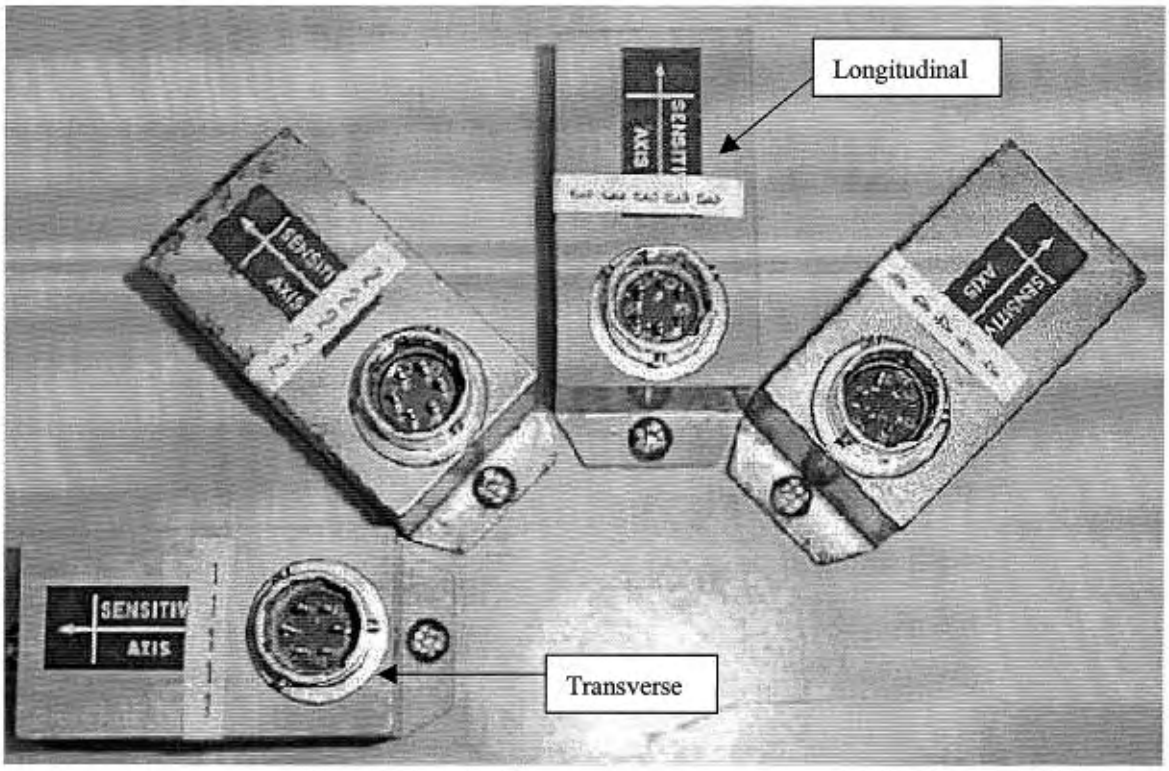


*Figure 8.* Accelerometer orientation was created by mounting the accelerometers on a plate, which was attached to the top of the luminaire with screws. Traffic barriers were removed prior to starting the recordings of traffic-induced acceleration of the fixtures.

The accelerometers used were Schaevitz Model LSBC-2-W/1G bias, with a sensitivity of 0.003V/g. Each accelerometer is calibrated by placing it in direct downward position to obtain 1 g. The accelerometers were oriented in four different axes 45° apart from each other, with the longitudinal and transverse being two of the four axes [see *Figure 8*]. The accelerometers were attached to a bracket that was bolted to the back of the luminaire. The accelerometers were setup to read the horizontal acceleration of the luminaire at the top of the pole. The acceleration was recorded in both (+) and (-) direction in each axes, providing a better understanding of the pole behavior during traffic-induced deflections.

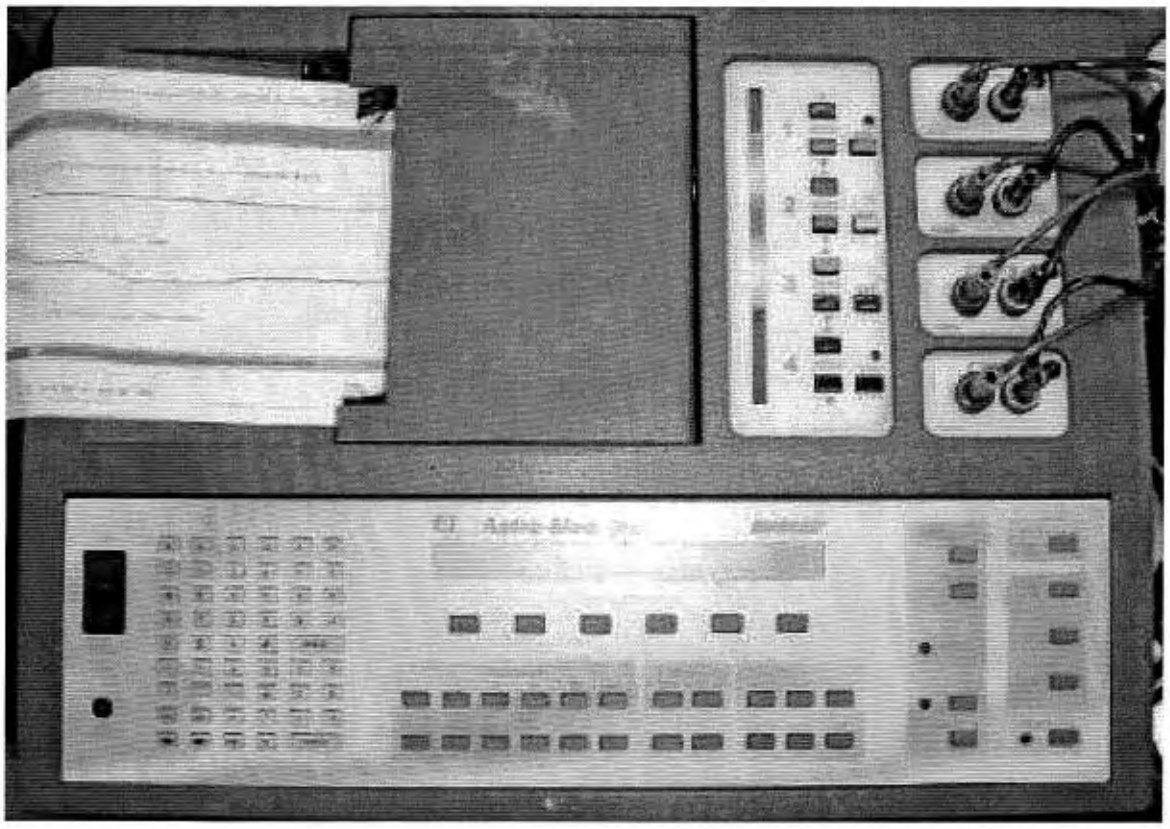

*Figure 9.* The Astro-Med Model Dash IV chart recorder was placed in a large instrument case during recording of events, and was placed on the right lane shoulder of the bridge. Power was supplied by an external generator.

The acceleration data was recorded on an Astro-Med Dash IV 4-channel chart recorder, shown in *Figure 9.* This instrument has a real-time sample rate of 250 kHz per channel, with data capture memory of 64 kilocycles per channel. Data sampling is limited by setting specific trigger voltages. The recorder plotted peak-to-peak values which represented positive and negative accelerations.

The test was intended to determine the behavior of the luminaire, and whether various pads have the ability to absorb vibrations, lessening their transmission to the luminaires. The pad is sandwiched between the pole and the parapet. The base of the poles is held in place with 4 anchor bolts and isolation washers. Nuts are then torqued to within Fabreeka's specifications,

limiting the amount of compression of the pad and washers. Along with the test on the Fabreeka pad, another test was conducted to determine if a 20 ft long, 1.5 in diameter high density polyethylene (HDPE) plastic tube, when placed inside the light pole, would attenuate the vibrations as well. A third material, made by Airloc, of Franklin, MA, was also tested for its properties in comparison to the Fabreeka pads.

The test pole was located on the parapet of the westbound lane of the LeClaire Bridge. The 40 ft pole was a straight, tapered aluminum tube, with a tenon top and a "cobrahead" luminaire. No davit arm is used with this style of luminaire. The tests were set-up such that the recorder would start receiving data once the traffic safety crew was cleared off the bridge, and full traffic load was regained. After personnel were cleared, the recorder then plotted data for 15 minutes. See *Figures 10, 11, 12 and 13* for additional details.

The data collected was a series of acceleration events generated by truck traffic for each test. From the data collected, the 20 highest spikes of data were selected for analysis. The average peak acceleration of the light pole in each of the four axes was then derived from these 20 acceleration spikes. Test #1 was configured with the Fabreeka pad installed, plus a 1.5-in diameter HDPE pipe placed inside the light pole. Test #2 had the Fabreeka pad, without the HDPE pipe in the pole.

*Figure 10.* Installation of accelerometers on the luminaire on the poles mounted on the parapets of the Le Claire Bridge.

*Figure 11.* Instrumentation case, recorder and power supply which was left on the bridge to record acceleration spikes generated by truck traffic.

*Figure 12.* Installation of the Airloc pad by contractor personnel.

*Figure 13.* Preloading of the Airloc washers and pad, resulting in compression bulging of the polymer and cork interior.

