LUMINAIRE VIBRATION SUPPRESSION STUDY

FINAL REPORT

BY

JAMES O. BURT
SPECIAL STUDIES RESEARCH GEOLOGIST

AND

EARL J. LEBLANC
RESEARCH SPECIALIST

UNDER THE GENERAL SUPERVISION OF

JOSEPH E. ROSS
CONCRETE RESEARCH ENGINEER

RESEARCH REPORT NO. 75
RESEARCH PROJECT NO. 71-3C(B)
LOUISIANA HPR 1 (11)

Conducted by
LOUISIANA DEPARTMENT OF HIGHWAYS
Research and Development Section
In Cooperation with
U. S. Department of Transportation
FEDERAL HIGHWAY ADMINISTRATION

"The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Louisiana Department of Highways or the Federal Highway Administration. This report does not constitute a standard, specification or regulation."

MARCH 1974

ACKNOWLEDGMENTS

Sincere appreciation is expressed to the following companies and individuals for assistance rendered in this study:

1. Mr. Don Edwards, research representative from General Electric Company Lighting Systems Department, Hendersonville, North Carolina for assistance in laboratory testing procedures planning.

2. Church-Dailing Company, New Orleans, Louisiana, for submission of Fabreeka Products Company dampening pads for evaluation purposes.

3. Hapco Company, Abingdon, Virginia, for submission of inertial vibration damper to be evaluated.

4. Mr. H. A. Van Dusen, area lighting division of McGraw-Edison Company, for providing valuable technical background information from prior research activities.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

LIST OF TABLES

ABSTRACT

This study was initiated to find solutions to problems of inadequate lamp life in luminaires located on the state's bridges and overpasses. Since the problem was known to be caused by excess traffic vibration reaching the bulbs, an investigation of the nature and extent of this vibration as well as possible methods of suppression was begun.

Nine major manufacturers of roadway lighting components were contacted and asked to submit suggestions for possible devices or methods which might be used for this purpose. Information obtained from this inquiry was used in choosing devices to be evaluated.

The first phase of active testing in the study involved the gathering of vibration data from five luminaires located on selected overpasses in the Baton Rouge area. Two of these were aluminum and three were steel types. Accelerometers were attached to the luminaire bulbs and wired to an oscillograph in order to produce a recorded trace of vibrational forces reaching the bulbs. This information was used in determining guidelines for the next phase of testing, which would be done under controlled conditions in a laboratory environment.

Four inertial dampers were tested during this laboratory phase. These included three sizes of Alcoa stockbridge dampers and one manufactured by Hapco.

Both steel and aluminum luminaires of comparable size and weight to those tested in the first phase were used in testing. Controllable vibration excitation was supplied to the luminaires by a motor driven eccentric weight device which could supply energy at frequencies in the range of those observed during the first field phase of testing. Accelerometers were again installed on the bulbs and their output recorded on an oscillograph. Each damper's performance was judged by the amount of reduction it produced in the luminaire's vibration decay time.

Results of this testing indicated that the undamped aluminum luminaire was inherently less of a carrier of vibration energy to its bulb than was the steel counterpart. Effectiveness of each damper type seemed to be proportional

to the damper's weight in this low frequency testing, with the 35 pound Alcoa type showing highest efficiency. The most efficient point of installation for all dampers was halfway up the vertical extent of the luminaire poles.

The final phase of the study involved field testing of all inertial types except the 31 pound Alcoa. This damper was not tested simply because its laboratory test results so nearly duplicated those obtained with the 35 pound device. Two thicknesses of "Fabco" material were also evaluated for their effectiveness in isolating the luminaires from higher frequency (above 100 Hz) vibration which normally enters at the base of the poles. The five original data gathering locations were used in this final field evaluation for both of these types of testing.

Since testing was carried out with relatively uncontrollable continuous traffic vibration, dampers were checked for their ability to reduce the average amplitude of vibration reaching the luminaire bulb rather than for their ability to reduce energy decay time.

Laboratory and final field testing both indicated that less vibration problems exist in aluminum luminaires than with the steel types, probably due to their lesser inherent rigidity.

All inertial dampers tested reduced duration and amplitude of low frequency vibration reaching the lamps. An excessive amount of this energy applied over extended periods of time can cause bulbs to loosen in their sockets and lead to bulb breakage and structural damage to poles and bracket assemblies.

Vibration attenuation obtainable from inertial dampers is seemingly proportional to the weight of the dampers themselves; however, dampers as heavy as the 35 pound Alcoa device would not be necessary in most instances to reduce vibration an appreciable amount in problem areas for increased lamp life. The 15 pound Alcoa device seems to have sufficient performance capabilities for all but the most severe problem areas.

The Fabco material offered little or no vibration suppression in field testing with steel and aluminum luminaires. If the product had been available in thinner stock than was offered at the time of testing, however, results may have been more favorable since a minimum static load is claimed necessary by the manufacturer.

The following recommendations are made in accordance with the findings of this study:

1) Aluminum light standards should be exclusively specified for use on elevated roadways on all new projects.
2) A program should be established to compile a maintenance history of roadway luminaires particularly on elevated structures, whereby areas having high incidences of bulb failure can be defined and located.
3) Where there is an abnormal amount of mercury vapor bulb failure, the installation of 15 pound Alcoa dampers and bulb clamps is recommended. In cases of an extremely large number of bulb failures, heavier dampers should be installed.

IMPLEMENTATION

An interim report discussing the findings and three basic recommendations of this study has been submitted to appropriate authorities within the Department for implementation. As of this writing, the recommendation that aluminum light standards be exclusively specified for use on elevated roadways on all new projects is under consideration and seems to stand a good chance of becoming a Department policy.

It is hoped that submission of this final report will provide needed impetus for the change and for the establishment of a luminaire maintenance history program throughout the state.

INTRODUCTION

The Louisiana Department of Highways is currently experiencing trouble with short lamp life in luminaires located on bridges and overpasses throughout the state. The exact magnitude of the problem is as yet unknown since failure rates have been documented in only one locale, a portion of Interstate 20 in the Shreveport area.

Complaints about lighting conditions in this area were investigated in early 1970 by the General Electric Company and Southwestern Electric Power Company. It was determined in March of 1970 that 17.5 percent of approximately 600 mercury vapor bulbs under maintenance contract from the center of Red River Bridge west to Monkhouse Drive required replacement within a five year period. Approximately 91 percent of these bulbs which failed due to breakage were located on bridges and overpasses which comprise approximately 16 percent of the total roadway.

Two basic types of traffic vibration are believed responsible for luminaire bulb damage in these cases. First, low frequency traffic vibration of 30 Hertz or less can easily reach a bulb via the rigid luminaire structure itself. This effect is usually accompanied by resonance conditions in the luminaire pole which serve to increase, even amplify, forces reaching the bulb. Over an extended period this can cause bulbs to loosen in their sockets and lead to bulb breakage from the resulting excessive "whipping" action. This type of vibration has also been known to cause structural damage to the poles and arms themselves although there are no documented cases of this at present in the state of Louisiana.

The second type of vibration involves higher frequencies of 100 Hertz or more which cause no resonance in the luminaire structure but nevertheless are believed to cause most bulb failure in which the internal elements of the bulb are broken loose from the base.

These maintenance problems and former interest which had been shown by the design and maintenance sections within the Department prompted the Research and Development Section to initiate a research study to investigate and find solutions to the problem as it related to this and other areas of the state.

