Final Report
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Warning Lights on Missouri Department of Transportation Vehicles

MISSOURI DEPARTMENT OF TRANSPORTATION
RESEARCH, DEVELOPMENT AND TECHNOLOGY

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16. Abstract

Warning lights for the MoDOT fleet has been the same system for the past 40 years. New technology in warning lights has offered different light systems for use on today's operations. Two problems MoDOT faces today that involve warning lights is the consistency of lights being used in the districts and being sufficiently bright to protect the traveling public and MoDOT employees. This report recommends a system of warning lights to increase visibility by using strobe lighting on MoDOT equipment and establishes an implementation schedule to increase the safety of MoDOT employees.

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EXECUTIVE SUMMARY

At the request of an employee idea statement from General Services, the "Warning Lights on MoDOT Vehicles" research investigation was initiated. The purpose of this investigation was to provide recommendations for warning lights on all department vehicles that will provide safety for MoDOT, traveling public and continuity between districts.

According to the MoDOT strategic plan, safety is a top priority. The September 1997 issue of "Inside MoDOT" newsletter, written by the Chief Engineer, included the following comments, "Since 1946, 113 employees have been killed in the line of duty. Five of these people died this year. I'm greatly concerned about your safety. It's our top priority."

The need for improved warning lights by utilizing strobe lights has been recognized by the operators of school buses, numerous utility companies, mobile home movers, garbage disposal companies and all commercial airlines. While the elimination of all accidents cannot be expected, reduction is certainly the goal of all MoDOT.

The following information reflects work zone statistics for 1998 and was gathered from MoDOT, Missouri State Highway Patrol or the National Safety Council:

Fatalities	13				
Injuries	305				
Total	318	x	$35,666*	=	$11,341,788
Property Damage Only	881	x	$6, 400**	=	$5,638,400
Grand Total =	1,199***				$16,980,188

Information Source:
*Missouri Highway Patrol
**National Safety Council
***MoDOT

The field data we had to work with was limited, however the two districts that placed some type of strobe lighting on their dump trucks received favorable results. District one's number of accidents dropped from 8 in 1996 to 2 in 1997 when they converted all of their dump trucks to strobe lighting. District 4 converted 13% of their dump trucks and experienced a drop from 16 accidents in 1996 to 7 accidents in 1997. It should be noted the number of accidents for district 4 averaged 8 for 1992 and 1993. Also, the number of accidents is dependent on the severity of the winter, but district 1 thought their winters were comparable for 1996 and 1997. By combining districts 1 and 4, accidents dropped approximately 60% after strobes were installed.

RDT looked for other statistical data that would show reason for accidents so we could determine if better lighting might have prevented accidents. By looking at the accident data recorded, it was extremely difficult to determine if better lighting would have prevented accidents.

The proposed lighting system will cost approximately 3.7 million dollars over the three year period. If this system reduces accidents in work zones only 20%, 3.4 million dollars would be saved, each year, which is almost equal to the total cost of the system. Any reduction in work zone accidents above 20% would represent an overall savings, each year, above the total cost of the project.

Systems recommended in this report are the consensus recommendations of the 36 member Warning Light Task Force group held on November 3-4, 1998. This task force was comprised of all districts and business units that reviewed systems displayed on a parking lot at a distance up to 600 feet. The Director of Operations took their recommendations and visited districts 4, 5 and 6 for additional input. The Director of Operations finalized the Warning Light Policy after this review with selected districts and submitted it to the districts as policy on April 2, 1999. Since then, the Director has retired, but his replacement reviewed and redistributed the same policy on March 10, 2000.

The specifications detail the power requirements and other features of the systems adopted in the policy, and were written by the team named by the task force, which included personnel from districts 1 and 6, and General Services, RDT and Traffic business units.

The basic standard warning lights on MoDOT vehicles have not been upgraded for approximately 40 years. Considering the cost of possible liability and the number of personal injury claims, it is recommended that MoDOT Senior Management dedicate up-front money to retrofit MoDOT vehicles with lighting systems that have proven effective in reducing accidents. The cost of one fatal accident and the cost to retrofit the entire dump truck fleet in the state with an adequate system are about the same.

Safety and uniformity can be achieved statewide and the entire MoDOT fleet (as identified in this report) can be equipped with quality systems over a 3 year period for approximately $3,700,000 plus miscellaneous support equipment and MoDOT labor for installation. The most cost-effective method of purchasing would be for monthly deliveries over the three-year period of initial implementation.

A statement from the 'Statewide Work Zone Safety Campaign' launched on TV and radio June 28, 1999 included the following: "Safety is our department's most important goal," said MoDOT Director Henry Hungerbeeler. "Missouri experienced nearly 1200 work-zone accidents in 1998 with 13 fatalities." "Anything we can do to improve safety, for motorists or ourselves, is extremely important."

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INTRODUCTION

The Missouri Department of Transportation (MoDOT) has always prided itself on providing the best quality of service to the residents and visitors to The State of Missouri. One of the most essential components that help produce this quality of service is the high degree of emphasis placed on safety to both Missouri's motorists and MoDOT employees.

MoDOT has equipped its construction and maintenance vehicles with the same basic type of warning lights for more than 40 years. When MoDOT first adopted revolving lights, they represented the best available technology at the time. Today, over 40 years later, technology has grown to provide us with vastly improved warning light systems that are brighter, more reliable, and therefore safer than their predecessors.

The two most demanding conditions for warning lights are plowing snow in a strong cross wind when a large snow cloud is being created, and bright sunny days. While the snowstorm conditions are more dramatic, they are less in number than the bright sunny days. Light systems that are the most effective on bright sunny days are the same systems that are most effective in snowstorm conditions. This changes the focus from dealing with a few days a year to dealing with most work days of the year, as most days have at least some sunshine during the day.

Major findings from a mid 1980's Minnesota investigation support the conclusion on the two most demanding conditions for warning lights:

- Eighty (80) percent of all snow removal related accidents occurred between 6:00 A.M. and 6:00 P.M. (day light hours.)
- Seventy-four (74) percent of all snow removal accidents involved vehicles rear-ending the snowplow truck.
- Fifty-four (54) percent of the snow removal accidents listed the "snow cloud" created by the snowplowing operation as a contributing factor.
- Warning lights were appreciably less effective during daylight hours.
- Amber lights were the overall best color choice.

It has not been generally perceived those days having the poorest visibility and the brightest days share the need for the highest intensity lights, or that the same light would fulfill both needs. In many cases it was felt we could not get lights that would be effective in bright sunlight.

Another concern in MoDOT has been the recommended lights could be too bright and blind approaching motorists. However, the highway patrol emergency lights have always been brighter than MoDOT warning lights and isn't an apprehension for them. Brightness capable of blinding oncoming motorists is a concern but warning lights are not as bright as vehicle headlights, which oncoming motorists meet almost constantly at night and, to a lesser extent, during daylight hours. The blinding effect of an “out of focus” headlight was so minimal that checking the aim of the headlights was removed from state inspection requirements.