*Table 1* Accelerations of Light Pole Luminaires on I-80 Bridge over Mississippi River

| Truck Loading | Test 1 values in gravity (g's) | | | | Test 2 values in gravity (g's) | | | |
|---|---|---|---|---|---|---|---|---|
| | Accelerometer | | | | Accelerometer | | | |
| Event | 0 deg | 45 deg | 90 deg | 135 deg | 0 deg | 45 deg | 90 deg | 135 deg |
| 1 | 4.27 | 4.49 | 1.80 | 3.00 | 4.36 | 5.14 | 3.09 | 3.88 |
| 2 | 4.23 | 4.89 | 2.13 | 3.06 | 4.14 | 4.61 | 1.91 | 4.02 |
| 3 | 3.80 | 4.77 | 1.97 | 2.88 | 4.22 | 4.76 | 2.31 | 4.00 |
| 4 | 4.22 | 5.00 | 2.14 | 3.20 | 4.31 | 4.87 | 1.73 | 4.25 |
| 5 | 4.08 | 4.80 | 2.16 | 4.10 | 4.03 | 4.82 | 2.68 | 2.79 |
| 6 | 3.70 | 4.65 | 1.72 | 2.85 | 3.18 | 4.95 | 2.27 | 2.43 |
| 7 | 4.25 | 4.76 | 1.71 | 3.81 | 4.29 | 4.96 | 1.95 | 4.05 |
| 8 | 4.39 | 4.74 | 2.21 | 3.65 | 4.11 | 5.00 | 2.64 | 3.65 |
| 9 | 4.38 | 4.88 | 1.76 | 3.70 | 4.32 | 4.99 | 2.23 | 3.50 |
| 10 | 3.98 | 5.03 | 1.75 | 2.83 | 4.25 | 4.04 | 2.11 | 2.82 |
| 11 | 4.31 | 4.40 | 2.36 | 3.79 | 3.90 | 4.71 | 2.48 | 2.55 |
| 12 | 4.25 | 4.73 | 1.93 | 2.87 | 3.29 | 4.77 | 2.18 | 2.75 |
| 13 | 4.12 | 4.62 | 1.70 | 2.93 | 3.64 | 4.74 | 1.45 | 2.48 |
| 14 | 4.40 | 4.63 | 2.74 | 3.73 | 4.24 | 4.77 | 2.04 | 3.38 |
| 15 | 2.48 | 4.63 | 1.55 | 2.43 | 4.31 | 4.92 | 1.78 | 3.03 |
| 16 | 3.63 | 4.47 | 1.60 | 2.48 | 4.28 | 4.79 | 1.89 | 3.84 |
| 17 | 3.30 | 5.00 | 2.00 | 3.18 | 3.91 | 5.02 | 2.25 | 3.65 |
| 18 | 3.79 | 4.71 | 1.85 | 3.15 | 3.99 | 4.80 | 2.30 | 2.64 |
| 19 | 4.06 | 4.68 | 1.75 | 3.27 | 4.12 | 5.00 | 1.62 | 2.78 |
| 20 | 4.21 | 4.75 | 2.32 | 3.23 | 4.29 | 4.70 | 2.90 | 3.63 |
| Average | 3.99 | 4.73 | 1.96 | 3.21 | 4.06 | 4.82 | 2.19 | 3.31 |

NOTE: Test 1 has Fabreeka pad, with internal 1.5" HDPE pipe; Test 2 has Fabreeka pad without pipe.

The accelerometers were labeled 1 through 4. Accelerometer 1 is at the axis that is transverse to the bridge. The number 2 accelerometer is at the axis that is 45° clockwise from the transverse. The longitudinal axis of the bridge is represented by accelerometer 3 and accelerometer 4 is 45° clockwise from longitudinal [see *Figure 14*].

*Table 1* shows that the luminaire is pitching both laterally and downward with substantial acceleration due to deflection as a truck passes by. The accelerations are almost 5 g, which is 1.67 g more than the rated acceleration of the Crouse-Hinds OVF 3G fixture. When the HDPE pipe is installed in the pole, the average peak acceleration is attenuated by only 0.09 g. Installation of the Fabreeka pad and washers proved to be ineffective in attenuating the acceleration of the luminaire to below 3 g's.

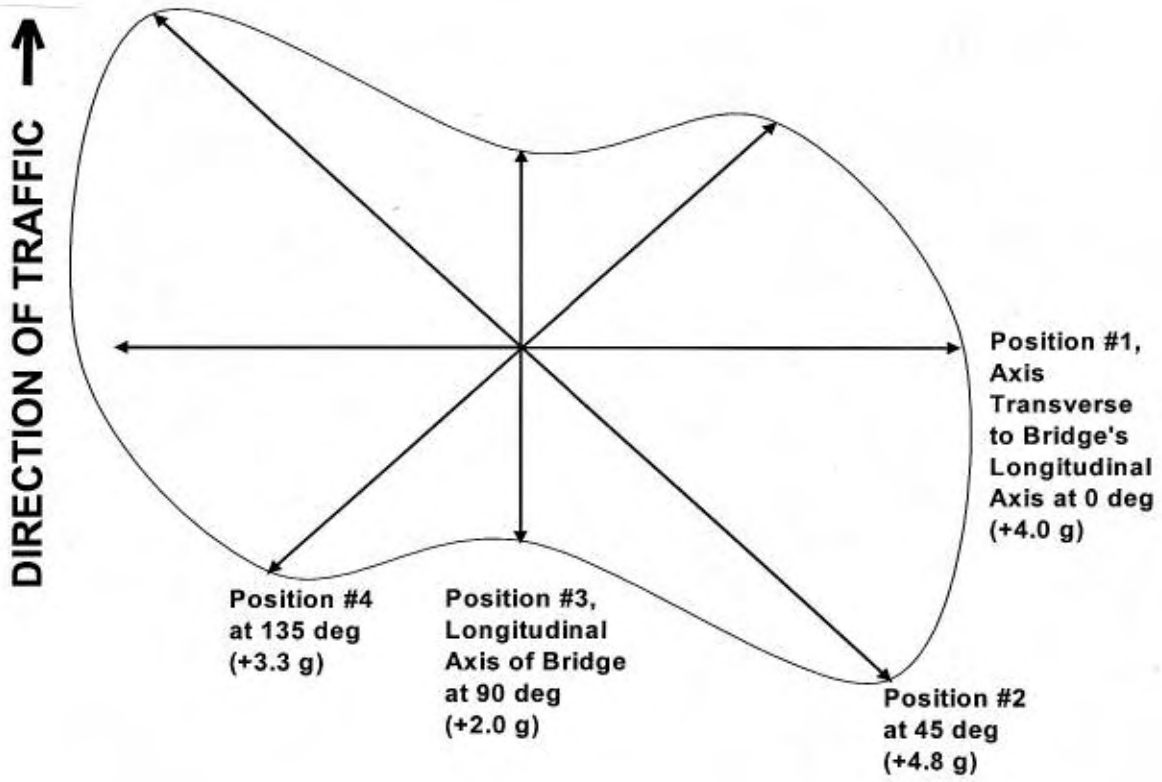


*Figure 14.* Distribution of luminaire acceleration shown as a geometric plot, which also describes the general motion of the luminaire when set into motion by truck passage.

By taking the accelerations recorded, and plotting them along each of the axes, the forces on the 56 lb [includes 10 lb ballast] luminaire can be estimated. These accelerations account for the dislodgement of the lens, bulb shock and frequent luminaire failures.

## Mechanism of Luminaire Acceleration

When a heavily loaded truck passes by a light pole, the truck creates a localized deformation roughly equivalent to its length, with its axles causing rapid deflections of the non-composite reinforced concrete bridge deck.

### *Truck-Induced Deck Deformations*

In *Figure 15a*, the time required for a 55-ft long truck to travel its entire length at 50-70 mph varies from 536 to 750 milliseconds (ms). Typical time for the entire series of axles to pass by the light pole is about 600 ms. Because trucks are traveling at speeds of 55 mph or more, the deflection for that axle only lasts for a very short period of time. The proportion of time that a heavily-loaded truck tire is in contact with 55 ft of deck length is quite small. Typical tire contact length varies from 12 to 18-in, depending on axle loading. The percentage of tire contact out of 55 ft for 12 to 18-in of contact for a truck at 55 mph varies from 1.8% to 2.7%. Depending on truck speed, this axle pulse can range from about 10 ms to 20 ms, as shown in *Figure 15b*.

### *Structural Relationships*

The pole is structurally connected to the roadway deck by way of anchor bolts embedded into an integral parapet made of reinforced concrete. When the deck deflects a certain distance, measured as downward deflection, the light pole also deflects. By approximating a linear deck deflection angle from the right lane, the light pole axis correspondingly deflects vertically and rotates laterally by approximately the same angle.

As the pole axis deflects, the luminaire is set in motion. The velocity of the luminaire is a function of the truck speed, and the amount of deflection. The heavier the axle load, the greater the deflection. Since the height of the pole was increased from 27½ ft to 40 ft, the luminaire travels laterally a greater lateral distance than in the original luminaire. However, the pulse time remains the same, resulting in a greater velocity.

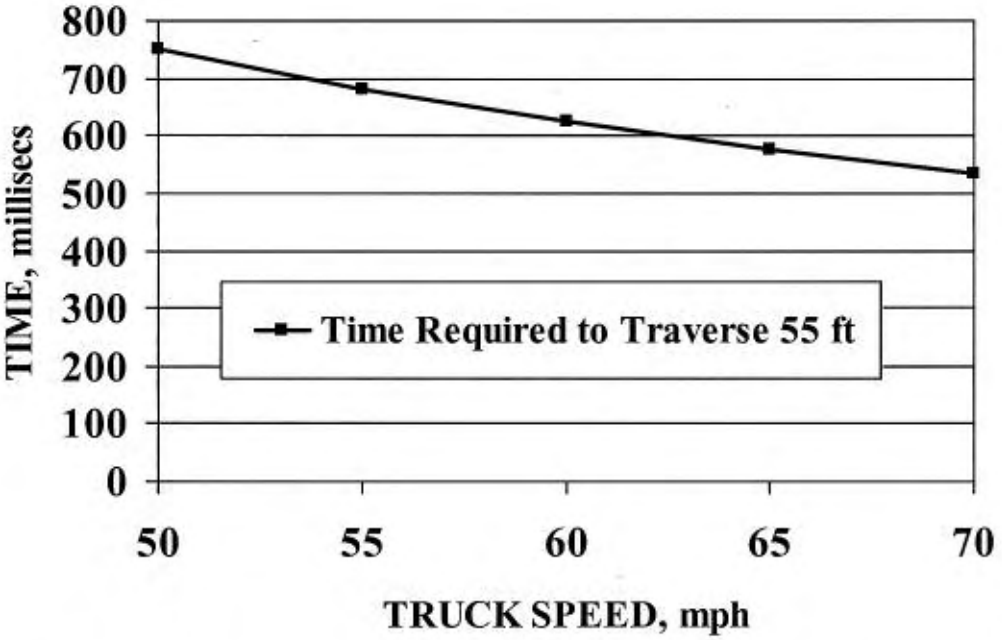


*Figure 15a.* The time required for the length of a typical tractor-trailer of 55 ft to pass by a lighting pole at various common truck speeds is plotted above. These times are typical cumulative durations of multiple load pulses exerted on the deck and pole by single trucks found in the oscillographic traces of accelerometer data.