SCOPE

The scope of this study was to investigate and find solutions to the problem of short lamp life in luminaires located on bridges and overpasses. The main thrust of the research effort was toward a careful field and laboratory evaluation of the effectiveness of several types of commercially available "add on" dampening devices which were recommended by luminaire manufacturers for vibration attenuation on existing in-place aluminum and steel luminaires. A comparison was also made of the vibration properties of steel and aluminum luminaires as they are affected by heavy traffic and artificially produced laboratory vibration.

METHOD OF PROCEDURE

Investigation of the problem was begun with letters being sent to nine luminaire manufactuers. These inquires requested recommendations for methods and/or devices which would suppress excess vibration reaching light fixtures of roadway luminaires. It was requested that any suggested remedies be compatable with poles, arms, and fixtures already in service. Replies were received from six of these manufacturers and used as a basis for choosing devices for evaluation.

Four of the manufacturers recommended installation of inertial devices such as Alcoa stockbridge dampers on the poles or arms of the luminaires for suppression of traffic induced low frequency vibration.

Two of these four manufacturers also recommended the use of shock absorbing isolation pads at the base of the poles for higher frequency suppression.

Final choices for inertial damper evaluation included 15, 31, and 35 pound Alcoa dampers, and a damper manufacturered by Hapco, intended for use with luminaires made by the manufacturer of the same name in vibration trouble areas.

Two thicknesses of material marketed by the Fabreeka Products Company under the name "Fabco" were evaluated for effectiveness in blocking entry of higher frequency (above 100 Hz) vibration at the base mounting flange of luminaire poles.

Prior to procurement of the dampening devices, five luminaires at various locations were picked for field evaluation of damper effectiveness. These locations were all on elevated roadway sections in the Baton Rouge area which seemed likely to produce lamp failure problems. Three of these luminaires were steel and the remaining two were aluminum. All five had truss type arm assemblies with lamp mounting heights of approximately thirty feet and lamps rated at 400 watts. With no dampers installed, accelerometers were attached to the bulbs at these locations and vibration readings from traffic were recorded by means of an oscillograph.

After procurement of the dampers, this initial field testing was followed by a laboratory phase in which four inertial dampening devices were tested at various mounting positions on ground-mounted steel and aluminum luminaires identical to the ones tested in the field. Vibrational energy of from 0 to 30 Hertz was coupled to the luminaires for this testing by a variable frequency vibrator mounted near the bottom of the poles. Accelerometer readings were taken from the bulbs as with the initial field testing; however, decay time instead of amplitude was checked, as will be discussed later.

The final phase of the study consisted of a field evaluation of a vibration barrier material sold under the name "Fabco" and of inertial devices showing the most promise from previous laboratory testing. A special high frequency measurement system was used in testing the effectiveness of the Fabco pads since this material is designed for attenuation of vibration above 30 Hertz. The usual method of accelerometer measurement was used in testing the inertial dampers in this final phase.

Results of this testing and conclusions which can be drawn comprise the remainder of this report.

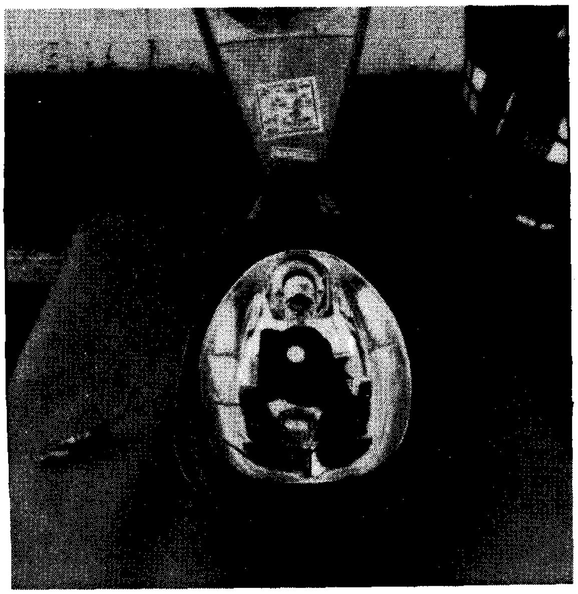
TESTING PROCEDURES AND DISCUSSION OF RESULTS

Luminaire and Damper Testing Description

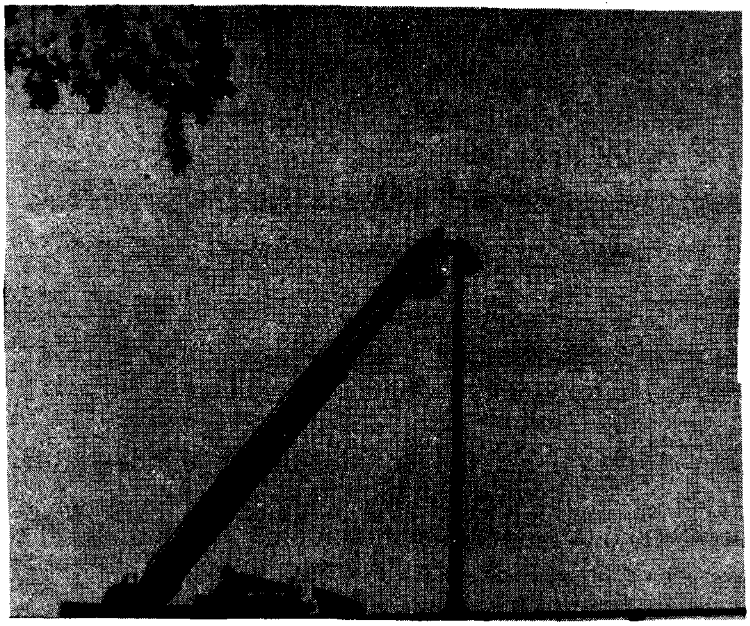
Preliminary Field Testing

This first phase of the study was undertaken to determine the types of vibrational forces which are transmitted to mercury vapor bulbs in luminaires on bridge decks and overpasses having probable high incidences of lamp failure. Five luminaire test locations were picked in the Baton Rouge area. Three of these were steel poles and two were aluminum counterparts. All five luminaires had truss type six foot bracket arm assemblies, bulb mounting heights of approximately 30 feet, and 400 watt mercury vapor fixtures.

Vibration test readings were taken from two accelerometers which were attached to the bulbs with the use of a rubber strap as shown in Figures 1 and 2.