Every year, MoDOT related accidents are becoming more frequent due to increasing motorist population, increasing speed limits, road rage, and more work zones. For MoDOT, increased accidents leads to more

liability, more money spent paying for accidents, and most importantly, more personal injury and sometimes death to motorists and our employees.

Finally, MoDOT has lost the uniformity between districts by using different types of lighting on the same pieces of equipment performing the same operation in the field. Districts, knowing the technology has changed, are searching for a better system than they have used in the past.

We need to do what is in our power to minimize the occurrence of these accidents because of the severe consequences that are a result. Improving our lighting systems on our construction and maintenance vehicles is a relatively inexpensive solution to the problem, as it would result in increased visibility of our vehicles and operations. This well-needed improvement would lead to earlier motorist perception of our operations, increased motorist alertness, a smaller factor of surprise, and safer conditions for motorists, pedestrians, and our employees.

Though a statewide warning light system upgrade would require a considerable amount of initiative and funds, benefits would greatly outweigh the costs of lost lives, liability, and associated costs.

OBJECTIVES

The objective of this investigation is to provide warning light systems for MoDOT vehicles that will protect Missouri motorists, MoDOT employees and provide district continuity.

The scope of this investigation is to recommend, assist in the bidding and evaluation, and assist in the implementation of these warning light systems.

PRESENT CONDITIONS

Work zone activities are becoming increasingly more dangerous as speed limits, traffic volumes and the number of work zones increase. Therefore, safety of the traveling public and our personnel is of great concern.

Safety is our top priority according to the MoDOT strategic plan. An article on the front of the September 1997 issue of 'Inside MoDOT' newsletter, written by a former Chief Engineer included the following comment, "Safety is our top priority."

A statement from the Statewide Work Zone Safety campaign launched on TV and radio on June 28, 1999 included the following statements:

> "Safety is our department's most important goal," said MoDOT Director Henry Hungerbeeler. "Missouri experienced nearly 1200 work-zone accidents in 1998 with 13 fatalities." "Anything we can do to improve safety for motorists or ourselves is extremely important."

Comments from highway patrol officers around the state usually include the statement "MoDOT warning lights just are not bright enough." Patrol officers in district one were very impressed with the way traffic responded to the strobe lights on snowplow trucks during the 1997 - 1998 snow season. This driver response must be responsible for the decrease in the number of accidents in both district 1 and district 4 following the installation of strobe lights.

Two problems that need to be solved concerning warning lights are:

1. Lights must be intensive enough to be seen on bright-sunny days and in snow clouds
2. Bring uniformity between districts by using the same lights on the same types of equipment. This should allow for upgrading vehicles which may encounter hazardous conditions.

Trucks with mounted attenuators, snowplow trucks, traffic's aerial units and sweepers seem to be some of the most at risk vehicles in the MoDOT fleet. Vehicles that perform these duties need the most effective lighting available. Most of the heavy and extra heavy-duty trucks and motor graders fall in this category. Stationary work zone areas, where pickup trucks and miscellaneous other vehicles are parked and or working, are also high-risk areas where fatalities occur. In reality, any time a MoDOT vehicle is stopped or slow moving on or near the roadway or shoulder, they need to be highly visible and putting a higher priority on one over another is very difficult.

At the present time some business units have funds and are purchasing light systems for new vehicles going into service. Some of these new systems meet the requirements of the new policy and many do not. Common practices being made are to buy a new system with inadequate power and physical size to achieve the long range visibility that would be available for a small extra cost. In these cases the long range visibility is very little, if any better, than the present halogen rotating lights now in service. Therefore, the money spent was for no benefit. In traveling around the country it is common to see strobe systems that lack the power to provide sufficient long range visibility to justify the expense of changing from the present systems.

In another situation, the work unit had purchased rotating halogen lights that have very good visibility but the personnel were not aware of the power generating capacity of the vehicle and were not aware the system they had installed required 64 amps to operate. Our recommended strobe system, which would have the same 360 degree coverage, would require 18 amps.

MoDOT should expect accidents to be reduced if more effective light systems are used. As for uniformity between districts, it has been lost because districts are going different directions while searching for light systems to meet their needs. This trend undoubtedly will continue until this policy is implemented.

TECHNICAL APPROACH

Our approach was to gather what data was available from Districts 1 and 4, perform literature searches, and gather information from other states. We looked at what is available today and we also looked at other light systems besides strobes. The approach to this study was:

1. May 23, 1997 - Assigned to this investigation.
2. Began literature search, and received copies of warning light investigations from Minnesota, South Dakota and New York.
3. Performed field checks on July 21, 1997, at Rockport and St. Joe South sheds and talked to maintenance personnel. Went to the district 1 office to talk to office personnel that drive snowplows occasionally, to get an idea of what they perceive as problems in snow removal.
4. On September 22, 1997, Larry Meisel of Risk Management, Steve Norman and Dennis Smith from district maintenance and Ivan Corp and Nelson Cook from RDT went to St. Paul, Minnesota to look at the fiber optic system on the MnDOT trucks. While fiber optics is promising and very versatile systems, we believe they need more development before MoDOT invests in them. While there, we got a look at the 'Whelen DOT 101A' System.
5. On April 7 and 8, 1998, a group representing 8 districts and General Headquarters met at the conference room at the Material's Lab to get consensus of what was needed to make our work areas more safe.
6. The first 3 weeks of May 1998 the R.D.T. conducted Falling Weight Deflectometer tests on I-70 from Blue Springs to Wentzville. Five different sets of strobe light systems that had been given to MoDOT for testing and evaluation were evaluated. 'Code 3' and 'Whelen' provided these systems for the vehicles in our moving traffic control setup.
7. On November 3, 1998 a task force of 36 employees representing all ten districts, and all business units in the support center met in the Laboratory conference room. The Director of Operations charged us to adopt recommendations that were acceptable to all segments of MoDOT. The preliminary recommendations that had been developed from the April task force meeting were reviewed and revised.
8. Research, Development and Technology reviewed MoDOT accident data to help determine what accidents enhanced lighting may have prevented. Actual cost data is not available and sorting by pavement or driving conditions was not possible at that time. Efforts to determine what accidents enhanced lighting may prevent, on a statewide scale, were not productive and the data was of little value.

Data from districts 1 and 4 did have the needed driving condition information and included data from before and after the use of strobe lights. This data provided the best information available.

RESULTS AND DISCUSSION (EVALUATION)

After the 'Warning Lights on MoDOT Vehicles' investigation was assigned on May 23, 1997, an extensive literature search was initiated to find what other states were doing and what new technology was available. Reports on other states activities were received and reviewed. It seems each state has unique thoughts on what the problems are and just how to deal with these problems.

On July 21, 1997, a trip was made to the Rockport, and St. Joseph South maintenance sheds. After discussing the situations maintenance personnel felt were important, District 1 office personnel that drive snowplows were interviewed to get an idea of what they perceive as problems in snow removal.