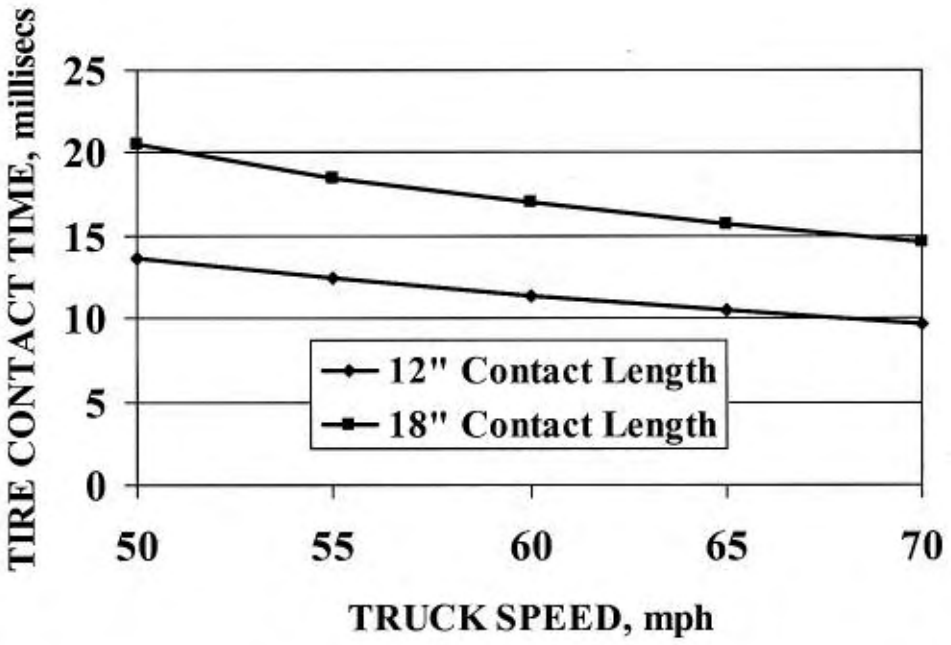


*Figure 15b.* The time that a truck tire is in contact with a deck length of 55 ft with with a tire contact length of 12 to 18-in. A length of 55 ft is an approximation of typical deformation zone casued by the truck. Pulses based on axle spacing, speed and time indicate that truck axles are causing localized deck deformations, triggering sharp pole vibrations.

***Pulse Recording by Oscillograph***

A typical oscilloscopic trace of multiple pulses from two trucks is shown in *Figure 16.* Each division of the recording paper is 16.7 ms. The typical cycle time (initiation-to-peak, to peak, then to reversal, and back to initial position) is 16.7 ms. The rise time, which is ½ of the cycle time, is 8.35 ms. In other words, the luminaire is pulsed forward in the direction of the roadway deck, and snaps back due to pole elasticity and pavement rebound.

The oscillographic recordings of the aluminum poles indicate that significant vibrations persist after the initial pulses trigger oscillation. Aluminum, in comparison to steel, gray iron and ductile iron, has poor damping capacity. Damping properties of various metals and alloys, including aluminum, are shown in *Figure 17.*

***Luminaire Deflection***

The extent of luminaire travel is a function of deck deflection, which directly affects the pole deflection angle. Deck deflection is non-linear when it is considered as either a beam fixed on both ends, or a cantilever beam propped on one end by a floor support, but restrained by a curb & parapet undergoing torsion. Since a beam fixed on both ends has no theoretical angle of deflection, a propped cantilever with end restraint was used to determine the deflection angle.

In *Figure 18,* $\delta_{15L}$ = the deflection at 15 ft, which represents deflection in the right lane (traffic is heading west bound). Truck axles in the right line are between 9 to 15 ft of the 27 ft roadway, for a range of 0.333 to 0.555 L, which can be averaged as 0.445 L, where L = 27 ft. For a centered point load at 0.5 L, a maximum deflection is sustained at 0.447 L using the propped cantilever formula for deflection. An estimate of the moment of inertia of center-loaded deck can be derived from this formula [Ref 1]:

$$\text{Max } y = \frac{WL^3}{107EI}$$

Where
$y$ = deflection, in
$L$ = width of the deck, 27 ft.
$E_d$ = dynamic modulus of elasticity for concrete, psi
$I$ = moment of inertia, $in^4$

During testing, the most commonly observed deflection was 2 in. $E_d$, the dynamic modulus of elasticity for concrete, was taken from its correlation to compressive strength [Ref 1, p319]. The Illinois DOT concrete standard for bridge decks is 4,000 psi minimum in compression. The dynamic modulus was determined to be $6.2 \times 10^6$ psi. In subsequent equations, E is in dynamic mode.

The moment of inertia for a propped cantilever beam with center loading is:

$$I_{pc} = -0.0093 \frac{WL^3}{yE}$$

Where:
$I_{pc}$ = moment of inertia of propped cantilever, $in^4$
$W$ = truck axle legal load, 32,000 lbs
$L$ = deck width, 27 ft = 324 in
$y$ = deflection, in
$E$ = dynamic modulus of elasticity, $6.2 \times 10^6$ psi

Inserting y = 2" for deflection and the other quantities, this formula yields moment of inertia for this deck as a propped cantilever at 818 $in^4$. The angle of deflection on the end of a propped cantilever beam [Ref 2] is given by :

$$\Theta = -\frac{W}{4EI}(b^3/L - b^2)$$

When b = L/2 at center loading, this reduces to:

$$\Theta = \frac{W L^2}{32 EI}$$

Using I = 818 $in^4$, and W = 32,000 lbs, and E as $6.2 \times 10^6$ psi, a nominal angle of deflection of 0.0207 radians is obtained.

However, the torsional resistance of the parapet, which is connected by studs to the support beam, restrains the angle generated by a centrally-loaded propped cantilever, limiting the deck end angle by reverse twist. The dynamic shear modulus of concrete is a function of Poisson's

ratio for concrete and its dynamic modulus of elasticity. This relationship [Ref 1, p 320] is as follows:

$$G = \frac{E}{2(1+\mu)}$$

Where
- $E$ = dynamic modulus of elasticity, $6.2 \times 10^6$ psi
- $\mu$ = dynamic Poisson's ratio; 0.24 in dynamic mode

Inserting these quantities provides a dynamic shear modulus of $2.5 \times 10^6$ psi for this concrete.

The torsional angle of twist [Ref 4, p 82] for a rectangle is:

$$\Theta = \frac{3.33\, T\, L\, (a^2 + b^2)}{a^3\, b^3\, G}$$

Where
- $\Theta$ = angle in radians
- $T$ = torque applied, 32,000 lbs x 15 ft x 12 in
- $L$ = midpoint length of parapet between supports = 139 in
- $a$ = width of parapet, 18 in
- $b$ = height of parapet, 36 in
- $G$ = dynamic shear modulus, $2.5 \times 10^6$ psi

Inserting these quantities results in a restraining angle of twist of 0.00635 radians. The deflection without the parapet would be 0.0207 radians. After subtracting 0.00635 radians, the parapet restrained end has a net deflection of 0.0143 radians.

There is an elastic limit for concrete by which the concrete cannot provide torsional restraint. When the torsional shear applied to the concrete section exceeds its shear strength, $V_c$ the plastic strain is transferred to the reinforcement, which continues to provide dimensionaility of the parapet. The shear strength per *AASHTO Standard Specifications for Highway Bridges,* as listed in 8.15.5.2, is:

$$V_c = 0.95\, [f_c]^{1/2}$$

Where
- $V_c$ = allowable shear strength
- $f_c$ = compressive strength of the concrete = 4,000 psi min

For this bridge deck, the shear strength of the parapet concrete was rated as 60 psi. The maximum shear on the parapet is determined by this relationship [Ref 4]:

$$V_{ct} = \frac{T\,(3a + 1.8\,b)}{a^2 + b^2}$$

Where

$V_{ct}$ = shear strength in torsion, 60 psi
T = torque applied, lbs-in
a = width of parapet = 18 in
b = height of parapet = 36 in

The allowable torque before shear yield of the concrete is 25,194,240 lbs-in. With an applied moment arm of 180 in, it would require a load of 213,510 lbs before shear yielding of the concrete would occur. Such a load would only be sustained if special permits for overloads were granted to cross the bridge. Taking into account the parapet restraint, a general moment of inertia for the deck can be determined at mid point loading, where $\Theta = 0.0143$ radians, by this expression:

$$I_{adj} = \frac{W\,L^2}{32\,(E\Theta)}$$

Where

$I_{adj}$ = torsional moment of inertia, adjusted for end restraint
W = load applied, 32,000 lbs
L = width of deck, 27 ft = 324 in
E = dynamic modulus of elasticity, $6.2 \times 10^6$ psi
$\Theta$ = deflection in radians, 0.0143

Using the above quantities, the adjusted moment of inertia is 1184 $in^4$.For deflections other than 2 in, a quasi axle load was determined which would result in these deflections. Quasi axle loads can be treated as variations of load distribution, impact, and truck overloads beyond the legal load of 32,000 lbs per axle. For these axle weights, the original formula for deflection of the propped cantilever was used, except that the moment of inertia was increased from I = 818 $in^4$ to $I_{adj}$ = 1184 $in^4$. The deflection formula was rearranged as follows:

$$W_{adj} = \frac{y\,E\,I_{adj}}{0.0093\,L^3}$$

Deflections presented in non-linear format are compared with linear approximations:

| Deck Deflection, in | Non-Linear Pole Angle, degrees | Linear Approximation of Pole Angle, degrees |
|---|---|---|
| 1.0 | 0.327 | 0.318 |
| 1.5 | 0.493 | 0.477 |
| 2.0 | 0.659 | 0.636 |
| 2.5 | 0.824 | 0.796 |
| 3.0 | 0.991 | 0.954 |

*Figure 19* is constructed using both the non-linear behavior and the linear approximations of deck deflection.

*NOTE:* The assumption of a linear deflection can be used simplify the analysis. The deflections of the deck were not measured by laser, due to the problem of height from the river pool and access to the deck stringers, nor were highly sensitive inclinometers used. The low cost inclinometers used in this investigation could not sense the rapid axle pulses due to their short 16 millisecond duration. It is recognized that because the pole is tapered, the pole axis is not perfectly linear when deflected, and could actually sustain even greater deflections than those predicted by a rigid linear pole axis.

Most trucks in Illinois generally travel in the right lane on a divided highway, since the speed limit for trucks in Illinois is 55 mph for heavy trucks, whereas the limit is 65 mph for cars and other light vehicles. As a result, luminaires mounted on parapet poles are more susceptible to damage.

***Luminaire Velocity***

The distance traveled by the luminaire by the luminaire after linear pole deflection is:

$$d = R \tan \Theta_p$$

Where: $d$ = distance traveled by the luminaire, ft
$\Theta_p$ = pole deflection angle $\approx \Theta_d$ = deck deflection angle
$R$ = pole height, ft

In the above tangent function, a simplified assumption is made that the pole axis is rigid. Because the pole is tapered, additional deflection is sustained at the tenon top, increasing the deflection and velocity of the luminaire even more. The distance traveled by the luminaire is a direct function of the deck deflection. The average velocity of the luminaire is:

$$v = \frac{d}{t}$$

Where $v$ = average velocity of the luminaire, ft/sec
$d$ = distance traveled, ft
$t$ = rise time of pulse, secs

Since the rise time of the pulse is only of the order of 0.008 secs [8 ms], it is not difficult to see why initial velocities induced by axle pulse deflections are so high. For trucks which substantially weigh over the legal limit of 80,000 lbs and are traveling in excess of 55 mph, deflections could increase to levels above 3" of deck deformation.