400 Watt Mercury Vapor Fixture with Accelerometers Attached
FIGURE 1

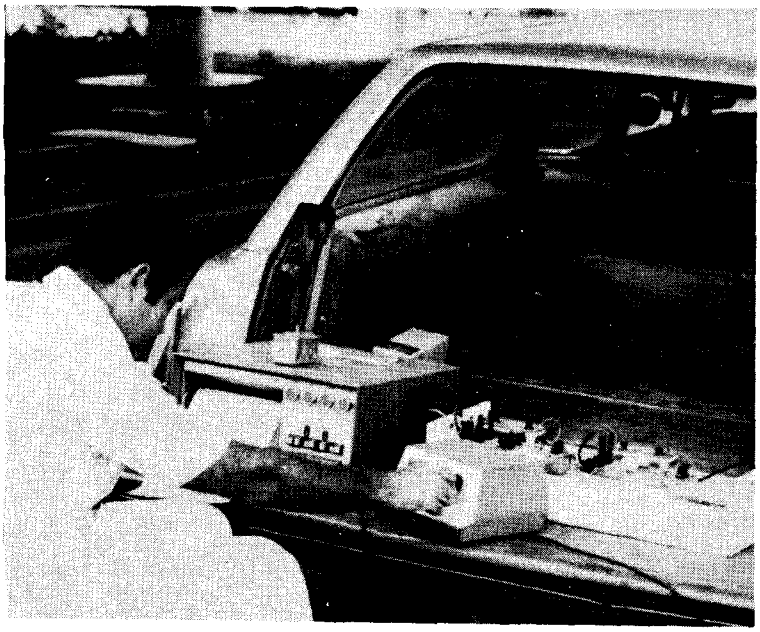


Installation of Accelerometers During Initial Field Testing Phase
FIGURE 2

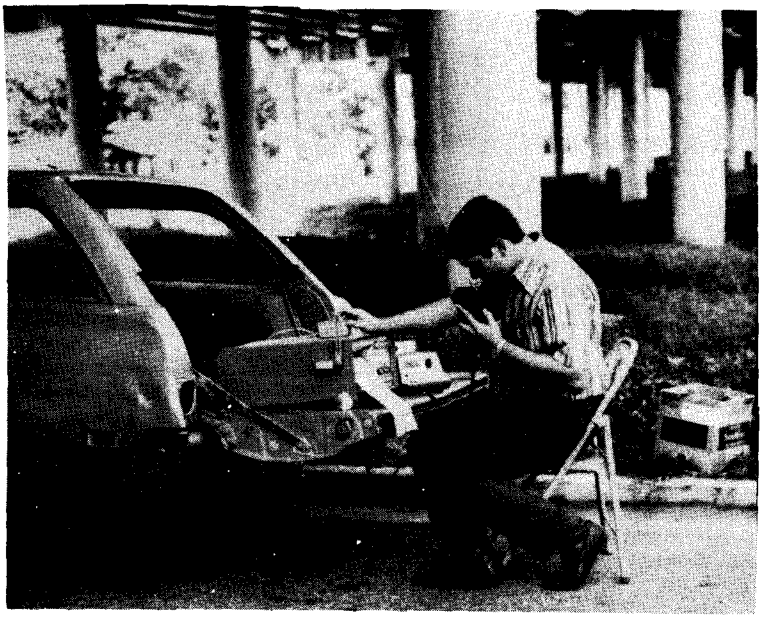
Accelerometers were secured with their sensing axes 90° apart so that one would respond to vertical and the other to horizontal movement of the bulb. Accelerometer leads were run out of the fixture, across the bracket assembly and down the pole to recording and monitoring equipment set up in the rear of a station wagon which was generally parked under the roadway structure at each test site. Figures 3 and 4 depict this setup at one test site.

Accelerometer readings which were recorded represented primarily the larger, heavier vehicles such as semitrailer trucks, sand and gravel haulers, and ready-mix trucks which produced the most severe vibration disturbances. Some readings of the vibration produced by lighter passenger-type vehicles were also recorded.

The procedure for recording field vibration was standardized into the following sequence of events:



Calibration of Accelerometers Prior to Vibration Recording
FIGURE 3



Vibration Recording From Luminaire Located Overhead
FIGURE 4

1) Observer at traffic vantage point announced impending approach of subject vehicle(s), giving description via walkie talkie to instrument operator below overpass.

2) Operator then wrote brief description of vehicle on recording chart and awaited further instructions.

3) Observer transmitted audible signal announcing vehicle's entry into test zone.

4) Instrument operator then started recorder, recording accelerometer readings until vehicle's vibration influence could visibly be seen to disappear from trace.

A summarization of G-level readings from these five test locations is located in Table 1 of the Appendix.

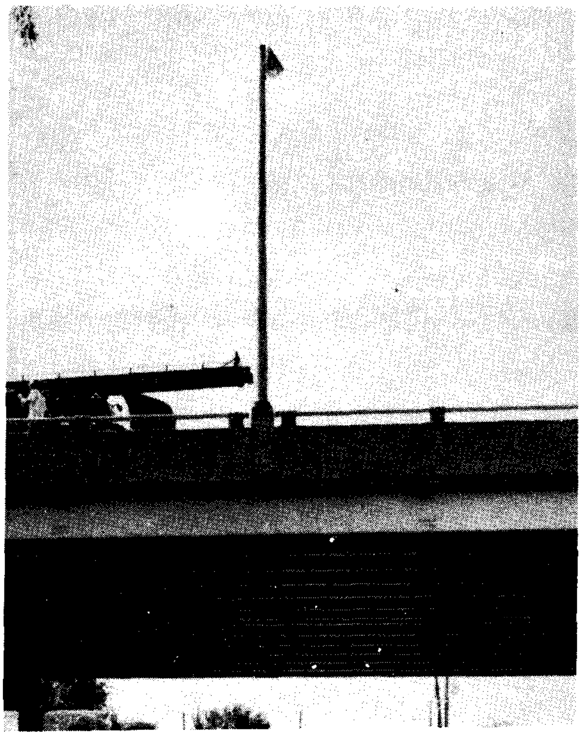
Summary of Observed Readings

The highest peak and highest average G-level readings were obtained from a steel pole located on the east approach (westbound) to the I-10 Mississippi River Bridge (see Figure 5).

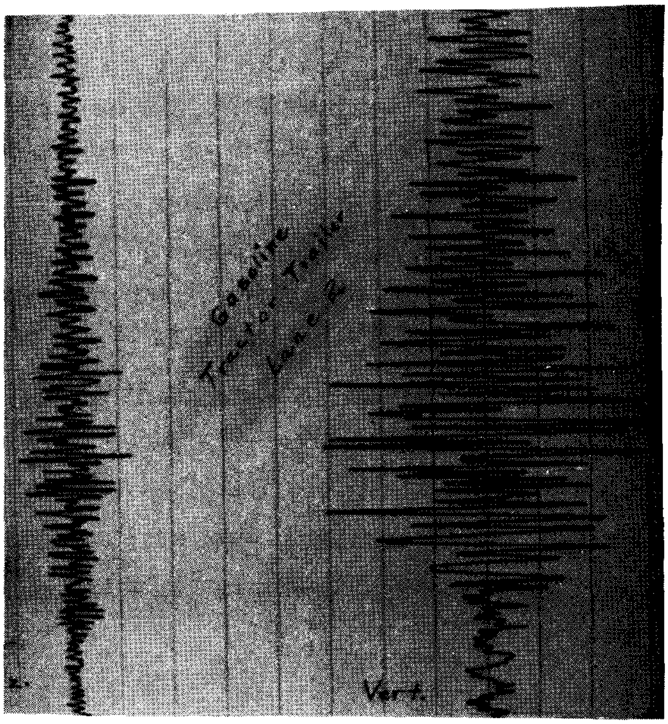
The luminaire in this instance was located at the approximate midpoint of a span in the overhead roadway. This factor was believed to be the greatest single cause of higher readings obtained at this location since the points of maximum roadway rigidity are directly over the pilings.

Other readings shown in Table 1 of the Appendix varied according to luminaire location on the bridge structure and the weight and speed of passing traffic.

A sample of vibration readings taken from one of the locations can be seen in Figure 6. This recorded interval shows deflections from horizontally and vertically placed accelerometers in response to a heavy gasoline tanker truck passing near the luminaire at approximately fifty miles per hour. This excerpt is typical of field readings taken during both this and the final field testing phase of the study.