On September 22, 1997, Larry Meisel of Risk Management, Steve Norman and Dennis Smith from district Maintenance and Ivan Corp and Nelson Cook from Research, Development and Technology (RDT) went to St. Paul, Minnesota to look at fiber optic systems on the MnDOT trucks. While fiber optics is promising and very versatile systems, we believe they need more development before MoDOT invests in them. While there, we got a look at the 'Whelen DOT 101A' strobe systems that were the standard on the MnDOT truck fleet. Following the Minnesota trip, preliminary recommendations were prepared for appraisal. These recommendations included strobe and halogen systems.

On April 7 & 8, 1998, personnel from eight districts, several General Headquarters' Business Units including the Chief Council Office, and the Missouri Highway Patrol, responded to an invitation to attend a review team conference. This team formed the following consensus:

- Strobe lights are more likely to gain the attention of the traveling public than other types of lights.
- MoDOT must upgrade the vehicle warning lights.
- Selecting warning lights to meet the needs of the location is more important than ensuring that every vehicle is equally equipped in all ten districts.
- When minimum standards are set, that minimum standard may need to be enhanced, or added to, in high traffic and metro areas.
- Districts should be allocated money to be used for upgrading warning lights to meet minimum standards. They also should be provided additional funds for lighting in high traffic and urban areas.
- Individual views of Business Units or District management on specific lights should not delay upgrading warning lights on MoDOT vehicles.
- Decisions on uniform standard systems should be provided by MoDOT Senior Management.
- The 1.9 million dollar cost for a fatality accident, reported in the High Accident Location manual, would pay for equipping the entire MoDOT dump truck fleet.

Advantages of strobe systems over other light systems include:

- No moving parts
- Longer bulb life (no metallic filament, expect 2000 hours or average of 2 to 3 years)
- Less sensitive to vibration and corrosion
- Less electrical current required (approx. 1/2 or less) per bulb
- The above listed advantages should decrease the lighting-related down time after vehicles are equipped with strobe lights.

Retrofitting the following vehicles with strobe systems was recommended:

- The entire dump truck fleet
- Signal and lighting vehicles
- Sweepers
- Asphalt distributor trucks
- Signing vehicles
- Falling Weight Deflectometer
- Stripping vehicles
- Mower tractors
- Motor graders and highloaders

The group felt it is difficult to determine how priorities should be set and which vehicles should not have the best lights available.

During the first 3 weeks of May 1998, RDT conducted Falling Weight Deflectometer tests on I-70 from Blue Springs to Wentzville. Five different sets of strobe light systems given to MoDOT for testing and evaluation were evaluated. 'Code 3' and 'Whelen' provided these systems for the vehicles in our moving traffic control setup. A statewide invitation was issued to observe and provide input into the evaluation of these systems. Three districts responded to this with very useful input:

1. There are significant differences between systems.
2. When first detected, all colors appear white.
3. White lights wash out in bright sunlight quicker than amber.

These findings concur with a Minnesota report, which stated 'Amber is the color of choice' and a Texas report concluded there is a definite "Color Hierarchy". The order of urgency to respond by color is red, blue and amber. This suggests that if the average motorist is going to respond quickly, an amber light will have to be more intense than the ordinary warning light. Intensity has the same hierarchy as color. The brighter a light is the more importance it implies.

Data on accident reductions was reviewed after strobe installations in two of our districts. Combined data from districts 1 and 4 show reduced accident rates by approximately 60% from 1996 to 1997. District 4 only has 13% of their dump trucks equipped with strobe systems. District 1 converted 100% of their dump trucks, motor graders and loaders to strobes. While neither system is equal to the Minnesota system, results have been dramatic. A 1997 quote from one safety officer stated "Are strobes making a difference? It may be too early to tell but crashes are becoming more of an exception rather than a given".

The following shows crash information before and after installation of strobe warning light systems:

District 4 13% of dump trucks used a strobe system

	2 year period before strobe	1 year period before strobe	1 year period after strobe	1 year period	1 year period
Year	1992-1993	1996	1997	1998	1999
Number of Accidents	16	16	7	9	18

Installation of strobe systems began in 1996. In 1997, a four light strobe system had been installed on approximately 22 TMA trucks. The data for 1998 and 1999 includes motorist assist trucks and unavoidable accidents. Data from 1998 and 1999 in district 4 is mixed but reported information indicates only 3 vehicles involved had enhanced lighting. The three with enhanced lighting were motorist assist vehicles.

District 1 100% of dump trucks, motor graders and loaders, used strobe system

	1 snow season before strobe	1 snow season after strobe
Year	1996-97	1997-98
Number of accidents	8	2

All dump trucks, motor graders, and loaders in district 1 were retrofitted with rear-mounted strobe lights prior to the 1997-1998 snow season. This trend has continued into the year 2000 in district 1. The district 1 Safety Committee stated, ”District 1 is much safer following the installation of strobes!”

Data gathered from the National Safety Council, Missouri State Highway Patrol and MoDOT shows accidents in work zones costs approximately 17 million dollars in 1998. Our data from districts 1 and 4 is limited but it did show a 60% drop in accidents after strobes were installed. If strobes decrease accidents by only 10%, that would save 1.7 million dollars per year just in work zones which is approximately 50% of the total cost for the lighting systems that cost $3.7 million.

Finally, a task force meeting was held November 3 & 4, 1998 with 36 people (Appendix P) representing all districts and business units. The task force viewed a demonstration of several different halogen and strobe lighting systems and adopted the “all strobe” policy. A consensus was reached and a final version was recommended to the Director of Operations. These recommendations were based on dependability, visibility, electrical requirements and motorist response.

The Director took the task force recommendation and visited districts 4, 5 and 6 for additional input. The Director of Operations issued a final warning light policy to all districts and business units on April 2, 1999. The original director has retired, but his replacement reviewed and redistributed the same policy on March 10, 2000. This Director also retired and the present Director began redistributing the same policy on May 8, 2000. The systems in this report are from that policy.

Implementing these recommendations will result in increased visibility of MoDOT vehicles and operations. This much needed improvement would lead to earlier motorist perception of MoDOT operations, increased motorist alertness, a smaller factor of surprise and safer conditions for motorists and MoDOT employees.

Approximate comparison of light systems:

(1) Single revolving light (2 per vehicle, light now in use)		4.4 Amps 2 lights	= 8.8 Amps
(2) Code 3 6105E (2 per vehicle)	(2 light mini bar)	12 Amps 2 mini bars	= 24 Amps
(3) Whelen DOT 3 101A *	(6 light strobe system)	13.5 Amps	= 13.5 Amps
(4) Whelen DOT 3 101A *	(8 light strobe system)	18 Amps	= 18 Amps

	New Cost	Replacement Parts Cost	Life Cycle Cost (15 year)	Cost/Year
(1)	$60	$255**	$315.	$21.
(2)	$180.	$750***	$930.	$62.
(3)	$845.	$975#	$1820	$121
(4)	$945.	$1,215##	$2160	$144

* No moving parts, 5 year warranty on controller, expected bulb life of 2000 hours, lightheads and wiring harness expected to last the life of the vehicle (15 years or more.)