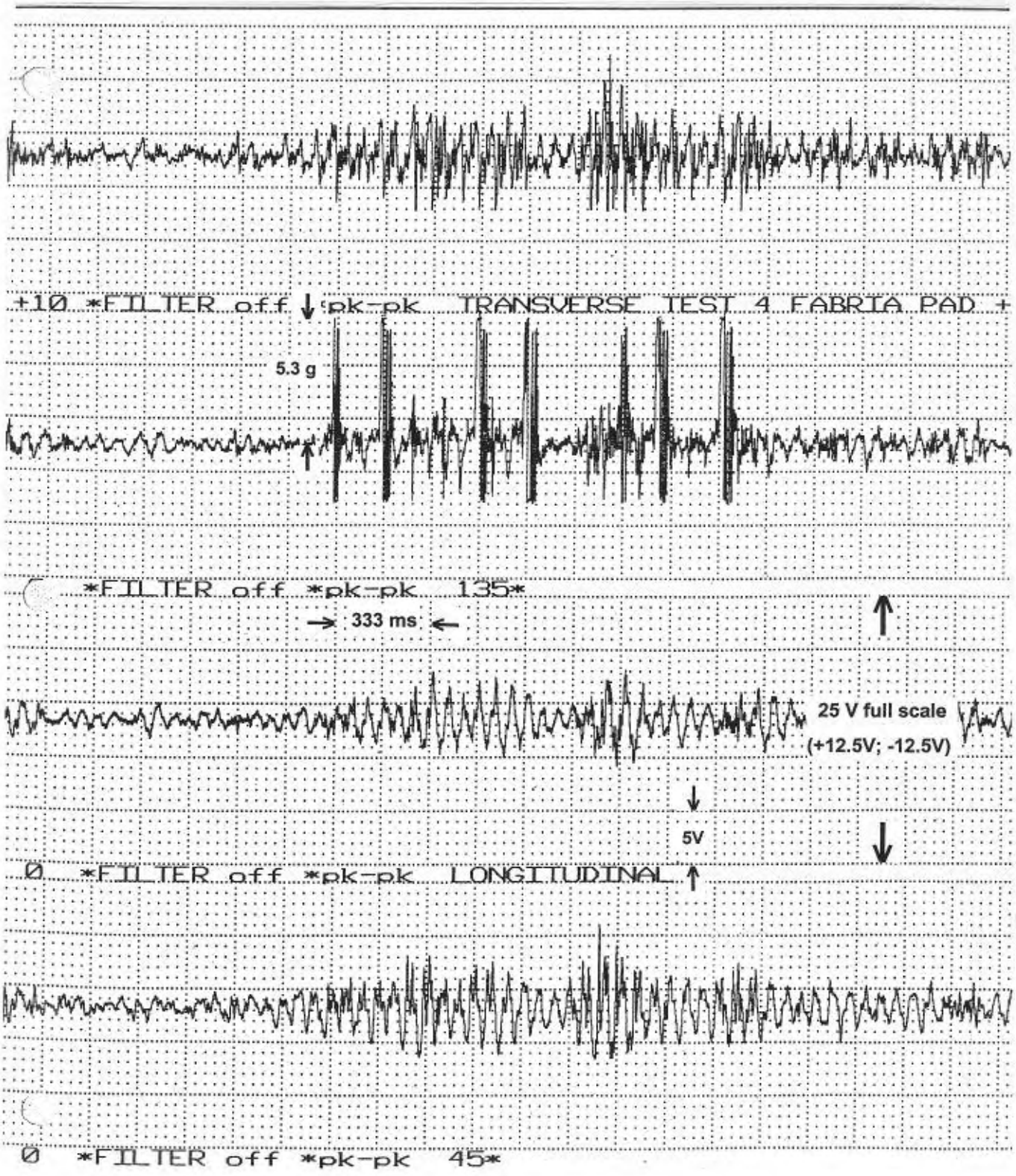


*Figure 16.* Oscillographic recording of the Astro-Med Dash IV of axle pulses of trucks passing by the instrumented light pole at about 55 mph. Pulses indicate the passage of two trucks, based on typical axle spacings. Calibration of the accelerometers indicated that 1V = 0.42 g. Each increment represents 33.3 milliseconds (ms), with pulse rise time at approximately 8 ms. After the initial pulse, there are additional decaying pulses from elastic rebound and vibration of the pole.

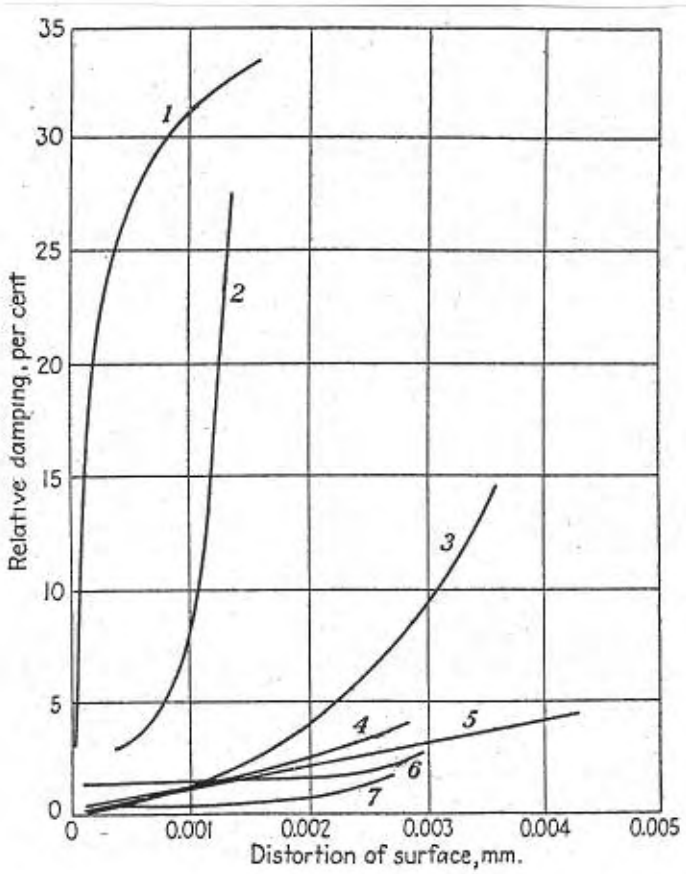


*Figure 17a.* Relative damping capacity of (1) gray cast iron; (2) case-hardened steel (SAE 1020); (3) silicon steel (SAE 9260); (4) nickel-manganese steel (SAE 4620); (5) nickel-chromium steel (SAE 4320; 4330; 4340); (6) chromium steel (SAE 4130; 4140); (7) red brass (CDA 836; 838). Adapted from [Ref 5].

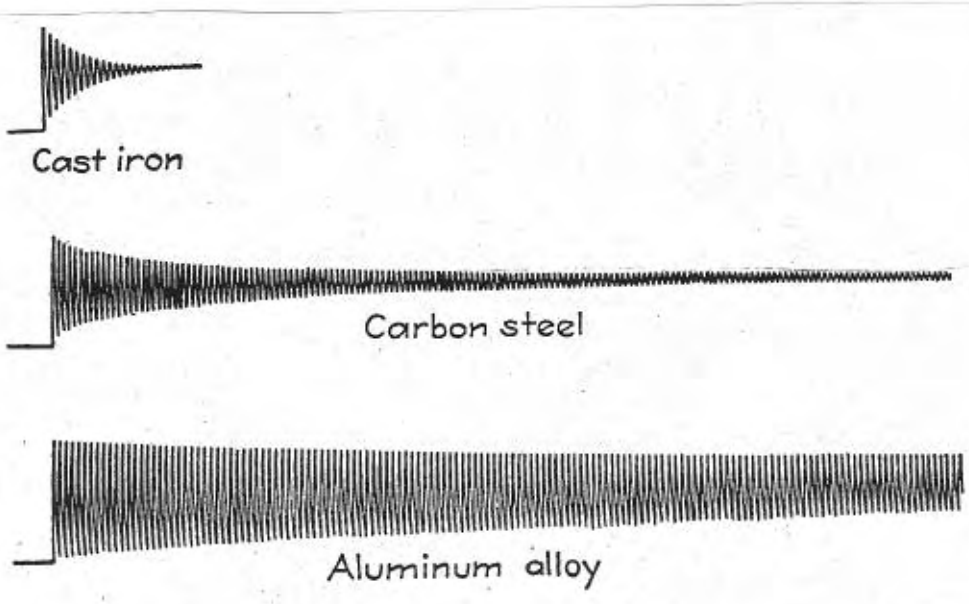


*Figure 17b.* Damping curves for carbon steel, aluminum alloys and gray cast iron, taken from initial deflection, subsequent oscillation, to vibration arrest, as a function of time. Damping capacity for ductile iron falls in between cast iron and carbon steel. Adapted from [Ref 6].