Location at Which Highest Readings Were Obtained During Initial Field Testing
FIGURE 5



Portion of Oscillograph Chart From Field Testing Operations
FIGURE 6

Laboratory Testing

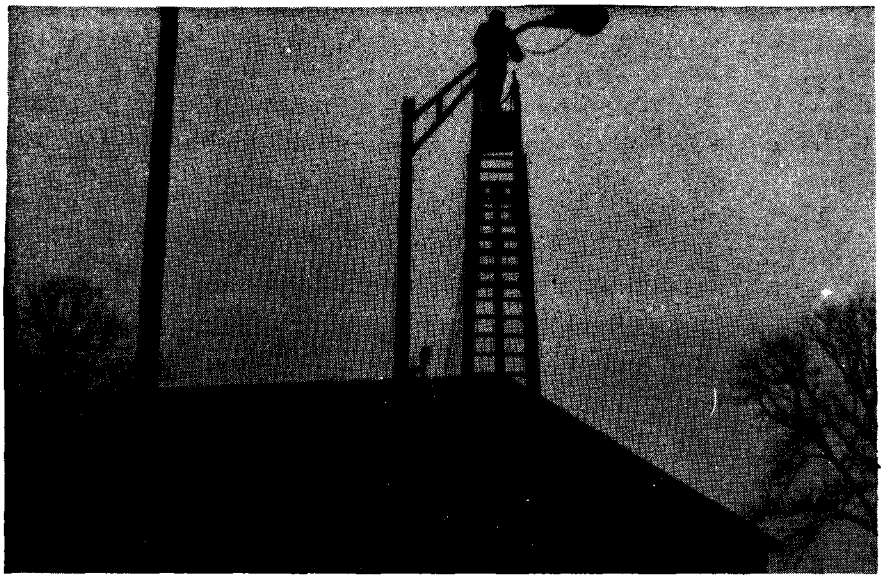
The exact set up and procedure to be used in the laboratory damper evaluation had been only vaguely outlined at the outset of the study. This phase of the study was intended to evaluate the effects of the dampening devices on steel and aluminum luminaires under controlled conditions. These controlled conditions would simulate traffic conditions such as would be encountered if the luminaires were located on a heavily traveled elevated roadway. Discussions concerning the most effective means of accomplishing these goals resulted in a decision to build a rotary mechanical excitation device which would be capable of "shaking" the luminaire at frequencies up to 30 Hertz.

Field testing had shown the poles' tendency to resonate at a number of different frequencies, depending on traffic speed and weight as well as pole location relative to the roadway supports. It was decided that more useful results would be obtained in the laboratory testing if the luminaires were tested for damper effect at all possible resonant frequencies up to 30 Hertz or so, since this was the highest resonant vibration frequency encountered in field testing.

A useful dampening device should reduce the amount of vibration force and the amount of time that this force acts on the light fixture (decay time). Only the amount of decrease in decay time realized from the installation of each damper at each mounting position was checked in the laboratory, however. Experimentation with test luminaires using artificially induced vibration prior to the beginning of formal testing showed that reductions in decay time were usually accompanied by reductions in the amplitude of accelerometer readings, and decay time measurements were believed to give a better overall indication of damper performance. An evaluation using both together in the laboratory would have become quite complex with doubtful benefits. The less ideal amplitude comparisons were used in the final field evaluation as will be explained later.

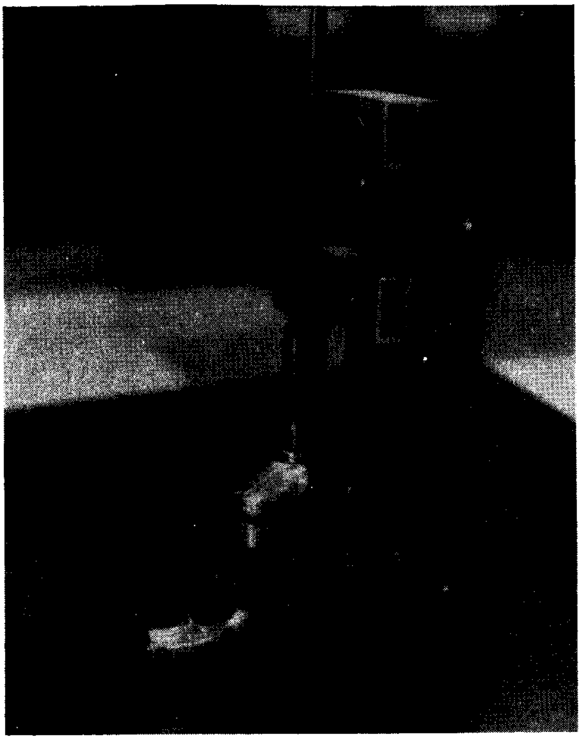
These tests were run on a steel and an aluminum luminaire which were installed near the rear of the Highway Research Center on the Louisiana State University campus. (see Figure 7). Since it was desirable that the poles be very securely anchored for testing, a standard LDH ground mount luminaire installation plan along with appropriate hardware and concrete footing was used in their installation. Cast aluminum frangible bases were used in order to install the poles at a convenient working height for vibrator manipulation.

Both luminaires had bulb mounting heights of approximately 30 feet and were outfitted with six foot bracket arm assemblies and 400 watt fixtures. These component sizes were used to correspond with luminaires most commonly utilized on bridges and overpasses throughout the Interstate System in Louisiana.

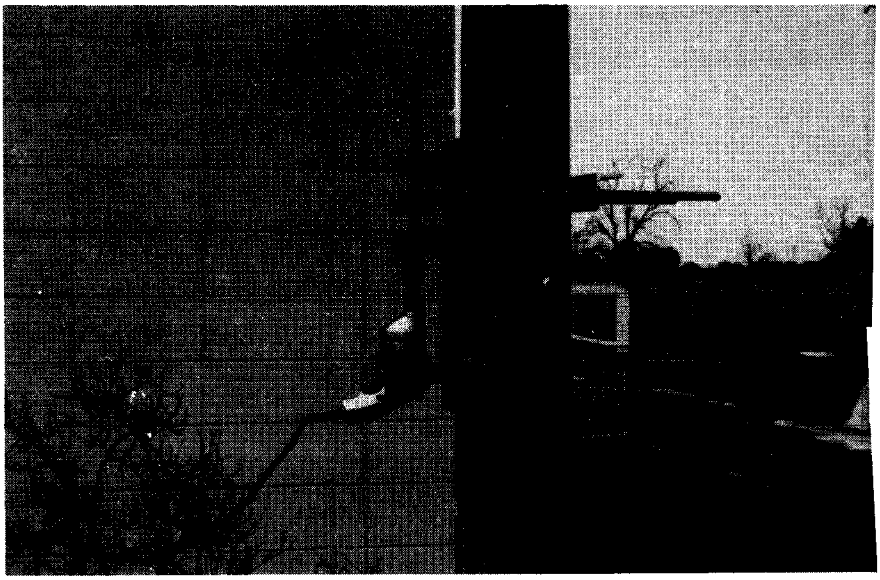


Aluminum and Steel Luminaires Used in Laboratory Phase of Testing
FIGURE 7

The vibrator (see Figure 8 and 9) was built on a 1/4 inch steel base which was small enough to clamp to the bases of the poles. It consisted of a balanced shaft supported between two low-friction bearings to which two steel counterweights were attached. This shaft was driven via a flexible coupling by an 1800 RPM electric drill supported in line with the shaft. The rotational speed of the drill was made controllable from 0 to 1800 RPM by the use of an SCR motor speed control located near the site at which accelerometer readings were recorded.



Vibration Device Used in Laboratory Tests
FIGURE 8



Vibration Device in Place on Luminaire Pole
FIGURE 9

Accelerometers were attached to the mercury vapor bulbs on each of the two poles in order to obtain representative readings as in the initial field testing, but only vertically placed accelerometers were used in this instance since a horizontal movement component was found to be practically non-existent.