** 3 year expected life (will vary depending on work conditions, need two lights per vehicle)
2 replacement bulbs @ $1.50 each = $3.00 per three year period per vehicle
New Units = 4 x $ 60 = $240: New Bulbs = 5 x $ 3 = $15 Replacement Parts Total = $255

*** 3 year expected life (will vary depending on work conditions, need two mini bars per vehicle)
2 replacement bulbs @ $1.50 each = $3.00 per mini bar, = $6.00 per three year period per vehicle.
New Units = 4 x $ 180 = $720: New Bulbs = 5 x $ 6 = $30 Replacement Parts Total = $750

\# 2 controllers (ISP188) and 3 or 4 service repairs (no more than $37.00 per repair,) and four sets of six replacement flashtube (bulbs) assembly's ($16.00 per assembly) equal a total of $975. (See Note 1 below.)

2 controllers (ISP188) and 3 or 4 service repairs (no more than $37.00 per repair,) and four sets of eight replacement flashtube (bulbs) assembly's ($16.00 per assembly) equal a total of $1,215. (See Note 1 below.)

These strobe system costs are based on worst case scenarios and are much higher than expected. The light-heads and wiring harness are expected to last 15 years. The expected number of replacements to achieve the 15 year life is: 1 controller, 2 or 3 service repairs, and 2 additional sets of flashtube/reflector replacements. Some lens material may need to be replaced.

Note 1: These cost estimates are from Whelen on August 28th 1998 and in conjunction with their quotation of July 8th 1998 for 'new units' comprise the 15 year cost estimate. These replacement costs are 1998 dollars and should be adjusted to the "Producers Price Index" annually.

APPLICATIONS / SYSTEMS FOR POLICY OF 10/04/00

Application	**Policy Systems**
New Dump Truck	4 lighthead 6 light remote strobe system (Appendix A)
In Service Dump Truck	4 lighthead 6 light remote strobe system (Appendix B)
Motor Graders	4 lighthead 6 light remote strobe system (Appendix C) with 24 Volt system
Specialty Vehicles	4 lighthead 8 light remote strobe system (Appendix D)
Pickup Trucks	2 lighthead 4 light remote strobe system (Appendix E (Specification A*, modified)) A* Modified = Without rear flush mount lightheads and with 4 outlet 90 watt output controller.
Vans	
Carryalls - SUV'S	
Loaders	4 lighthead 6 light remote strobe system (Appendix F - 12 Volt) or (Appendix C - 24 Volt) system.
Tractors	**For tractors and backhoes without cabs** 360 degree self-contained strobe beacon (Appendix G). **For tractors and backhoes with cabs** = 2 lighthead 4 light remote strobe system (Appendix A* modified) A* = Without rear flush mount lightheads and with 4 outlet 90 watt output controller.
Backhoes	
Pool - Cars, Pickups and Minivans	2 light minibar (Appendix H)
Attenuator Trucks	3 light minibar (Appendix I)
Motorist Assist Pickups	8 light strobe lightbar (Appendix K) **and** 12 light arrow (Appendix L)
Dump Trucks	TPR Cable harnesses (Appendix M) No splicing will be allowed
Distributor Trucks	
Motor Graders	
Loaders	
All other uses with remote power systems.	

Near the close of the task force meeting, teams were set up to write specifications for and evaluate the systems for acceptance. The designated specification team included district 1 General Services (later reassigned to district one Maintenance), district 6 Traffic, Headquarters General Services, and Research, Development and Technology. Headquarters Traffic was asked and accepted an invitation to assist in writing the specifications. Most of the other team members were named at a later date and all are listed in Appendix Q.

Research, Development, and Technology developed the detailed evaluation and acceptance criteria after the basic format and point breakdown was established by Senior Management on February 28, 2000.

This breakdown is as follows:

Characteristic to be evaluated	Type of evaluation	Acceptance points
Visibility	Head to head comparison in the field by evaluation team (See appendix Q)	50%
Life Cycle Cost	Commitment of replacement parts cost 15% Original price 10% Cost to refurbish power controllers 5% (by statistical team)	30%
Compliance with specifications	General compliance with specifications (by specification team)	10%
Workmanship and Quality	General workmanship and quality (subjective evaluation by the workmanship and quality team)	10%
	Total	100%

CONCLUSIONS

From the limited information available it appears an approximate 60% reduction in accidents occurred after the installation of strobe systems in districts 1 and 4. A similar record would be expected after all vehicles are equipped with one of the systems in this report, as the other districts include both urban and rural areas also.

Conclusions of this study include:

- Technology has changed over 40 years.
- We do not have district continuity.
- Fiber optics need more development.
- Snow clouds are dangerous.
- Bright sunshine days are dangerous.
- Warning lights helped reduce accidents involving MoDOT vehicles in District 1 & 4.
- The cost of a fatality (average of 1.9 million dollars per fatality) may pay for the light system of all MoDOT dump trucks.
- A 20% reduction of accidents in work zones, in one year, would save approximately the same amount of money the total lighting system would cost.

Items for present and future consideration include:

- Districts may not have the money to implement the recommended upgrades.
- The need to upgrade warning light systems may justify the use of off the top, up-front money.
- Decisions on standard systems and up front money should be provided by MoDOT Senior Management so state wide uniformity can be maintained.
- Accidents are a real expense factor and while they cannot all be eliminated, money spent avoiding accidents is better spent than money spent paying for accidents.

Vehicles that are kept less than 3 years after installation should expect very minimal maintenance costs while vehicles kept 15 years or more could have up to $1,215 additional maintenance costs. Below are the life cycle costs for specialty vehicles, dump trucks, and 'hazardous condition' motor graders. Light systems for most other vehicles would cost significantly less than these systems. Prices quoted for the 6 and 8 light systems are 50% off of their regular price due to producing 70 units per month for 3 years.

Life cycle cost for Specialty Vehicles with the 8 light strobe system.

New Cost	Replacement Parts Cost	Life Cycle Cost (15 year)	Cost Per Year
$945	$1,215*	$2,160	$144

This converts to approximately $0.55 cents per workday per vehicle for 15 years.

Life cycle cost for Dump Trucks and some Motor Graders with the 6 light strobe system

New Cost	Replacement Parts Cost	Life Cycle Cost (15 year)	Cost Per Year
$845	$975*	$1,820	$121

This converts to approximately $0.47 cents per workday per vehicle for 15 years.