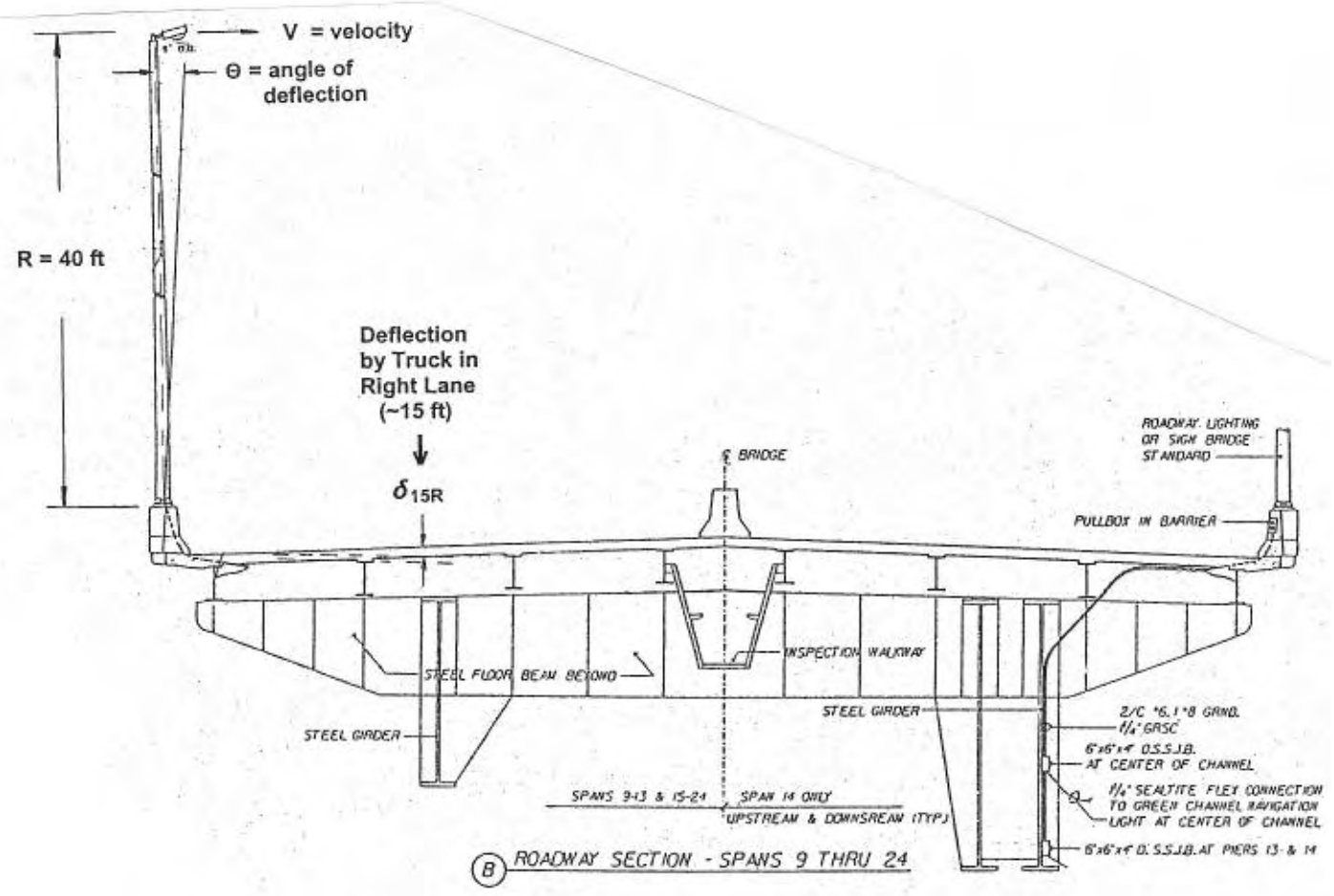


*Figure 18.* Typical cross section of the roadway cut between floor beams at spans 9 through 24. The deck stringers (24 WF 68) are composite with the deck between floor beams, permitting rigidity of the deck as a truck passes by. In the analysis of this report, truck axle loadings cause an approximate center loading, inducing deck deflection $\delta$. The deck ends are restrained by the parapet, resulting in a final net deck end angle $\Theta_d$ . After $\Theta_d$ is generated at the parapet, that angle results in an approximately equal pole axis angle of deflection $\Theta_p$.

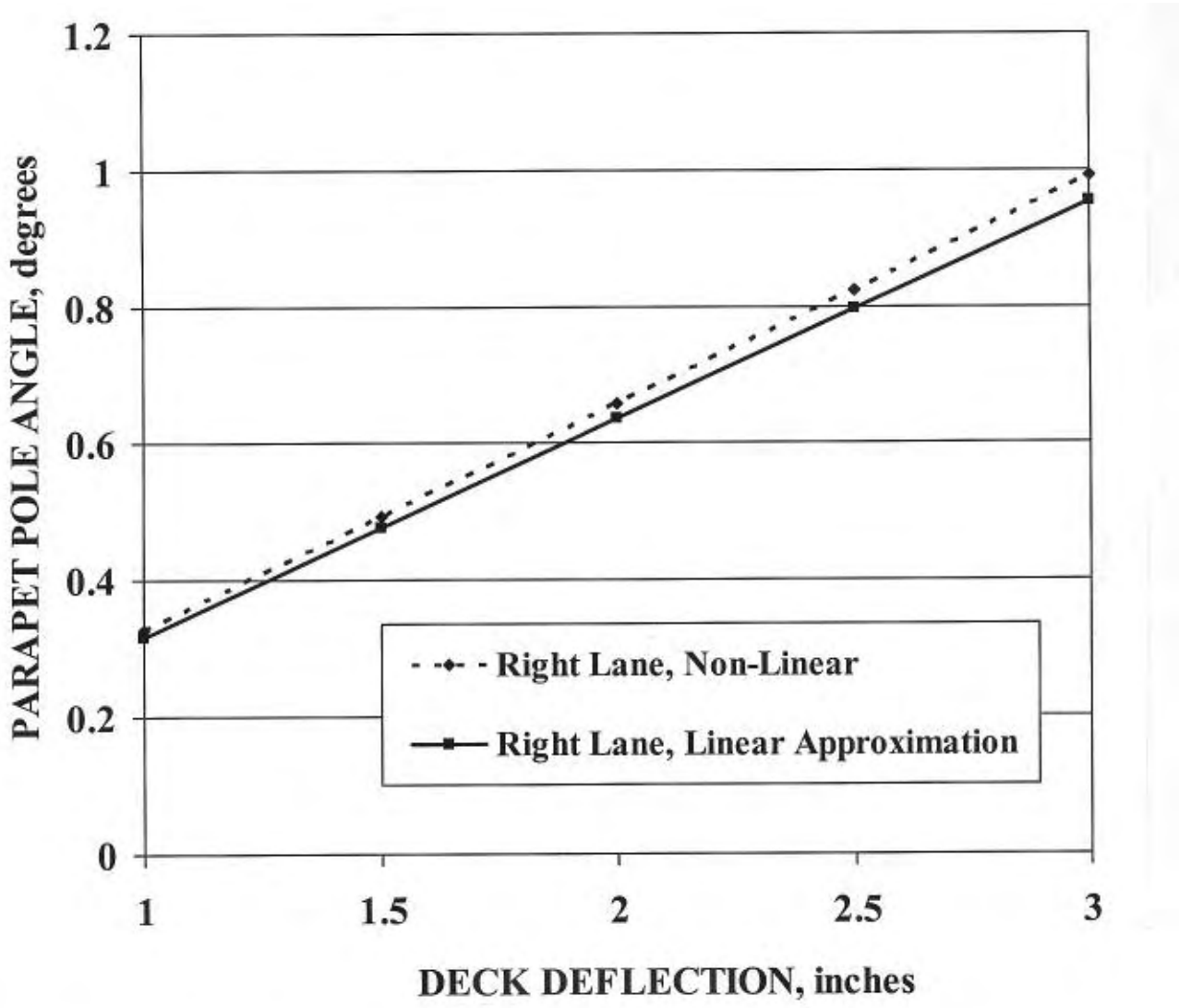


*Figure 19.* In this graph, the deck deflection from truck axle loads results in a deck deflection angle $\Theta_d$, minus the parapet restraint, and is approximately equal to the pole axis deflection angle $\Theta_p$. Conversion of deflections, using both non-linear methods and linear approximations, are plotted. Linear approximations from the tangent formula can be used for a limited range of axle loadings without generating substantial deviations from actual non-linearity.

***Acceleration of the Luminaire***

The luminaire is subject to sudden acceleration and deceleration forces as the deck and pole deflections occur. Because these load pulses occur so quickly, there is a rapid acceleration of a very localized area of the deck, which runs through the pole and to the luminaire. The acceleration of luminaire [Ref 7] is as follows:

$$a = \frac{v^2}{R}$$

Where: $a$ = acceleration, ft/sec$^2$
$v$ = average velocity of luminaire, ft/sec
$R$ = luminaire height, ft

With a pulse rise time of 8 ms or less, accelerations can easily reach levels of 4-5 g. For example, a 3-in deflection in the right lane results in an angle of pole deflection of about 0.95°. The distance traveled by the luminaire is 8.38 in = 0.698 ft. In 8.3 ms, the velocity is 84 ft/sec. For a 40 ft pole, the acceleration is approximately 177 ft/sec$^2$. The gravitational acceleration for East Moline, IL, at 42° latitude [Ref 8], as determined by a swinging pendulum, is 32.16 ft/sec$^2$. To determine g-forces, the relationship is:

$$g = \frac{a}{32.16}$$

Where: g = magnitude of acceleration, compared to earth gravity at 42° latitude
a = measured acceleration, ft/sec$^2$

For an acceleration of 174 ft/sec$^2$, the g-forces exerted on the luminaire are about 5.4 g. For trucks passing by at speeds greater than 55 mph, g-forces will be exponentially magnified. The accelerations sustained by luminaires subjected to pole deflections by trucks traveling at 55 mph are shown in *Figure 20* for 40 ft and 27.5 ft poles. In this figure, pulse rise times are set at 8.35 ms, and are for poles mounted on the right lane parapets.

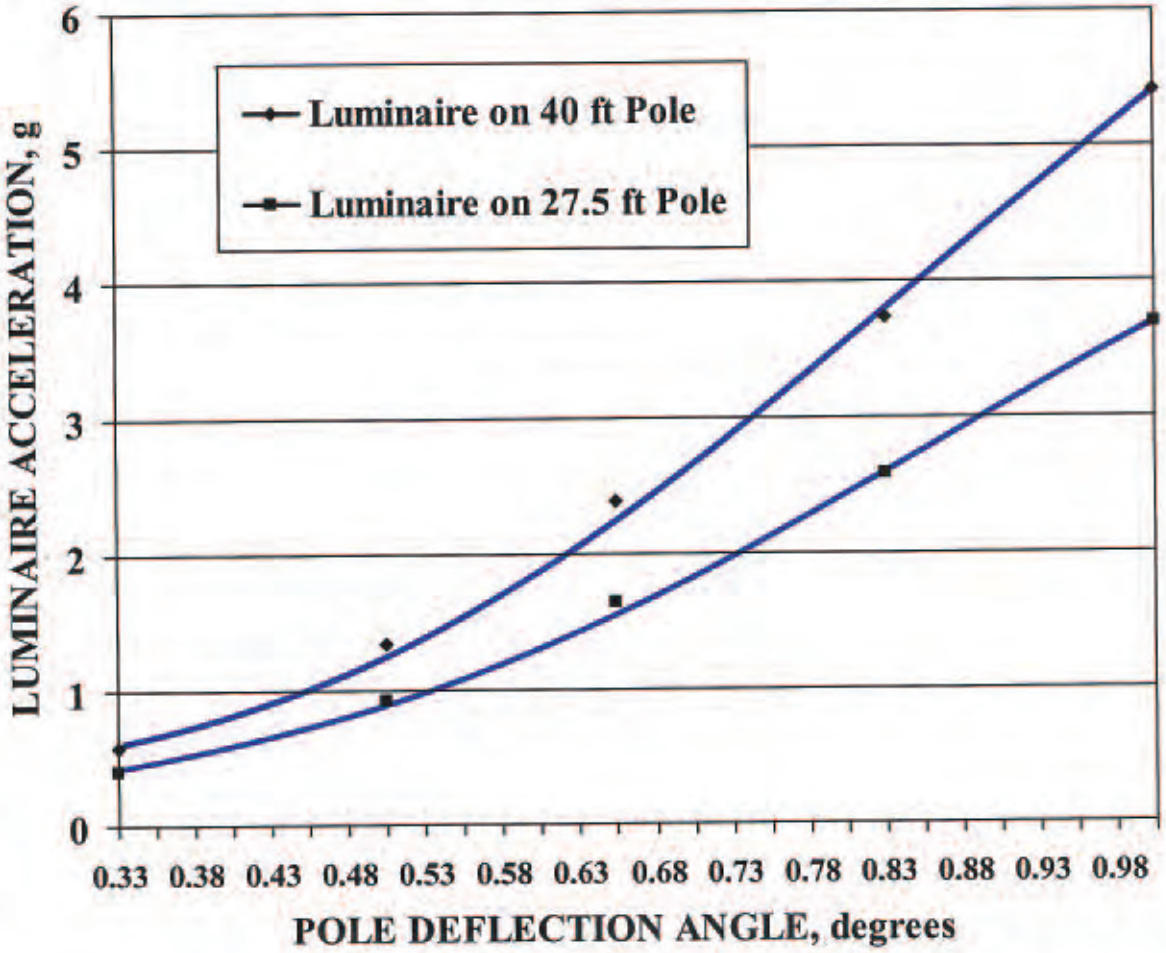


*Figure 20.* A plot of the accelerations experienced by luminaires mounted on the 40 ft aluminum pole, compared with a 27.5 ft pole, as a function of pole deflection angle. These accelerations are generated by load pulses of trucks passing by at 55 mph, and apply to poles mounted on the parapets. Since trucks in Illinois predominantly use the right lane, luminaires on the parapet are more vulnerable to vibration and acceleration. A shorter pole results in a lesser distance traveled by the luminaire during the pulsed deflection. Greater accelerations of luminaires would be experienced as trucks heavier than legal load pass by traveling at speeds significantly in excess of 55 mph.