The aforementioned testing scheme basically involved a comparison of decay times. Decay time readings taken included:

1) Steel and aluminum luminaires at 0 to 30 Hertz with no damping

2) Steel luminaire at 0 to 30 Hertz with three sizes of Alcoa dampers and Hapco damper.

3) Aluminum luminaire at 0 to 30 Hertz with three sizes of Alcoa dampers and the Hapco damper.

The testing sequence for each of these situations proceeded as follows:

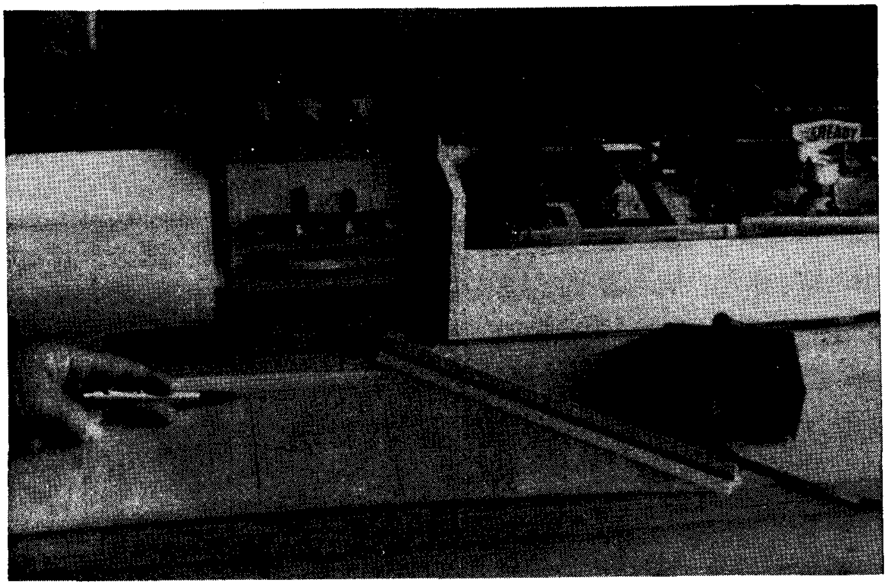
1) Voltage to vibrator motor and hence the frequency of vibration was increased until a noticeable increase in accelerometer output could be seen, signifying a resonance point.

2) Recording chart was started and run for approximately ten seconds under steady state resonance conditions.

3) With recorder continuing to run, power to vibrator was abruptly switched off. Exact point of cutoff was marked electronically on edge of chart.

4) Chart was stopped as soon as all vibrator influence was seen to disappear from the oscillograph trace and information was recorded.

This testing continued for all vibration resonance points (modes) up to 30 Hertz for each luminaire. Decay time readings from this testing appear in Table 2 of the Appendix.



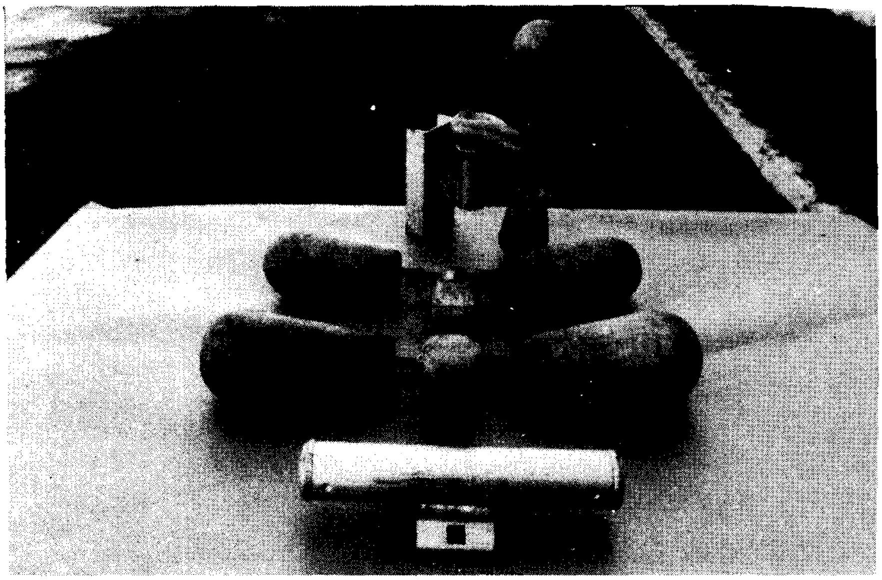
Vibration measurement equipment as used in laboratory testing. Pencil and left line indicate point at which power to vibrator was cut. Second line to right is drawn at end of decay time interval.

FIGURE 10

Decay time was computed from the charts on the basis of decreasing amplitude in accelerometer output. It is the elapsed time in seconds from the point at which power was cut off to the vibrator to the point at which the accelerometer output voltage dropped to 10 percent of the peak value prior to vibrator cutoff. These values were empirically developed to compensate for changing wind conditions at the test site.

Summary of Observed Performance

All dampers produced noticeable results in decreasing the basic first, second, and third modal decay times of both the aluminum and steel luminaires. The mounting position found to be the most efficient for reducing vibration decay time in each case was midway up the luminaire poles. Various other mounting positions along both the arm and pole of the luminaire were tried with only moderate success.



Inertial dampers evaluated during laboratory and final field phases of study. Hapco is in foreground. Other three types are manufactured by Alcoa. Note special pole attachment bracket fabricated for testing on damper in rear.

FIGURE 11

The heaviest device tested, a 35 pound Alcoa damper, (see Figure 12) produced the greatest overall reduction in decay time. A comparison with decay time on both poles in an undamped condition revealed that this damper caused a 74 percent reduction in first modal decay time of the steel luminaire and an 85 percent reduction in first modal aluminum luminaire decay time.

It was hoped that the Hapco inertial damper would be effective since it can be installed inside luminaire poles with only two bolt heads showing. These dampers are also low in cost, but yielded the poorest results of any inertial type tested.