*** These costs are based on worst case scenarios and are much more than expected. Costs are in 1998 dollars , which must be adjusted to the "Producers Price Index" annually.**

TASK FORCE RECOMMENDATIONS

New Dump Trucks (6 light remote)

Specifications in Appendix A

It is recommended that all new heavy and extra heavy dump trucks equipped at General Headquarters shall be equipped with a four lighthead six-light strobe system, with flush mount tailgate area rear strobes, as described in Appendix A.

The cost to equip one new truck and to maintain for 15 years would be:

New Cost	Replacement Parts Cost	Life Cycle Cost (15 year)	Cost Per Year
$845	$975	$1,820	$121

This converts to about $0.46 per workday. The cost of the light system is approximately $1,820 to protect a $50,000 vehicle for 15 years. Replacement Parts Cost = 2 new controllers, 3 or 4 service repairs and 4 sets of 6 replacement flashtube/reflector assembly's equal a total of $975. These replacement costs are 1998 dollars and should be adjusted to the "Producers Price Index" annually.

Note: These costs are based on worst case scenarios and are much more than expected. The expected number of replacements to achieve the 15 year life is 1 controller, 2 or 3 service repairs, and 2 additional sets of flashtube/reflector replacements.

In Service Dump Trucks (6 light remote)

Specifications in Appendix B

In service heavy and extra heavy-duty dump trucks shall be equipped with four-lighthead six-light strobe system, with flush mount tailgate area rear strobes. All dump trucks in service should be retrofitted with strobe lights equal to the system as described in Appendix B. Trucks already equipped or retrofitted with rear strobes should have lightheads compatible with the existing controller added, replacing the rotating beacons now in service.

The cost associated with installing and maintaining a 6 light strobe system for one truck would be:

New Cost	Replacement Parts Cost	Life Cycle Cost (15 year)	Cost Per Year
$845	$975	$1,820	$121

Replacement Parts Cost = 2 new controllers, 3 or 4 service repairs and 4 sets of 6 replacement flashtube/reflector assembly's equal a total of $975. These replacement costs are 1998 dollars and should be adjusted to the "Producers Price Index" annually.

Note: These costs are based on worst case scenarios and are much more than expected. The expected number of replacement to achieve the 15 year life is: 1 controller, 2 or 3 service repairs, and 2 additional sets of flashtube/reflector replacements.

Motor Graders, Backhoes and Loaders (3 light remote)

Specifications in Appendix F

Motor graders, backhoes, and loaders shall be equipped with lights mounted so visibility will be 360 degrees around the piece of equipment. Light will have to be mounted on top to get 360 degree coverage. The cost of the 3 light systems in Appendix F is estimated at $600. The cost to equip one new vehicle and to maintain for 15 years would be:

New Cost	Replacement Parts Cost	Life Cycle Cost (15 year)	Cost Per Year
$600	$700	$1,300	$90

Replacement Parts Cost = 2 new controllers, 3 repairs and 4 sets of 3 replacement flashtube/reflector assembly's equal a total of $700.

Note: These costs are based on worst case scenarios and are much more than expected. The expected number of replacements to achieve the 15 year life is: 1 controller, 2 or 3 service repairs, and 2 additional sets of flashtube/reflector replacements.

Specifications in Appendix C (Loaders)

The principle investigator believes the system of choice for loaders is a four lighthead remote system C with 2 flashtubes per lighthead like the Hazardous Duty Motor Grader system described in Appendix C. This requires a 24 Volt system.

Specifications in Appendix A (Backhoes)

The principle investigator believes the system of choice for backhoes is a two lighthead remote system A with 2 flashtubes per lighthead (like the new heavy and extra heavy dump trucks system described in Appendix A, except the rear flush mount lightheads would not be needed) would be used with a 90 watt output 4 outlet controller.

The cost to equip one loader or backhoe and to maintain it for 15 years would be:

New Cost	Replacement Parts Cost	Life Cycle Cost (15 year)	Cost Per Year
$600	$600	$1,300	$90

Replacement Parts Cost = 2 new controllers, 3 repairs and 4 sets of 4 replacement flashtube/reflector assembly's equal a total of $700.

Note: These costs are based on worst case scenarios and are much more than expected. The expected number of replacements to achieve the 15 year life is: 1 controller, 2 or 3 service repairs, and 2 additional sets of flashtube/reflector replacements.

Motor Graders - Hazardous Conditions (6 light remote)

Specifications in Appendix C

Motor graders working in hazardous conditions may be allowed to upgrade to the 6 light systems. All motor grades should be retrofitted with the four lighthead six light remote strobe system described in Appendix C.

The cost associated with installing the 6 light strobe system for one grader would be:

New Cost	Replacement Parts Cost	Life Cycle Cost (15 year)	Cost Per Year
$845	$975	$1,820	$121

Replacement Parts Cost = 2 new controllers, 3 or 4 service repairs and 4 sets of replacement flashtube/reflector assembly's equal a total of $975. These replacement costs are 1998 dollars and should be adjusted to the "Producers Price Index" annually.

Note: These costs are based on worst case scenarios and are much more than expected. The expected number of replacement to achieve the 15 year life is: 1 controller, 2 or 3 service repairs, and 2 additional sets of flashtube/reflector replacements.

Specialty Vehicles (8 light remote)

Specifications in Appendix D

It is recommended that all specialty units, such as signal, lighting, striping, and other vehicles with special needs, shall be equipped with have a four lighthead eight light remote strobe system, as described in Appendix D.

The cost to equip one new vehicle with an 8 light strobe system and to maintain for 15 years would be:

New Cost	Replacement Parts Cost	Life Cycle Cost (15 year)	Cost Per Year
$945	$1,215	$2,160	$144

This converts to about $0.55 per workday. Replacement Parts Costs = 2 new controllers, 3 or 4 service repairs and 4 sets of 8 replacement flashtube/reflector assembly's equal a total of $1,215. These replacement costs are 1998 dollars and should be adjusted to the "Producers Price Index" annually.

Note: These costs are based on worst case scenarios and are much more than expected. The expected number of replacement to achieve the 15 year life is: 1 controller, 2 or 3 service repairs, and 2 additional sets of flashtube/reflector replacements.

Pickup Trucks, Vans and Carryalls (4 light minibar)

Pickups, vans and carryalls shall have one 360° self-contained strobe beacon as described in Appendix G. However if traffic conditions warrant, the system can be upgraded to one or two 4-strobe linear flashtube light bars as described in Appendix E. Also a two lighthead remote system with 2 or 3 flashtubes per lighthead (like the dump truck system described in Appendix A) may be used with a 90 watt output 4 outlet controller. The 2 flashtube lightheads should be used with a 90 watt output 4 outlet controllers.

Specifications in Appendix G

The cost of a beacon system described in Appendix G is estimated at $175. The actual expected life cycle cost should be no more than $350.

New Cost	Replacement Parts Cost	Life Cycle Cost (10 year)	Cost Per Year
$175	$175	$350	$35

It should be noted the principle investigator believes 2 beacons should be used because some of the terrain, ditches or in slopes can tilt vehicles to where a single beacon would not be seen.