**Suggested Solutions**

Several potential solutions can be applied to attenuate the problem of luminaire acceleration and vibration, and its resulting reduction of luminaire life.

a. *Light pole height.* By decreasing light pole height, the distance traveled by the luminaire is decreased after the pole receives a deflection induced by the passage of truck axles at 55 mph or more. Since the 27.5 ft poles are still available, they should be considered for re-use, shortening them to a tenon-top arrangement. Davit arms should be removed, since they introduce high vertical accelerations onto the luminaire, according to tests recently performed by the University of Illinois at Champaign-Urbana [Ref 9]. By decreasing pole height to 27 ft or less, g-forces should be reduced to more manageable ranges of 3 to 4 g when trucks pass by at 55 mph

b. *Reducing truck speed.* High speeds of heavy trucks contribute to sharp, rapid deflections of the poles. Signs posted at ¼ mile and ½ mile before the approaches of the bridge should have the following warning: "Speed limit for vehicles more than 4 tons, 55 mph, strictly enforced". Stationing devices at the foot of the bridge which display the speeds of oncoming vehicles are strongly recommended.

c. *Increasing vibration resistance of luminaires.* High intensity luminaires with greater resistance to vibration and g-forces are required if lighting poles are to be used in their present locations. Moving lights to areas over existing piers would decrease deflection, but this would require new foundation anchors and rewiring. This relocation expense may be substantial, but this option should be compared with other viable options.

d. *Use of vibration pads with low modulus of elasticity.* Elastomeric vibration pads and washers with low moduli of elasticity, such as encapsulated cork or synthetic neoprene rubber, are preferred for isolation of the pole base connection to the parapets or median. For example, Airloc®-style pads, composed of granulated cork in a polymer matrix, should help to attenuate deflection and vibration to some degree for wind-induced

oscillation, but are probably insensitive to higher order frequency-induced pulses from trucks (25 Hz or more).

e. *Lower overhead and parallel light alternatives.* There are several new or existing lighting systems which are inherently vibration-resistant. There are overhead systems with high vibration resistance at lower pole heights, but have lesser wattage than high-intensity discharge lamps previously specified for this bridge. Parallel light systems generally illuminate the bridge with light directed roughly parallel to the deck, rather than with overhead lighting, which relies more on pavement luminosity. Both overhead and parallel light systems include light-emitting diodes, inductive lighting, and explosion-resistant fluorescent fixtures. Examples of these systems can be found in Appendix 1.

   *NOTE*: The specific citation of products of various manufacturers included in Appendix 1 does not constitute an endorsement, nor is it a specification. Product citations are provided for illustrative purposes only.

f. *Light emitting diodes (LEDs)* do not have the intensity of sodium or mercury vapor lamps, but are not as susceptible to acceleration-induced failure. Linear arrays of high output LEDs are available. However, they would require new wiring, and numerous mountings on the parapets and median [Ref 10].

g. *Inductive lighting,* which does not employ an internal filament in the gas tube for illumination, is available, except that wattage is limited to upper ranges of 150 W to 165 W. Depending on their design, inductive lights are more vibration-resistant than conventional fluorescent tubes. There are several prominent manufacturers of this type of lighting [Ref 11; Ref 12], but they would also require new wiring and mounts on the parapets and medians.

h. *Explosion-resistant fluorescent* fixtures are used in hazardous locations, such as flour mills, coal mines and paint shops. They have very high g-ratings, and could be mounted in a guard rail tube, focusing light downward toward the pavement at a low angle of incidence. Because their power rating is limited to a range of 40 to 60 W, their intensity

is significantly less than high intensity vapor lamps. This lesser wattage would require substantial strings of these fixtures along parapets and median. Fixtures are available from 120 V to 387 V; however, transformers to step down to lesser voltages from the current 480 V supplied would be required [Ref 13].

## Conclusions

A. Poles and luminaires on the LeClaire Bridge are sustaining acceleration forces on the order of magnitude of 4-5 g.

B. The g-forces are initiated by heavy trucks traveling at speeds of 55 mph or more, and are further accelerated by increased axle loading.

C. Typical pole pulse deflection rise time was about 8 milliseconds at 55 mph.

D. Aluminum poles experience substantial continuing oscillation due to their lower damping coefficients. They also have greater deflection characteristics than an equivalent steel pole, due to the lower modulus of elasticity of aluminum compared to steel.

E. The harder and stiffer Fabreeka® vibration pad would provide greater transmission of deck deflection to the pole than would the softer SA-47 and Airloc® pads. However, considering the rapid pulses sustained by the luminaires, vibration pads may not provide any significant relief from high frequency vibration and acceleration, regardless of the type of pad used.

## Recommendations

1. If pole base pads are installed for seating and leveling purposes, use of the harder Fabreeka pad is not recommended for this application. Torque specifications for SA-47 and Airloc vibration washers and pads should be developed if the pads are replaced. If some anchor rods are too short, modifications may be required.

2. Since there are higher g-forces in poles of 40 ft in length, it is recommended that shorter poles be installed, which will sustain less deflection and vibration. Since 27.5 ft poles are available, it is recommended that their davit arms be removed, and made into tenon tops. The final pole height would be determined by the roadway lighting design and the photometry of the 5-g luminaire.

3. Heavy truck speeds on the bridge should be strictly enforced, limiting trucks weighing more than 8,000 lbs to 55 mph, in accordance with Illinois statute 625 ILCS 5/11-601(d).
4. A luminaire capable of withstanding at least 5 g or more should be used in the future if poles with heights of 27.5 ft or more are to be reinstalled or used.
5. Accelerated development and testing of 5-g luminaires by leading lighting manufacturers should be supported by either state or federal funds, such as SPR pooled fund studies, IL light-pole revolving funds, or with direct R&D funds. Several experienced manufacturers of high intensity lighting should be considered to bid on supplying 5-g luminaires, such as General Electric, Holophane, WideLites, Sylvania-Osram, Phoenix Lighting, or other manufacturers of military or marine lighting.
6. To augment or replace high-intensity overhead lighting, particularly in case of lighting failure, flush-mounted inductive lighting on the medians and parapets should be considered. The reflective shade should direct the beam from LED, induction or fluorescent lights downward and away, so as to illuminate the roadway, and not blind the driver. A combination guard rail with internal lighting focused on the deck could serve this purpose.
7. Retro-reflective lane delineators and right & left lane shoulder stripes should be prominently marked and maintained, particularly after each winter season.
8. Vibration studies should be conducted to determine whether changing pole material to steel or fiber composite, either exacerbates, decelerates, or has negligible effects on luminaire acceleration.

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[10]. "Luxeon Line", Lumileds Lighting, LLC, San Jose, CA, 2004.

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[12]. "QL 165 Watt Induction Lighting System", Philips Lighting Co., Somerset, NJ, April, 2001.

[13]. "Explosion Proof Lighting, 380 Series Specifications", LDPI, Inc., Eau Claire, WI, 2004.

## APPENDIX 1 Examples of Vibration-Resistant Lighting of Lesser Intensity

**Light-Emitting Diodes** ..... **A-1**

**Inductive Lighting** ..... **A-4**

**Explosion-Resistant Fluorescent** ..... **A-8**

***NOTE*: The specific citation of products of various manufacturers included in Appendix 1 does not constitute an endorsement, nor is it a specification. Product citations are provided for illustrative purposes only.**

# White Luxeon Line

Update Alert Be automatically notified if this item goes on sale, the price drops, or delivery time improves.

Simulated Illumination

- 12 row mounted Luxeon Emitters produce 250 Lumens of pure White light
- Lights with 21 VDC
- Each LED is equipped with PMMA secondary optics for tightly focused light
- Standard AMP connectors on either end of the array allows design flexibility and daisy-chaining
- Fully dimmable
- Up to 100,000 hour lifespan
- Superior ESD protection
- Cool beam, safe to the touch
- Instant light (less than 100 ns turn-on time)
- No UV

Additional Information

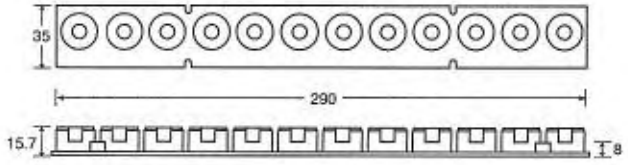
Using Luxeon LEDs For Lighting
Luxeon LED Thermal Design Guide
Luxeon LED Plug & Play Information
Luxeon LED Design Guide
Maintaining Maximum Output Of White LEDs
LXHL-NW99 Technical Data Sheet (Published By Lumileds)

| Part No | 1 + | 10 + | 25 + | 50 + | 100 + | 250 + | Ships In | Order Qty |
|---|---|---|---|---|---|---|---|---|
| LXHL-NW99 | $154.10 ea (USD) | $139.25 ea | $135.97 ea | $132.85 ea | $128.42 ea | $121.66 ea | 10 Day(s) | |

Pricing and availability are subject to change without notice.

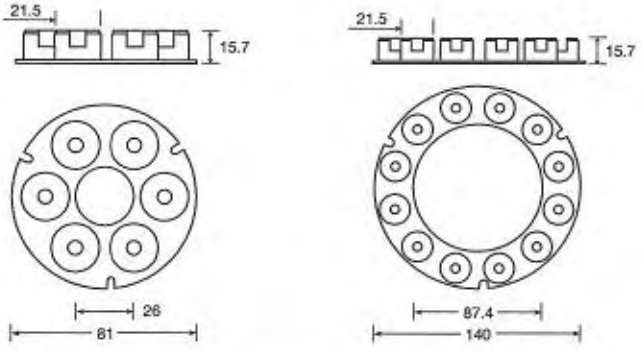
## Luxeon line

Luxeon Line takes brightness and beauty to great lengths—as long as you like. Twelve Luxeon emitters are aligned on a solid board and fitted with efficient collimating lenses to project the light forward. Luxeon line is fantastic for cove, shelf and architectural lighting—indoors and outdoors. Line 'em up!