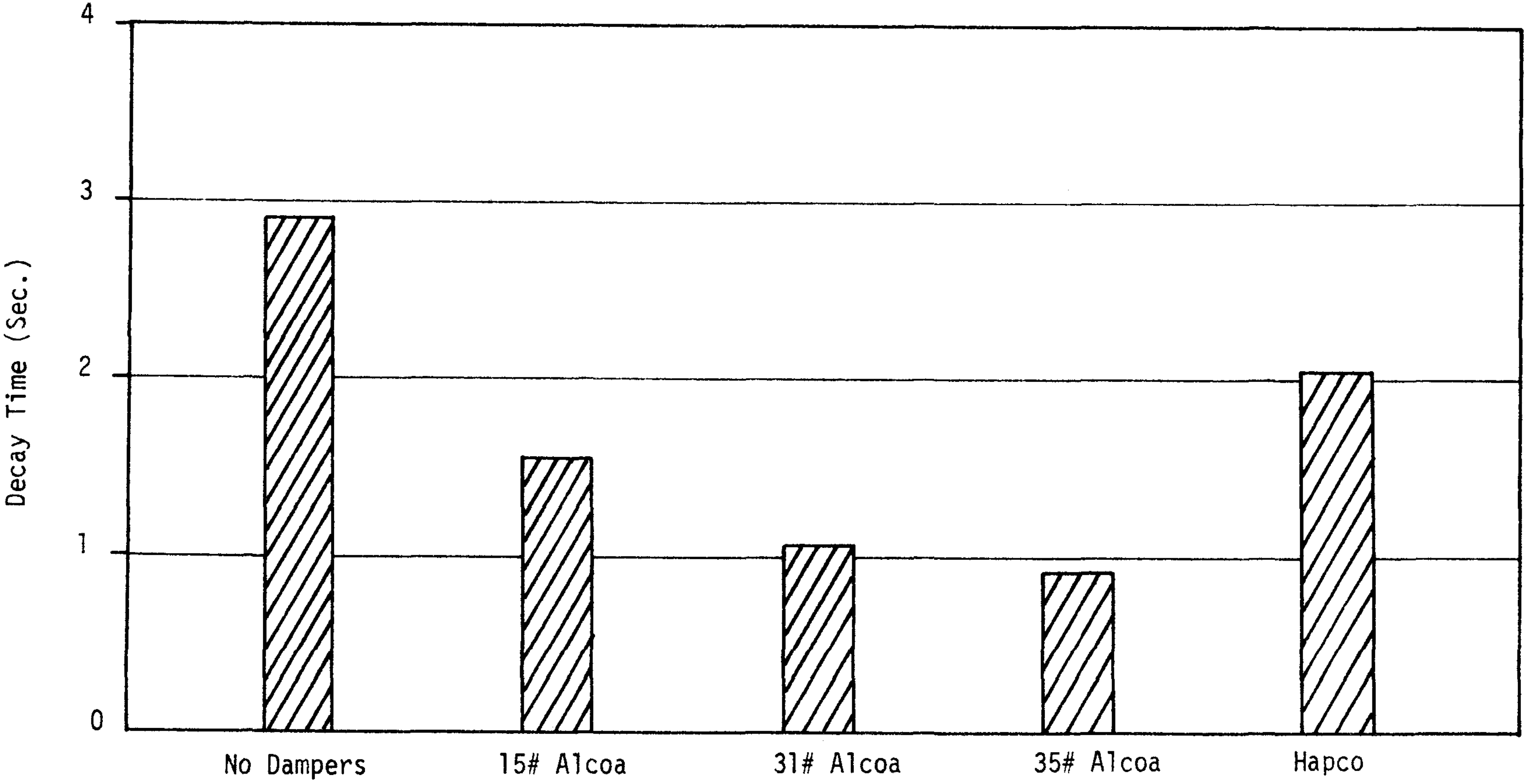
The same vibrator eccentric weight setting was used in coupling vibrational energy to each of the two luminaires during testing, but the aluminum structure allowed a faster dissipation of this energy as can be seen in the test data in Table 2 of the Appendix.

Thirty-Five Pound Alcoa Damper at Mid-Pole Position on Steel Luminaire

FIGURE 12

Test data also reveals that dampers generally had more damping effectiveness percentage-wise on the aluminum structure than on the steel in all modes. Although the resonant frequency points of the luminaires changed when dampers were installed, the change was never more than a few cycles. In some cases, however, one of the resonant points would actually disappear. These cases are recognizable on the laboratory data tables by the absence of third mode decay time figures.

Another interesting phenomenon noticed during laboratory testing sometimes occurred when the vibrator was turned off to obtain decay time readings. If the luminaire was being tested in the second or third mode, it would quite often fall into resonance at the lower mode(s) as the decaying action progressed, causing the resultant recorded trace to momentarily widen as the frequency and stored energy in the structure diminished.



Laboratory Decay Time of Steel Luminaire with Various Inertial Dampers
(Average of All Modes)

FIGURE 13

Final Field Testing

The last phase of the study involved a field evaluation of the better performing inertial devices plus an evaluation of two thicknesses of "Fabco" material manufactured by the Fabreeka Products Company. These "Fabreeka Pads" were not subjected to laboratory evaluation because of their principle of operation, i.e. providing an isolation barrier, being incompatable with the excitation method used in the laboratory testing.

The five luminaire locations which were used in the initial field testing were again used in this final phase so that damped versus previous undamped results could be readily compared.

It was decided to field test all inertial dampers which had undergone laboratory testing except the 31 pound Alcoa damper which yielded comparable results to its 35 pound counterpart. Fabreeka Pads were tested at one of these sites.

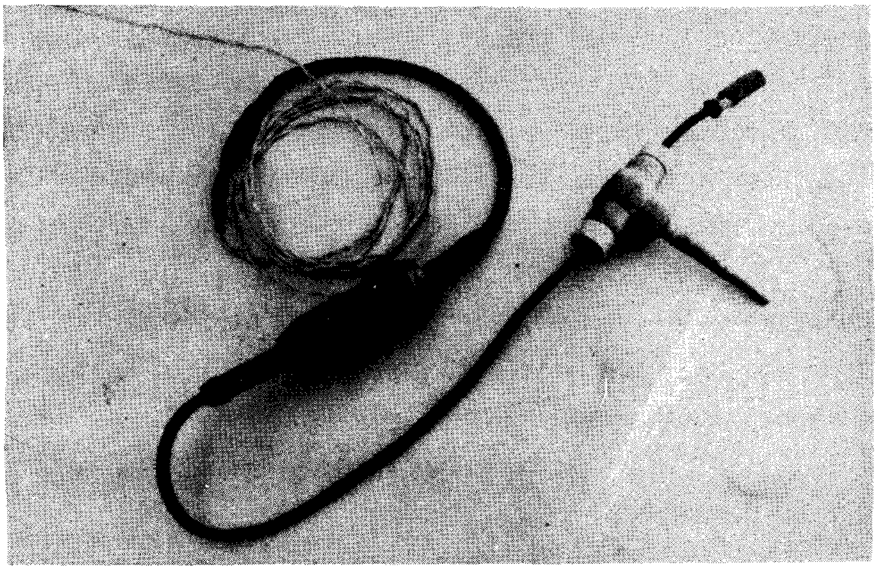
The dampers were installed in the mid-pole position in each instance, and the parameter used in evaluation was the difference in amplitude between the undamped and each damped condition. Random time distribution and overlapping traffic vibration in the input demanded the use of this type of testing in preference to the decay time method used in the laboratory phase.

After each device was installed, a 1 1/2 ton Louisiana Department of Highways signal maintenance truck was driven over the elevated roadway on which the luminaire was located so that a constant vibrational force reading would be available for comparison. Most of the recording, however, was done of typical vehicular traffic through the areas, with emphasis on trucks which would produce large amounts of disturbance.

Procedural steps used in recording events in this phase were identical with those used in the first field testing stage for the three inertial types tested, but a new approach had to be devised for the Fabreeka Pad testing.

The Fabreeka material, marketed in several thicknesses under the name "Fabco" is a laminated rubber and cotton fibre material which is used in industry for vibration isolation in heavy machinery. Two luminaire manufacturers, however, suggested its use, or the use of a similar material beneath the mounting flange of the poles for vibration attenuation of frequencies in the range of 30 to 200 Hertz. Since this range of frequencies was for the most part above the effective operating range of accelerometers which had previously been used, a new method of measurement was necessary.

The method devised involved the use of a geophone (see Figure 14) mounted on top of the subject pole. The output from this device was fed into a General Radio sound level recorder to provide a graphical record. Frequency sensitive filter circuitry in the recorder allowed attenuation of unwanted low frequency readings. This hookup was capable of responding to vibration frequencies up to several hundered cycles per second and seems to have served the purpose.