Specifications in Appendix E

The cost of the two mini bars system described in Appendix E, per vehicle, with a five-year minimum expected life per mini bar would be:

New Cost	Replacement Parts Cost	Life Cycle Cost (10 year)	Cost Per Year
$800	$800	$1,600	$160

The actual expected life cycle cost should be no more than $1,200. Off road vehicles should have breakover mounts and /or steel mesh protective guards**.**

Specifications in Appendix A

A two lighthead remote system with 2 flashtubes per lighthead (like the dump truck system described in Appendix A) may be used with a 90 watt output 4 outlet controller. The cost to equip one new vehicle and to maintain for 10 years would be:

New Cost	Replacement Parts Cost	Life Cycle Cost (10 year)	Cost Per Year
$600	$425	$1,025	$100

Replacement Parts Cost = 1 new controller and 1 set of 4 replacement flashtube/reflector assembly's equal a total of $425.

Backhoes, Tractors and Loaders (360 deg. self contained)

Specifications in Appendix G

Backhoes, tractors, and loaders, shall be equipped with lights mounted so visibility will be 360° around the piece of equipment, and shall have the option of one or two 360° strobe beacons or four linear flush mount type strobes, (one facing each direction). If installed on rental tractor and kept 3 years, replacement cost should be minimal.

The cost of 2 lights in Appendix G is estimated at $350. Lights will need to be shielded on the cab side to avoid flashes coming in on the operator from both sides

New Cost	Replacement Parts Cost	Life Cycle Cost (10 year)	Cost Per Year
$350	$350	$700	$70

Specifications in Appendix J

The cost of a 4 light remote system in Appendix J is estimated at $400 each and would not have a 90 watt controller or 5 year warranty. No actual price has been obtained. The cost of master/slave 2 light system, (2 required), is estimated at $150 each or $300 per vehicle. No actual price has been obtained.

New Cost	Replacement Parts Cost	Life Cycle Cost (10 year)	Cost Per Year
$350	$700	$1,050	$105

Replacement Parts Cost = 2 new systems equal a total of $700.

Specifications in Appendix F

Motor graders, backhoes, and loaders shall be equipped with lights mounted so visibility will be 360 degrees around the piece of equipment. Light will have to be mounted on top to get 360 degree coverage. The cost of the 3 light systems in Appendix F is estimated at $600. The cost to equip one new vehicle and to maintain for 15 years would be:

New Cost	Replacement Parts Cost	Life Cycle Cost (15 year)	Cost Per Year
$600	$700	$1,300	$90

Replacement Parts Cost = 2 new controllers, 3 repairs and 4 sets of 3 replacement flashtube/reflector assembly's equal a total of $700.

Note: These costs are based on worst case scenarios and are much more than expected. The expected number of replacements to achieve the 15 year life is: 1 controller, 2 or 3 service repairs, and 2 additional sets of flashtube/reflector replacements.

Cars and Pickup Trucks (2 light minibar)

Cars, minivans, and pickups normally used as pool vehicles or passenger vehicles may use portable, 2-linear flashtube strobe units as conditions warrant. Cars assigned to employees shall have one or two, portable or fixed 2- linear flashtube strobe units in back window and as an option one or two additional units in front, as described in Appendix H.

The two light minibar systems in Appendix H are estimated at $150 each. The systems are warranted for 2 years.

Attenuator Trucks (3 light minibar)

It is recommended all attenuator trucks shall be equipped with a three light minibar, as described in Appendix I. The lightbar shall be a strobe type. Amber shall be the only color emitted from this unit. All electronics, including the power supply, shall be contained inside the lightbar.

Systems are estimated at $200 each.
(No actual price has been obtained).

Mower Tractors (master/slave or 4 light remote)

It is recommended that mower tractors shall be equipped with a master/slave, or a 4 light remote strobe warning system that will provide 360-degree coverage, as described in Appendix J.

Specifications in Appendix J

Cost of 4 light remote systems is estimated at $400 each (this would not be with a 90-watt controller). No actual price has been obtained.

The cost of master/slave 2 light system is estimated at $150 each. (2 required) (No actual price has been obtained).

Motorist Assist Pickups (8 light lightbar)

It is recommended that motorist assist pickups shall be equipped with an eight strobe light strobe lightbar, as described in Appendix K.

Specifications in Appendix K

Motorist Assist vehicles shall have a strobe 8 light lightbar system with turn signals and forward and rear work lights.

Systems are estimated at $1,200 each.

Motorist Assist Pickups (12 light arrow)

It is recommended that motorist assist pickups shall be equipped with a twelve light arrow, as described in Appendix L.

Specifications in Appendix L

Motorist Assist vehicles shall have a multi functional arrow 4 feet long with 12 lights, either strobe or halogen.

Systems are estimated at $800 each.

IMPLEMENTATION PLAN

If approved by upper management, a 3 year implementation of 2,578 vehicles will require approximately 70 units per month. In addition to these systems, 3,512 other systems will need to be installed on other vehicles. Warning lights could be placed on the vehicles at General Headquarters and the 10 districts. Installation and continuity responsible would belong to General Services. A decision will need to be made by General Services on how the lights will be mounted on rental tractors. Due to the magnitude of the task of installing light systems on more than 6,000 pieces of equipment, it seems logical to implement this project over the 3-year period. The cost should be approximately $100,000 per district per year for three years. Each Business Unit and District will need to submit quantities of each system needed for their Business Unit / District. The department may want to place warning lights on the higher risk equipment first.

SPECIFICATIONS FOR 10/04/00 POLICY

04-04-01

Appendix A – SPECIFICATION A,B, AND F - FOR A FOUR LIGHTHEAD 6 LIGHT 12 VOLT REMOTE STROBE SYSTEM FOR MoDOT DUMP TRUCKS, AND LOADERS

GENERAL REQUIREMENTS:

All connectors, grommets, and strain relief apparatus as needed for a completed installation shall be included.

No splicing will be allowed in the wiring harness.

1.0 STROBE POWER SUPPLY:

1.1 The strobe power supply used in this system shall have a maximum input of 230 watts. The desired power output rating is approximately 180 watts. The strobe power supply shall operate on 12 volts DC and operate through the range of approximately 10-16V DC with nominal degradation of performance in either intensity or flash rate. All standard mounting hardware shall be included. A telephone type jack for a 'lamp on' indicator panel is desired.

1.2 The strobe power supply shall have RFI suppression circuit(s) to prevent radiated, as well as conducted, interference problems.

1.3 The power supply(s) should be designed with two independent power circuits that prevent total system shutdown should one power circuit fail.

1.4 The strobe power supply(s) shall have eight (8) output outlets, each using 3-pin AMP Mate-N-Lock or equivalent connectors. It shall also have two (2) other 4-pin connectors, one for input power and the other for outlet switching capability. Systems that incorporate a "lamp on" indicator panel shall provide a jack.

1.5 The strobe power supply shall produce a burst of four impulses per burst to each flashtube, at a minimum flash rate of 70 bursts per minute.