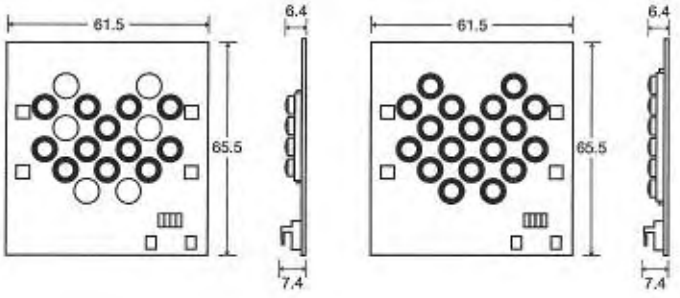

## Luxeon ring 6—
## Luxeon ring 12

The 6 and 12 unit Luxeon rings elicit stunning effects individually and form a smooth pattern when combined. Uplight the ceiling, wash a wall, brighten with a bollard. Solidly mounted collimated lenses focus light forward—very alluring for general, architectural and entertainment lighting.

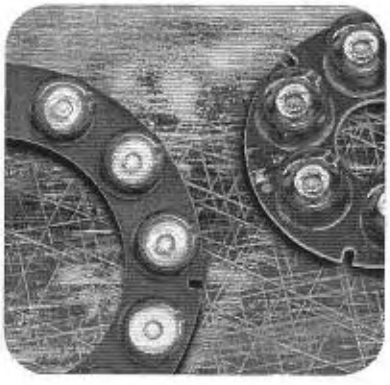



## Luxeon flood

Need some horsepower? Luxeon flood is an array of either 12 or 18 emitters mounted closely together to crank out the light. The batwing configuration provides a more even light distribution. The lambertian configuration maximizes light output. Flood a space with light, backlight the work, shine brightly with Luxeon flood.




(dimensions in mm)

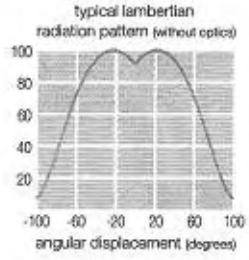


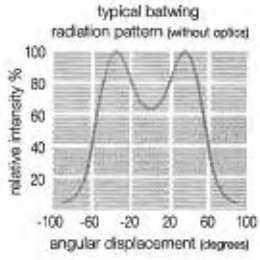
# technical story

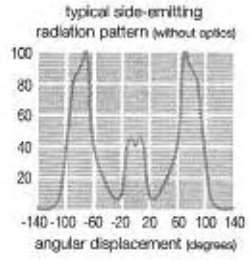
## Light distribution

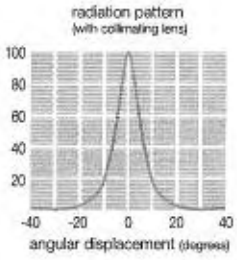
Luxeon is available with three different lenses and a collimator.

- Lambertian—an even distribution in all directions
- Batwing—a flatter, forward distribution designed to evenly fill the illuminated surface.
- Side-emitting—a radial distribution, ideal for reflector design and waveguides
- Collimator—a lens that tightens the beam angle to 12 degrees

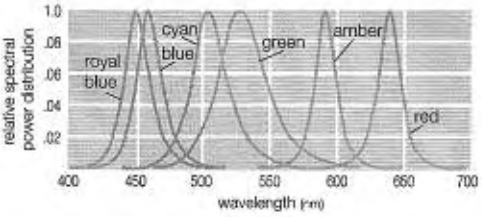


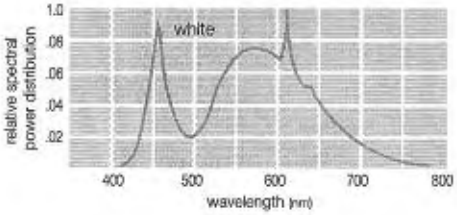




## Spectral distribution curves




## Lumen maintenance, CRI, efficacy

See the most up to date information in our enclosed Luxeon Plug and Play Guide or on the web at www.luxeon.com or www.lumileds.com.

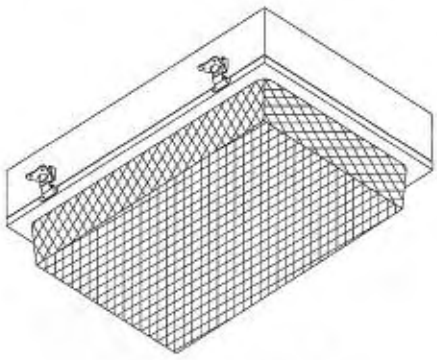
# 1st Source Lighting — Ultra Inductive Series

## UICB-1x11

Fixture Type

Approved By

- *100,000 Hour Lamp Life*
- *Extremely Low Maintenance Costs*
- *Instant On / No Re-strike*
- *High Efficacy*
- *82 CRI*
- *Designed for Quick Installation*



### Applications

The Ultra Bay Cold Box fixture is designed for use in industrial refrigerated spaces. We have provided these fixtures for retail and industrial food preperation and storage facilities. The heavy gauge aluminum construction assures a long fixture life to match the 100,000 hour lamp life. The fixture is UL listed fixture and can be mounted in a variety of ways.

The *UICB* is constructed of welded .090" aluminum that has been powder coated for heavy duty service throughout the life of the fixture.

We use rotary action draw latch to securely lock the door and lens into position. These draw latches provide a strong, positive grip to withstand abusive environments.

The *UICB* is a flexible system with many options to help you meet your job specifications. With motion sensors, alternate switching, and cord and plugs available to you, every fixture can be custom fitted to you needs.

### Construction

***Body*** .090" Aluminum, powder-coated white

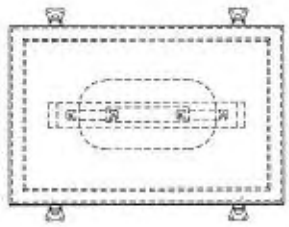
***Weight*** Approx 25bs.

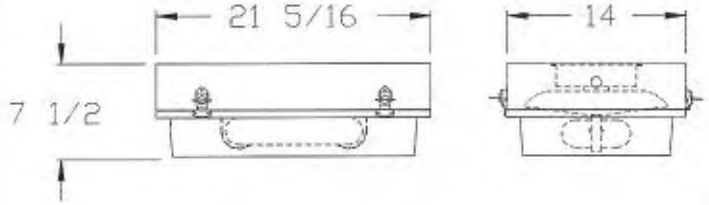
***Lamp*** Osram Sylvania 100 Watt Icetron

***Ballast*** Osram Sylvania 150 Watt Icetron

***Reflector*** Customer choice:
MIRRO 4 95% reflectance anodized .020 aluminum
WH 91 91% reflectance white .020 aluminum

***Lens*** Clear Prismatic Polycarbonate






### Ordering Information on back

For further information, please call. We specialize in replacing all HID's with fluorescent. Whatever your lighting needs, we have a fixture to suit those needs.

1st Source Lighting

www.1stSourceLight.com • 1730 Industrial Drive, Auburn, CA 95603 • Phone (530) 887-1110 • Fax (530) 887-0807

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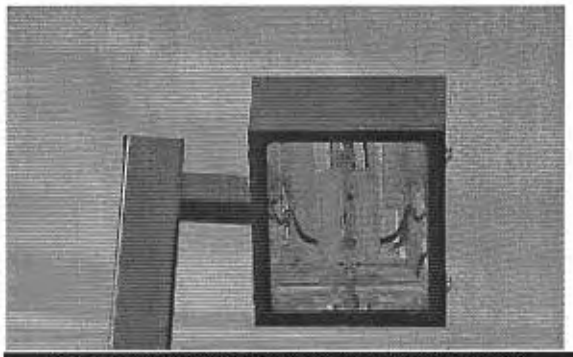
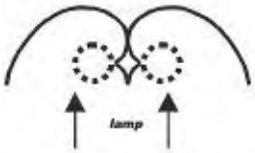


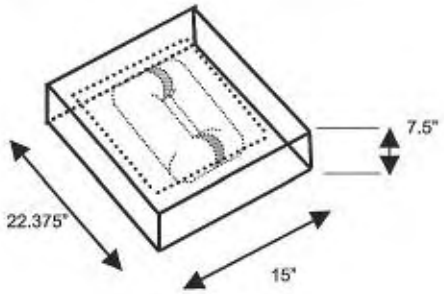
Pole Mount reflectors are perfected for peak quality...

**Pole Mount Reflector**




...High/Low Bay light dispersal performances

**Dimensions**




# Induction Pole Mount / IPM-1X11/35K-WH-M4-1-U

v. 7.13.09

Induction SERIES

High/Low Bay Industrial

## Construction

### Body
.090 welded aluminum.

### Lamp Bracket
.090 die formed aluminum, bolted (2) 10/32 insert on body, (2) 10/32 nuts with lock washers.

### Reflector
MIRRO 4, 95% reflectance anodized aluminum or WH 91, 91% reflectance white, all .020 aluminum.

### Lamp Stand Offs
.625 aluminum rod, 10/32 bolt with lock washers thread on lamp bracket and stand off, locktite at stand off and lamp bracket.

### Paint
Powder coated, white is standard color, no paint at ballast mounting area, other colors available.

## Specifications

The fixture shall be specifically engineered and manufactured for the inductive lamp and ballast system. The fixture shall be approved by the lamp and ballast manufacture up to a specific ambient operating temperature of 105°F at 277 V.

Reflectors shall be designed in accordance to lamp manufacturer recommendations and made of MIRRO 4, MIRRO 27, or WH 91 material. Reflectors shall provide each lamp with 1% retro reflectance into same or neighboring lamp. Such design shall increase the efficiency of the fixture, allowing longer lamp life.

System (lamp and ballast) shall be inductively coupled electrodeless lamp and electronic ballast system. Lamp and ballast shall have a 5 year or 20,000 hour no-fail manufacturers warranty from date of installation including labor allowance or replacement of lamp or ballast if determined to be defective by manufacturer when installed in fixtures approved by the system manufacturer and operated in accordance with their approval. Lamp and ballast shall have an average rated life of 100,000 hours.

