7150100 HIGHWAY LIGHTING SYSTEMS
COMMENTS FROM INDUSTRY REVIEW

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Dan Hurtado
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Comments:
715-16 (m): "The Contract unit price will include the pole, internal vibration device…." should read "The Contract unit price will include the pole, internal vibration **damping** device…."
(The language should be consistent with 715-1, paragraph 2.)

Response:

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David OHagan

Comments:
Since the light poles in question are on the QPL, why are we specifying a submittal to the Engineer on every project? Why can't we simply have two types of QPL poles – one with and one without the damper?

Response:

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Bill Newlin
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Comments:
Would it be more consistent with active voice if the second sentence read: When installed, ensure the device provides a minimum 2% minimal damping.

Response:

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Ray Haverty
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Comments:
In 715-16 (m) it reads:

(m) Lighting Pole Complete: The Contract unit price will include the pole, *internal vibration device,* truss arm, luminaire with lamp, anchor bolts with lock nuts and washers, frangible base and foundation.
Should the added portion have been "internal vibration **damping** device"?

Response:

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Bernard Freeman

Comments:
Will the new spec (7150100)require dampening pads. What if we have existing installations without these internal vibration dampners? Would we use external type dampners ?

Response:

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Joseph M. Bowman, P.E.
Director of Research and Development
Hapco Pole Products
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Comments:
We are in receipt of your Memorandum dated June 30, 2009 regarding expanded language to 715-1 (page 808) proposed to read *" Provide metal lighting poles, excluding high mast lighting, with internal vibration damping devices installed when shown in the contract plans and in all installations on bridges, walls, concrete median barriers, and causeways. When installed, the device shall provide a minimum 2 % critical damping. Submit documentation to the Engineer demonstrating the device and pole meet this requirement."* Hapco is a manufacturer of aluminum lighting poles for FDOT number S715-001 on the FDOT Qualified Product List, Specification 715 and we offer the following review comments:

1. We agree with the first sentence as to at which installations internal vibration devices be installed in the lighting poles except we would recommend adding a group, changing it to read "*...barriers, causeways and all poles with post top mounted fixtures*."

2. We are concerned, however, with the two sentences that follow regarding the "*2 % critical damping*" and associated "*documentation*" to be submitted "*demonstrating the device and pole meet this requirement."* To our knowledge, to date, there is no published accepted test method for determining performance of damping devices in lighting poles. Damping characteristics of lighting poles in the field are highly variable depending on the wiring, anchor bolts, foundation, pole size, luminaire and, very importantly, the mode of excitation. A high first mode damping ratio may be present accompanied by low second mode damping. Based upon our experience and testing, we believe that second mode *"2 % critical damping"* is not attainable or necessary to mitigate vortex shedding

induced second mode vibration of the round profile aluminum lighting poles in the size ranges we produce. Based on our over 38 years of success using our 53373 canister type second mode damper, we believe it provides adequate protection against wind induced second mode vibration of our aluminum pole products.

We agree that a method of testing damping these devices should be developed. The test needs to measure the device effectiveness in second mode damping using a standardized procedure designed to eliminate as many of the aforementioned variables as possible. We offer the following suggestion:

In the 1960's lighting pole fatigue failures due to wind induced second mode vibration were much more common than today. In 1969, Ray Minor an engineer at Hapco Aluminum Pole Company studied these failures and undertook a testing and development program to mitigate this problem. Hapco developed their second mode tuned mass impact damper (Hapco p/n 53373) and successfully mitigated the problem.

To optimize the damper design Ray developed a test method to measurably compare the effectiveness of different damping devices and configurations. To do this he designed and constructed a rotating eccentric mass vibrator that's speed could be varied to match the second mode resonant shaft frequency. He also constructed a device to shut off the vibrator at predetermined shaft vibration maximum amplitude and count the cycles of free vibration. This allowed the shaft to freely vibrate at second mode vibration to a predetermined minimum amplitude during which the number of cycles were counted. With the maximum and minimum amplitudes and the number of cycles between, a damping coefficient could be calculated by the equation:

$$\zeta = [1/(2\pi * n)] \cdot [\ln (y_1/y_{n+1})] \cdot 100 \qquad \text{(equation 1)}$$

where:

ζ = damping coefficient (per cent)
n = number of cycles counted between set amplitudes
y_1 = maximum amplitude (in.) set for start of count
y_{n+1} = maximum amplitude (in.) set for end of count

Using these methods, Hapco damper 53373 was developed to provide maximum damping with economy and manufacturability. The tests demonstrated that for the test shaft (8" bottom diameter X 4" top diameter X .250" wall shaft X 32.4 ft with a 93 lb mass at the top) our damping device increased the damping from .18 percent to .83 percent of critical. Hapco, as a standard, includes this damper in those products that in Hapco's experience has shown to be susceptible to second mode vibration. Ray and Hapco held the patent (no. 3612222) for this damper until it expired on October 12, 1988. It remains the industry standard with other manufacturers copying it. Hapco is aware of no wind induced second mode vibration fatigue failures of lighting poles containing this damper.

The need for second mode dampers in certain lighting poles is widely recognized. Many states' departments of transportation specify dampers in certain of their lighting poles. Florida DOT on their Index 17515 standard specifies, "Equip poles with a damping

device if the pole location is within 5 miles of the coastline." and "Include damping device information, details and performance data with the QPL information." FDOT engineers expressed their concern to Hapco that there is no standard measure by which they can evaluate and approve these damping devices. Toward assisting FDOT, Hapco, with Ray's assistance, has revived and improved the test procedure through which damping performance may be measured, as follows:

The original Hapco eccentric weight variable speed vibrator was used to excite the shaft at its second mode natural frequency. The Hapco amplitude range vibrator speed controller was used to control the vibrator speed and to terminate the vibrator at preset amplitude. The counter provided real time information regarding the relative damping effectiveness. Strain gage voltage data vs. time was captured with a Vishay amplifier, Windaq analog to digital converter and recorded on a laptop. This data was plotted. Tests were performed on the Hapco p/n R457G1B0071M001 shaft with a 75 lb. weight at the top with and without damper. This shaft was selected because it is the largest aluminum shaft on the Florida DOT qualified products list and consequently the most challenging to dampen. Both the original Hapco p/n 53373 and Hapco p/n 16383 dampers were tested.

From the plots of strain gage data, for each test, two peak amplitudes were selected at n cycles apart. The damping coefficient was calculated as follows:

$$\zeta = [1/(2\pi \cdot n)] \cdot [\ln (y_1/y_{n+1})] \cdot 100 \qquad \text{(equation 1)}$$

where:

ζ = damping coefficient (per cent)
n = number of cycles between selected peaks
y_1 = initial selected peak amplitude (voltage)
y_{n+1} = selected peak amplitude (voltage) after n cycles

The calculated damping ratios from each test were averaged by group (with and without damper). The selected peak amplitudes, number of cycles and calculation were tabulated along with the strain gage plots.

On each strain gage plot a curve showing its calculated damping coefficient was plotted along with a curve showing the average damping coefficient for the group. The equation for these damping coefficient plots is as follows:

$$y_{n+1} = y_1 \cdot e^{[(-\zeta/100) \cdot 2\pi(tn+1-t1) \cdot fn]} \qquad \text{(equation 2)}$$

where:

ζ = damping coefficient (per cent)
f_n = shaft natural frequency (cps)
f_n = $n/(t_{n+1} - t_1)$
n = number of cycles between selected peaks
t_1 = time at initial selected peak amplitude (sec.)
t_{n+1} = time at selected peak amplitude after n cycles (sec.)
y_1 = initial selected peak amplitude (voltage)

y_{n+1} = selected peak amplitude (voltage) after n cycles

The average damping coefficient was plotted against the calculated damping coefficient specific to the individual plot for comparison.

These tests demonstrated that inclusion of either Hapco damper p/n 53373 or p/n 16383 improved the damping coefficient of the test shaft from an average of 0.088 percent to 0.5 percent critical, an almost six fold increase.

If FDOT finds that this test method and results may be acceptable Hapco can submit the results with data and associated calculations. We believe that such a submittal would demonstrate the acceptability of our damping devices for use in our FDOT products.

We applaud FDOT efforts to lead the states in defining acceptance criteria for lighting pole damping devices and Hapco looks forward to discussing our work in this regard and what other assistance we may provide FDOT in this endeavor.

Thanks you your consideration. Please call or email any questions anytime we can be of service.

Response:

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