Geophone Used in Fabco Material Evaluation
FIGURE 14

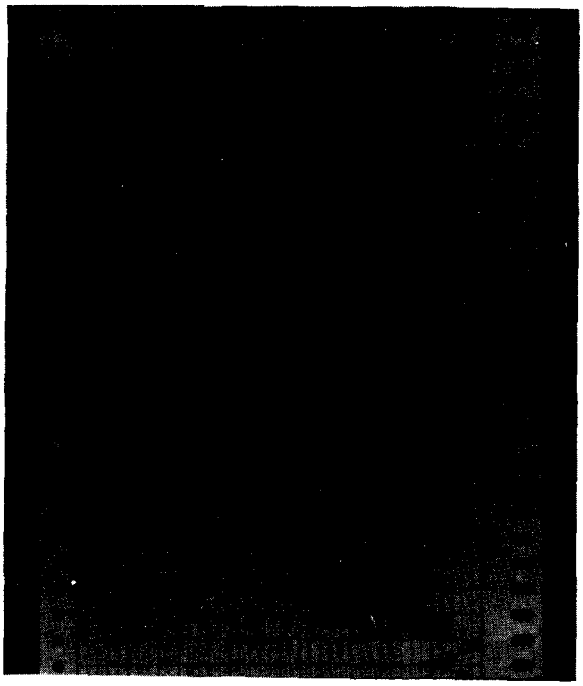


Chart from General Radio sound level recorder used in "Fabco" evaluation. Lower frequency impulses were filtered out so that the trace showed no appreciable response to vibration less than 100 Hertz.

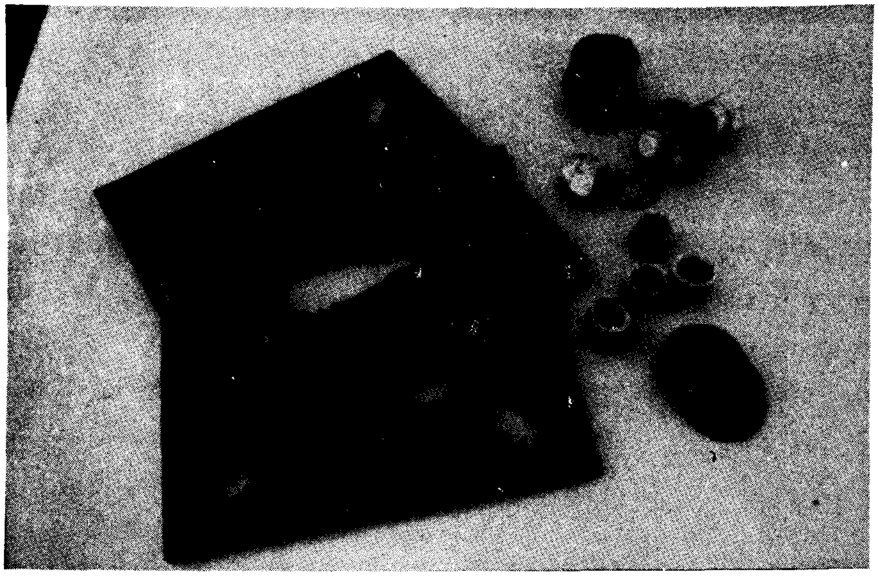
FIGURE 15

Fabreeka Pad evaluation involved the testing of two thicknesses of the material, namely the 15/64 inch and 1/2 inch sizes, on steel and aluminum poles at the same location. These installations were made according to factory recommendations, using components shown in Figure 16, which supposedly provided a completely isolated and padded attachment for the luminaires to the overpass structure.

The testing procedure relative to types of traffic recorded, procedural sequences, etc. was the same as that used with both the initial field testing and final field testing of the inertial dampers.

Summary of Observed Performance

In light of work done in the first two phases of the study, the final field phase held no surprises as far as test results on inertial dampers were concerned. The thirty-five pound Alcoa damper again produced the most effective damping action, yielding a maximum vibration amplitude reduction of 56 percent at one of the aluminum pole test sites while reducing vibration an average of 33 percent at the five locations.



Fabco Material and Associated Hardware Used in Installation
FIGURE 16

The fifteen pound damper produced a maximum amplitude reduction of 42 percent at the aforementioned aluminum pole test site and an average of 26 percent overall. G-level readings from the final field testing of the inertial dampers can be seen in Table 3 of the Appendix.

The steel luminaire near the I-10 Mississippi River Bridge which yielded the highest readings during the initial phase of the study was perhaps the best overall indicator of damper performance. Some readings on this undamped luminaire prior to damper installation were well over 1.5 G, while the average undamped vertical reading at this site was about 1.2G for heavy traffic.

The Fabreeka Pad test results were disappointing. Readings taken before and after pad installation showed no clear cut differences, as can be seen in Table 4 of the Appendix. Two thicknesses of Pads were tried on the steel luminaire, but there was no noticeable difference in their effect on the high frequency energy reaching the bulb.

It should be stated in all fairness that even though the Fabreeka distributor's installation instructions were followed to the letter and a poor display of performance was the result, this product, or a similar one may still have potential as a luminaire vibration suppressor. When details of pad installation were discussed with the distributor, it was pointed out that loading of the pads would be very pertinent to the amount of damping obtained at any one installation. Using graphs supplied by Fabreeka Products Company for damping factor prediction, it was theorized that optimum high frequency vibration isolation of luminaire assemblies in the weight class to be tested would require a thinner pad than was available from the manufacturer. The graphs also indicate that actual intensification of incident vibration levels can occur if minimum loading is not present.

400 watt mercury vapor bulb showing early failure from vibration damage. Large outer envelope was removed and broken inner assembly re-positioned to show inner components. Failure occurred when continuous traffic vibration caused a fatigue break in one of the wires supporting the small inner light emission envelope. This was in all probability caused by higher frequency vibration.

FIGURE 17

CONCLUSIONS

After extensive testing it is apparent that there is much less of a vibration problem on bridges and overpasses with aluminum poles than with their steel counterparts. In working with steel and aluminum poles during installation of accelerometers, changing bulbs, etc. on overpasses open to traffic, the aluminum structures seemed basically less vibration prone. Lower accelerometer readings were obtained in laboratory and field testing with and without dampening devices from fixtures mounted on aluminum poles. Typical accelerometer readings in the field on undamped steel poles averaged fifty to sixty percent higher than readings on undamped aluminum poles with identical vehicles traveling past them at the same speed. This was probably due to the inherent rigidity of the steel structures and their superior but undesirable ability to transmit mechanical motion to the fixtures.

All four of the inertial dampers tested on luminaires reduced both the duration and amplitude of low frequency vibrational force which reached the lamps. This low frequency vibration is believed to be capable of causing the large screw base mercury vapor bulbs used in luminaires to loosen in their sockets, often leading to bulb breakage. This type of vibration can cause structural damage to the poles and arms themselves although there are no documented cases of this at present in the State of Louisiana.

The amount of vibration attenuation obtainable from the inertial dampers is seemingly proportional to the weight of the dampers themselves. Thus the most effective results were obtained from the heaviest inertial damper tested, a thirty-five pound Alcoa. In all but the most severe cases, however, the fifteen pound Alcoa damper seems sufficient to reduce bulb vibration to G-levels which are conducive to long lamp life. When installed, this lighter damper is much smaller and less of an eyesore than the heavier ones tested. It also costs only about half as much (27.50) per unit as the thirty-five pound device.

It should be noted that even though no less than three large pole manufacturers recommended use of the Alcoa Stockbridge dampers, these devices are not designed to attach directly to a luminaire pole. It was necessary to fabricate a small bracket to allow attachment for testing. Such a device could be fabricated in a welding shop for several dollars; or arrangements might be made with Alcoa to supply "attachable" dampers if quantities justified.

It was hoped that the Hapco inertial damper would be effective since it can be installed inside luminaire poles with only two bolt holes showing. These dampers are also low in cost, but yielded the poorest results of any inertial type tested.