1.6 The strobe power supply shall be designed with, built-in, output switching capabilities. A minimum of three selective switching circuits, two that control two outlet pairs and one that controls a set of four outlets. These circuits shall be controlled by remote on/off switches, via external connection. Four pairs of two would be satisfactory if the above criteria could be met.

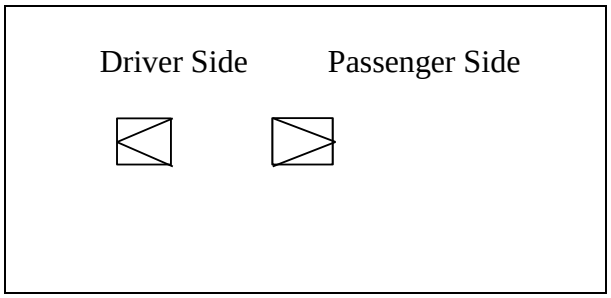
1.7 The strobe power supply shall have two external spade-type fuses mounted near the input power connector for easy field replacement.

1.8 Strobe power supply(s) shall have a manual High/ Low switch which allows the operator to reduce the intensity for nighttime operation.

1.9 The strobe power supply shall be completely input reverse polarity and short-to-ground protected via diode and fuse circuitry combination. Full output short protection, which will shut down the operating power supply circuitry and not damage the power supply or strobe lamps in any manner, is required.

2.0 <u>CAB COVER (TOP) LIGHTHEAD ASSEMBLIES</u>:

2.1 To be mounted on the cab cover of the dump bed shall be two lightheads, one on each side of the vehicle. Each lighthead assembly must contain a minimum of two strobe modules, the xenon flash tube should be permanently affixed to the reflector. One strobe module shall face diagonally to the front, and the other shall face diagonally to the rear. These shall be placed in a outward < position and each pair will provide 270 degrees coverage. When one lighthead is placed on the driver side and one on the passenger side of the vehicle in a diamond (<>) configuration the combination of the two will provide 360 degrees coverage for the vehicle. Additional flashtube per lighthead is not a disqualification but is not desired.



2.2 With the use of a 8 outlet power supply with selective output switching capabilities, the lighthead assembly shall allow for front flashtubes operation, rear flashtubes operation, or both front and rear flashtubes operation. The two front flashtubes may flash simultaneously, and the two rear flashtubes may flash simultaneously or they may flash alternately. These circuits shall be controlled by manual on/off switches.

2.3 The dimensions of each lighthead should be as small as practical to allow for minimum of approximately 6-inch linear flashtube modules and for the lens of each flashtube to have a minimum of approximately 21 square inches.

2.4 All lenses shall be amber in color and have a smooth outer surface.

2.5 The lighthead assemblies shall be provided with permanent mounting capabilities.

3.0 REAR LIGHTHEAD ASSEMBLIES:

3.1 To be mounted into the rear of the dump beds shall be two strobe flushmount lightheads. Each lighthead shall be capable of emitting a full 180° of light in the vertical plane while being recessed into the rear of the dump bed or other similar location.

3.2 The two rear lightheads shall utilize the same power supply unit(s) as the top lighthead assemblies.

3.3 The lighthead modules shall be easily replaceable. A waterproof connector for each module shall be used to connect to the cable harness.

3.4 The lighthead lenses shall be made of polycarbonate, amber in color, and have a smooth outer surface.

3.5 The rear mounted lighthead assemblies shall be suitable for mounting in the steel boxes attached to the sides, or inside the rear structure of the dump bed. All grommet's, strain relief items, and connectors will be included in the bid. The lens size shall be a minimum of approximately 21 sq. inches(7"x3").

4.0 SWITCH CONTROL CENTER:

4.1 A 5-position switch bracket assembly shall provide for permanent mounting.

4.2 Provided shall be one High/Low toggle switch, and three heavy-duty rocker style, aircraft-type on/off switches. The 5th position shall be open for the 'light on' indicator panel if provided with the system. All switches shall be prewired with 6-inch pigtail wires.

5.0 WIRING:

5.1 The heavy-duty TPR foil jacketed cable shall maintain its electrical, mechanical, and environmental integrity for the life of the vehicle on which it is originally installed. In addition, it shall be of a quality that will comply with the following parameters: (Note: No substitutions will be accepted for TPR wire and no splicing will be allowed.)

5.2 Be flexible in cold weather, to minus forty degrees Fahrenheit (-40°) and tolerant of hot temperatures to 194° Fahrenheit.

5.3 Outside TPR insulation jacket shall be highly resistant to abrasion, corrosion, oil/grease, and normal highway chemicals or environmental abuse for the normal life expectancy of the vehicle. The minimum TPR thickness shall be approximately:

3 Conductor = .070 inch.
6 Conductor = .080 inch.

5.4 Each cable shall be foil jacket shielded and have a minimum sixteen (16) gauge, 16 full tin coated stranded uninsulated pure copper wire.

5.5 Each power conductor shall be a minimum fourteen (14) gauge with 41 pure copper fully tin coated strands with a minimum .032" TPR insulation.

5.6 The cable will be supplied without fillers.

6.0 WARRANTY:

6.1 The strobe power supply shall be identified by serial number and warranted to MoDOT directly, to be free of defects of material and/or workmanship for a period of five (5) years from the date of delivery. The flashtube modules in the cab cover lighthead assemblies shall be warranted for a period of twenty-four (24) months. The rear module assemblies shall be warranted for a period of twelve (12) months. Written proof of this warranty must be provided with bid.

Appendix C – SPECIFICATIONS FOR A FOUR LIGHTHEAD 6 LIGHT 24 VOLT REMOTE STROBE SYSTEM FOR MoDOT MOTORGRADERS, AND SOME LOADERS

GENERAL REQUIREMENTS:

All connectors, grommets, and strain relief apparatus as needed for a completed installation shall be included.

No splicing will be allowed in the wiring harness.

1.0 STROBE POWER SUPPLY:

1.1 The strobe power supply used in this system should have a output rating, of a minimum of 180 watts. The strobe power supply shall operate on 24 volts DC and operate through the range of 20-28 VDC with nominal degradation of performance in either intensity or flash rate. All standard mounting hardware shall be included. A telephone type jack for a 'lamp on' indicator panel is desired.

1.2 The strobe power supply shall have RFI suppression circuit(s) to prevent radiated, as well as conducted, interference problems.

1.3 The power supply(s) should be designed with two independent power circuits that prevent total system shutdown should one power circuit fail.

1.4 The strobe power supply(s) shall have eight (8) output outlets, each using 3-pin AMP Mate-N-Lock or equivalent connectors. It shall also have two (2) other 4-pin connectors, one for input power and the other for outlet switching capability. Systems that incorporate a "lamp on" indicator panel shall provide a jack.

1.5 The strobe power supply shall produce a burst of four impulses per burst to each flashtube, at a minimum flash rate of 70 bursts per minute.