**Ordering Information & Catalog Number Logic Below**

**Ordering Guides:** IPM-1X11/35K-WH-M4-1-D-U

**Fixture Model**
Pole Mount ..... IPM

**Lamp Type**
ICETRON™ 100 watt 8,000 Lumen w/ 35K Color Temp. /X8/35K
ICETRON™ 100 watt 8,000 Lumen w/ 41K Color Temp.... 1X8/41K
ICETRON™ 150 watt 11,000 Lumen w/ 35K Color Temp /X11/35K
ICETRON™ 150 watt 11,000 Lumen w/ 41K Color Temp.. 1X11/41K

**Color**
White..... WH Custom Coloring..... CU

**Reflector**
MIRRO 4..... M4 MIRRO 27 ..... M27 WH 91 ..... W91

**Voltage**
120v ..... 1 277v..... 2

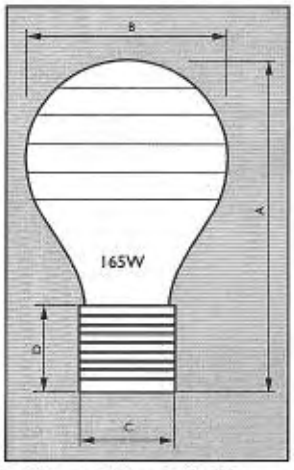
**Damp Location/Wet Location**
Damp Location Settings ..... D Wet Location Settings..... Not Available

**Options**

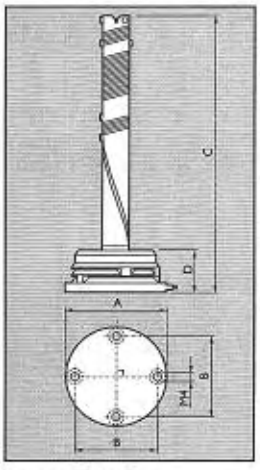
| | |
|---|---|
| Surface mount tabs..... S | Acrylic #P35 Lens..... P35 |
| U bracket)..... U | Acrylic #A12 Lens..... A12 |
| Yok..... Y | Lexan Lens..... LX |
| Wire Cage..... WC | Temper Glass Lens..... TG |

innovative Energy Ideas
(800) 234-1877
www.ienergyideas.com

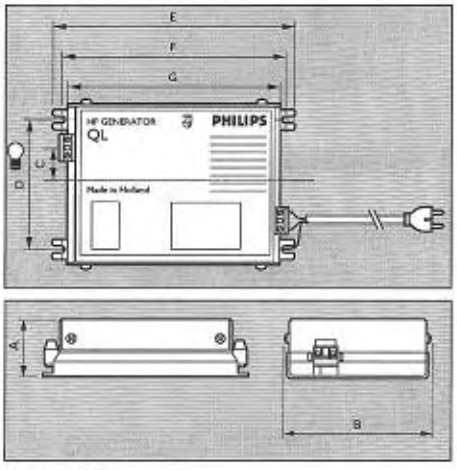
# 165 Watt QL Induction Lighting Lamp System



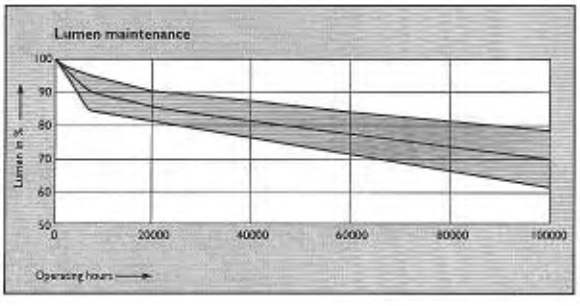

Discharge Vessel (Bulb)



Power Coupler




Generator




## ■ Ordering Information

| Ordering Code | Product Number | Description | Pkg. Qty. |
|---|---|---|---|
| QL165W/S01 | 377994 | Generator, 200/277V | 6 |
| QL165W/PC | 369165 | Power Coupler | 6 |
| QL165W/830 | 369173 | Discharge Vessel (3000K) | 6 |
| QL165W/840 | 369181 | Discharge Vessel (4000K) | 6 |

Note: QL system requires all three components to operate.

## ■ Mechanical Characteristics

| Discharge Vessel (Bulb), Max.: | Power Coupler, Max.: |
|---|---|
| A) 8.27" (210mm) | A) 2.22" (56.5mm) |
| B) 5.16" (131mm) | B) 1.58" (40.1mm) |
| C) 2.25" (57mm) | C) 7.28" (185mm) |
| D) 1.94" (49mm) | D) 1.063" (27mm) |
| | M4 = 4mm screw diameter |

| Generator, Nom.: | Coaxial Cable, Length |
|---|---|
| A) 1.97" (50mm) | 17.0" (431.8mm) |
| B) 4.41" (112mm) | |
| C) 0.55" (14mm) | |
| D) 2.75" (70mm) | |
| E) 7.4" (188mm) | |
| F) 7.0" (178mm) | |
| G) 6.33" (161mm) | |

## ■ Physical Characteristics

| | |
|---|---|
| Discharge Vessel (Bulb) Finish | Phosphor-Coated |
| Max. Discharge Vessel (Bulb) Wall Temp. | 135°C (275°F) |
| Max. Generator Temp. | 65°C (149°F) |
| Max. Power Coupler Temp. | 100°C (212°F) |

## ■ Operating Characteristics

| | |
|---|---|
| Rated Initial Lumens | 12,000 |
| Mean Lumens, Approximate | 9600 |
| Rated Average Life, Hours | 100,000 |
| Correlated Color Temp. (CCT) | 3000K, 4000K |
| CIE Chromaticity, Approx.: | |
| 3000K | x-.442, y-.404 |
| 4000K | x-.392, y-.385 |
| Color Rendering Index (CRI) | 80+ |
| Efficacy (lpw) | 71 |

**Philips Lighting Company**
**200 Franklin Square Drive • P.O. Box 6800**
**Somerset, NJ 08875-6800**
**1-800-555-0050**
**www.lighting.philips.com/nam**
A Division of Philips Electronics North America Corporation
Printed in USA 4/01 QL 165

**Philips Lighting**
**281 Hillmount Road**
**Markham, Ontario L6C 2S3**
A Division of Philips Electronics Limited

# QL 165 Watt Induction Lighting Lamp System

Additional Data (Subject to change without notice)

## ■ Operating Position

Universal

## ■ Electrical Characteristics

| | |
|---|---|
| System Power Wattage, Nom. | 165 |
| System Power Wattage, Min. | 155 |
| System Power Wattage, Max. | 175 |
| AC Supply Voltage, Nom. | 230 |
| AC Supply Voltage, Min. | 184 |
| AC Supply Voltage, Max. | 294 |
| DC Supply Voltage, Nom. | 230 |
| DC Supply Voltage, Min. | 190 |
| DC Supply Voltage, Max. | 305 |
| Supply Frequency Hz, Nom. | 50/60 DC |
| Supply Frequency Hz, Min. | 47 DC |
| Supply Frequency Hz, Max. | 63 DC |
| Supply Current mA, Nom. | 700/580* |
| Inrush Current Amps, Max. | 45 |
| Duration Inrush Current (50% pulse width) ìsec, Max. | 500 |
| Power factor, Nom. | 0.96 |
| HF Output Frequency MHz, Nom. | 2.65 |
| HF Output Frequency MHz, Min. | 2.3 |
| HF Output Frequency MHz, Max. | 3.0 |
| HF Output Voltage kV, Max. | 1.5 |
| Leakage Current mArms, Max. | 0.5 |
| Min. Operating Temp. | -40° C (-40° F) |

* With V mains of 277V, the applied currents are lower.

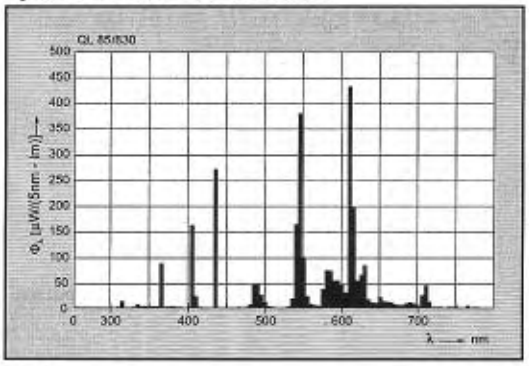
## ■ Standards and Approvals

**Philips QL systems comply with all relevant international rules and regulations, including:**

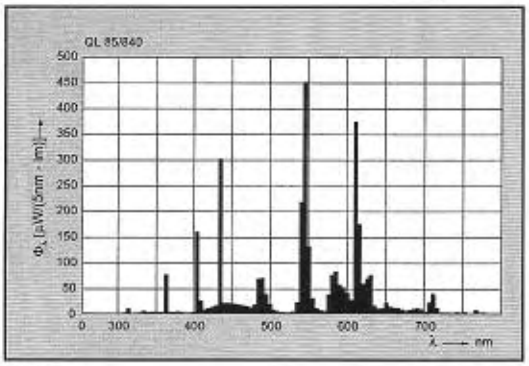
| | |
|---|---|
| Safety | EN 60928 |
| Performance | EN 60929 |
| Harmonics | EN 61000-3-2 |
| Radio Freq. Interference <30MHz | EN 55015* |
| Radio Freq. Interference >30MHz | EN 55022* |
| Immunity to: Supply transients, voltage dips and electrostatic discharge | EN 61547 |
| Vibration and Shock Tests | IEC 68-2-29 FC<br>IEC 68-2-29 EB |
| Approvals: | UL #935, #840 |
| CSA C22.2#74-92, C22.2#950-M89 (Bi-national UL 950) | |
| Quality Standard | ISO 9001 |
| Environmental Management System | ISO 14001 |

*(RFI is measured in FCC Class A, FCC Part 18, Subpart C a reference luminaire) ANSI C63.4-1992.

**Spectral Power Distribution**




3000K




4000K

A–8

# Explosion Proof Lighting



## 380 Series: Explosion Proof Locations

2 Lamp 2 Ft. Fixture

UL 595, 844, 1598
Patent Pending

**General:** Explosion proof lighting for hazardous locations, available as 2 lamp 2 Ft. or 4 Ft. fixtures, 4 lamp 2 Ft. or 4 Ft. fixtures, 6 lamp 4 Ft. fixtures

**Housing:** Cast Natural Aluminum
Seismic tested by Structural Dynamics Research Corporation (full scale) fragility qualification) tested in frequencies of 1 to 31.6 Hertz in 3-plane axis With maximum G force of 18.67 achieved.

**Reflector/Lens** Aluminum White Paint/Clear Glass Globe

**Mounting:** See Specifications/Options below

**Listings:** UL 844 listed and labeled - Hazardous Locations
UL 595 listed and labeled - marine type lighting fixture. Outside Type (salt water)
UL 595 tested equivalent to NEMA 4X requirements for hose-down and corrosion resistance. Class I, Division 1, Group C and D; Class I, Division 2, Groups A, B, C and D; Class II, Division 1 and 2, Group E, F and G; Class III.
UL listed 1598
UL listed and labeled for use inside paint spray booths and rooms.
Also meets requirements for National Fire Protection Association Standard 33 and National Electrical Code Article 516.
UL c approved and labeled Class I, Division 1 and 2, Group C and D.
NEMA 3, 4X, 7CD, 9EFG

**Options:** Optional Polycarbonate Shield and Stainless Steel Guard. See Specifications/Options
Emergency battery back-up pack available. (Consult factory)
National Electrical Code Article 516.