Fabreeka isolation pads had little effect in alleviating high frequency (above 100 Hertz) vibration problems. This material is designed to provide a barrier for transmission of vibration primarily at these higher frequencies. One of the larger manufacturers of stree lighting fixtures believes that this type of vibration causes bulb failures in which internal elements of the bulbs are broken.

Bulbs clamps used in some installations around the bases and tops of luminaire bulbs effectively "stiffen" the light fixture and reduce the bulb's tendency to loosen in the socket from vibration, thereby reducing breakage. These damping devices were noticed on one group of steel luminaires located on I-110 near Florida Boulevard and appear to be a good feature to include on the stiffer steel poles.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations should be considered:

1) Aluminum light standards should be exclusively specified for use on elevated roadways on all new projects.

2) A program should be established to compile a maintenance history of roadway luminaires particularly on elevated structures, whereby areas having high incidences of bulb failures can be defined and located.

3) Where there is an abnormal amount of mercury vapor bulb failure from low frequency damage, the installation of 15 pound Alcoa dampers and bulb clamps is recommended. In cases of an extremely large number of bulb failures, heavier dampers should be installed.

REFERENCES

1. Hogan, James A., "Highway Lighting Maintenance," Public Roads, Vol. 36, No. 11, pp. 229-239, December 1971.

2. "Your Street Light Image and the Mercury Myth," Outdoor Lighting, Vol. 8, No. 6, pp. 4-6, November-December 1968.

3. Specifications for the Design and Construction of Structural Supports for Highway Luminaires, AASHO, 1971.

4. Van Dusen, H. A. Jr. and Wandler, Donald, Illuminating Engineering, November 1965.

APPENDIX

TABLE 1

SUMMARIZATION OF G-LEVEL READINGS FROM INITIAL FIELD TESTING

Location	Luminaire Type and Number of Readings	Approximate Resonant Frequency	Min. Reading		Max. Reading		Avg. Readin	
			Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert
I-110 Over Florida Boulevard	Aluminum 19	15Hz	.25G	.15G	1.10G	1.35G	.47G	.45
Essen Lane Overpass at I-12	Steel 18	7Hz	.03G	.10G	.20G	.38G	.07G	.22G
I-10 College Drive Overpass	Steel 22	25Hz	.17G	.09G	.68G	.58G	.48G	.35G
E. Approach to I-10 Miss. River Bridge	Aluminum 18	17Hz	.03G	.11G	.18G	.43G	.08G	.28G
E. Approach to I-10 Miss. River Bridge	Steel 22	18Hz	.10G	.19G	.50G	2.8G	.26G	.87G

TABLE 2

LABORATORY PERFORMANCE OF INERTIAL DAMPERS

Luminaire Type	Damper Type	Mode	Freq. (Hz)	Decay Time (Sec.)
ALUMINUM	None	1st	11.5	2.75
		2nd	12.5	2.20
		3rd	24.0	2.25
	Hapco	1st	11.0	2.10
		2nd	23.0	1.15
		3rd	----	----
	15# Alcoa	1st	10.5	2.05
		2nd	23.0	1.15
		3rd	----	----
	31# Alcoa	1st	14.0	0.40
		2nd	23.5	1.00
		3rd	----	----
	35# Alcoa	1st	15.5	0.40
		2nd	23.5	0.70
		3rd	----	----
STEEL	None	1st	14.5	3.30
		2nd	22.5	2.55
		3rd	25.5	2.75
	Hapco	1st	14.0	2.55
		2nd	21.5	1.75
		3rd	25.5	1.80
	15# Alcoa	1st	14.5	1.50
		2nd	22.0	1.50
		3rd	26.0	1.65
	31# Alcoa	1st	18.5	0.90
		2nd	22.5	0.95
		3rd	26.0	1.25
	35# Alcoa	1st	18.0	0.85
		2nd	22.0	0.70
		3rd	26.0	1.15

TABLE 3

SUMMARIZATION OF G-LEVEL READINGS FROM FINAL FIELD TESTING OF INERTIAL DAMPERS

Damper Type	Minimum Reading		Maximum Reading		Average Reading		Average Reduction	
	Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
I-110 Over Florida Boulevard Aluminum Luminaire								
Undamped	0.18G	0.18G	0.90G	1.25G	0.46G	0.55G	---	---
Hapco	0.15G	0.28G	0.73G	1.10G	0.43G	0.60G	7 Percent	---
15# Alcoa	0.13G	0.10G	0.68G	0.85G	0.33G	0.50G	27 Percent	9 Percent
35# Alcoa	0.08G	0.10G	1.35G	1.35G	0.24G	0.33G	48 Percent	39 Percent
Essen Lane Overpass at I-12 Steel Luminaire								
Undamped	0.05G	0.08G	0.38G	0.55G	0.14G	0.21G	---	---
Hapco	0.05G	0.08G	0.36G	0.30G	0.12G	0.19G	14 Percent	10 Percent
15# Alcoa	0.05G	0.08G	0.35G	0.28G	0.11G	0.16G	25 Percent	22 Percent
35# Alcoa	0.08G	0.08G	0.20G	0.35G	0.13G	0.14G	11 Percent	32 Percent
I-10 College Drive Overpass Steel Luminaire								
Undamped	0.18G	0.18G	0.70G	0.95G	0.46G	0.48G	---	---
Hapco	0.20G	0.15G	0.78G	1.08G	0.44G	0.44G	3 Percent	8 Percent
15# Alcoa	0.13G	0.15G	0.80G	0.55G	0.36G	0.30G	21 Percent	60 Percent
35# Alcoa	0.05G	0.05G	0.63G	0.58G	0.35G	0.28G	24 Percent	42 Percent
East Approach to I-10 Mississippi River Bridge Aluminum Luminaire								
Undamped	0.10G	0.20G	0.75G	1.15G	0.30G	0.74G	---	---
Hapco	0.10G	0.23G	0.55G	1.00G	0.25G	0.51G	17 Percent	31 Percent
15# Alcoa	0.05G	0.10G	0.70G	0.80G	0.20G	0.43G	33 Percent	42 Percent
35# Alcoa	0.05G	0.13G	0.30G	0.58G	0.17G	0.33G	43 Percent	55 Percent

TABLE 3 (CONTINUED)

SUMMARIZATION OF G-LEVEL READINGS FROM FINAL FIELD TESTING OF INERTIAL DAMPERS

Damper Type	Minimum Reading		Maximum Reading		Average Reading		Average Reduction	
	Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
East Approach to I-10 Mississippi River Bridge Steel Luminaire								
Undamped	0.07G	0.30G	0.68G	1.80G	0.38G	1.16G	---	---
Hapco	0.23G	0.70G	0.60G	2.15G	0.40G	1.26G	---	---
15# Alcoa	0.10G	0.38G	0.83G	1.50G	0.38G	0.92G	---	21 Percent
35# Alcoa	0.08G	0.25G	0.50G	1.35G	0.27G	0.91G	29 Percent	22 Percent

TABLE 4

FIELD PERFORMANCE OF FABCO MATERIAL

Damper Type	Minimum Reading (Amplitude Index) Number	Maximum Reading (Amplitude Index) Number	Average Reading (Amplitude Index) Number	Average Reduction (Amplitude Index) Number
		East Approach to I-10 Mississippi River Bridge Aluminum Luminaire		
Undamped	13	33	20	----
15/64 inch Fabco	16	30	21	----
		East Approach to I-10 Mississippi River Bridge Steel Luminaire		
Undamped	21	37	31	----
15/64 inch Fabco	10	39	31	----
1/2 inch Fabco	24	36	30	3 Percent