1.6 The strobe power supply shall be designed with, built-in, output switching capabilities. A minimum of three selective switching circuits, two that control two outlet pairs and one that controls a set of four outlets. These circuits shall be controlled by remote on/off switches, via external connection. Four pairs of two would be satisfactory if the above criteria could be met.

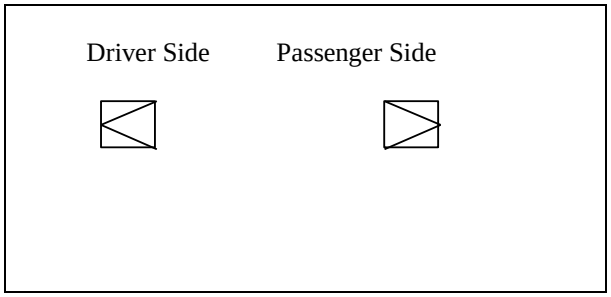
1.7 The strobe power supply shall have two external spade-type fuses mounted near the input power connector for easy field replacement.

1.8 Strobe power supply(s) shall have a manual High/ Low switch which allows the operator to reduce the intensity for night time operation.

1.9 The strobe power supply shall be completely input reverse polarity and short-to-ground protected via diode and fuse circuitry combination. Full output short protection, which will shut down the operating power supply circuitry and not damage the power supply or strobe lamps in any manner, is required.

2.0 TOP LIGHTHEAD ASSEMBLIES:

2.1 To be mounted on the cab of the motorgrader shall be two (2) lightheads, one on each side of the vehicle. Each lighthead assembly must contain a minimum of two strobe modules, the xenon flash tube should be permanently affixed to the reflector. One strobe module shall face diagonally to the front, and the other shall face diagonally to the rear. These shall be placed in a outward < position and each pair will provide 270 degrees coverage. When one lighthead is placed on the driver side and one on the passenger side of the vehicle in a diamond (<>) configuration the combination of the two will provide 360 degrees coverage for the vehicle. Additional flashtube per lighthead is not a disqualification but is not desired.



2.2 With the use of a 8 outlet power supply with selective output switching capabilities, the lighthead assembly shall allow for front flashtubes operation, rear flashtubes operation, or both front and rear flashtubes operation. The two front flashtubes may flash simultaneously, and the two rear flashtubes may flash simultaneously or they may flash alternately. These circuits shall be controlled by manual on/off switches.

2.3 The dimensions of each lighthead should be as small as practical to allow for minimum of approximately 6-inch linear flashtube modules and for the lens of each flashtube to have a minimum of approximately 21 square inches.

2.4 All lenses shall be amber in color and have a smooth outer surface.

2.5 The lighthead assemblies shall be provided with permanent mounting capabilities.

3.0 REAR LIGHTHEAD ASSEMBLIES:

3.1 The two rear lightheads shall utilize the same power supply unit(s) as the top lighthead assemblies.

3.2 The lighthead modules shall be easily replaceable. A waterproof connector for each module shall be used to connect to the cable harness.

3.3 The lighthead lenses shall be made of polycarbonate, amber in color, and have a smooth outer surface.

3.4 The rear mounted lighthead assemblies shall be suitable for mounting in steel boxes attached to the rear of the motorgrader. All grommet's, strain relief items, and connectors will be included in the bid. The lens size shall be a minimum of approximately 21 sq. inches (7"x3").

4.0 SWITCH CONTROL CENTER:

4.1 A 5-position switch bracket assembly shall provide for permanent mounting.

4.2 Provided shall be one High/Low toggle switch, and three heavy-duty rocker style, aircraft-type on/off switches. The 5th position shall be open for the 'light on' indicator panel if provided with the system. All switches shall be prewired with 6-inch pigtail wires.

5.0 WIRING:

5.1 The heavy-duty TPR foil jacketed cable shall maintain its electrical, mechanical, and environmental integrity for the life of the vehicle on which it is originally installed. In addition, it shall be of a quality that will comply with the following parameters: (Note: No substitutions will be accepted for TPR wire and no splicing will be allowed.)

5.2 Be flexible in cold weather, to minus forty degrees Fahrenheit (-40□) and tolerant of hot temperatures to 194□ Fahrenheit.

5.3 Outside TPR insulation jacket shall be highly resistant to abrasion, corrosion, oil/grease, and normal highway chemicals or environmental abuse for the normal life expectancy of the vehicle. The minimum TPR thickness shall be approximately:
3 Conductor = .070 inch.
6 Conductor = .080 inch.

5.4 Each cable shall be foil jacket shielded and have a minimum sixteen (16) gauge, 16 full tin coated stranded uninsulated pure copper wire.

5.5 Each power conductor shall be a minimum fourteen (14) gauge with 41 pure copper fully tin coated strands with a minimum .032" TPR insulation.

5.6 The cable will be supplied without fillers.

6.0 WARRANTY:

6.1 The strobe power supply shall be identified by serial number and warranted to MoDOT directly, to be free of defects of material and/or workmanship for a period of five (5) years from the date of delivery. The flashtube modules in the cab cover lighthead assemblies shall be warranted for a period of twenty-four (24) months. The rear module assemblies shall be warranted for a period of twelve (12) months. Written proof of this warranty must be provided with bid.

Appendix D – SPECIFICATIONS – D - FOR A FOUR LIGHTHEAD 8 LIGHT REMOTE STROBE SYSTEM FOR MoDOT SPECIALTY VEHICLES

GENERAL REQUIREMENTS:

All bids shall include connectors, grommets, and strain relief apparatus as needed for a completed installation.

1.0 STROBE POWER SUPPLY:

1.1 The strobe power supply used in this system shall have a maximum input of 230 watts. The desired power output rating, is approximately 180 watts. The strobe power supply shall operate on 12 volts DC and operate through the range of approximately 10-16V DC with nominal degradation of performance in either intensity or flash rate. All standard mounting hardware shall be included. A telephone type jack for a 'lamp on' indicator panel is desired.

1.2 The strobe power supply shall have RFI suppression circuit(s) to prevent radiated, as well as conducted, interference problems.

1.3 The power supply(s) should be designed with two independent power circuits that prevent total system shutdown should one power circuit fail.

1.4 The strobe power supply(s) shall have eight (8) output outlets, each using 3-pin AMP Mate-N-Lock or equivalent connectors. It shall also have two (2) other 4-pin connectors, one for input power and the other for outlet switching capability. Systems that incorporate a "lamp on" indicator panel shall provide a jack.

1.5 The strobe power supply shall produce a burst of four impulses per burst to each remote strobe head, at a minimum flash rate of 70 bursts per minute (per outlet).

1.6 The strobe power supply shall be designed with, built-in, output switching capabilities. A minimum of three selective switching circuits, two that control two outlet pairs and one that controls a set of four outlets. These circuits shall be controlled by remote on/off switches, via external connection. Four pairs of two would be satisfactory if the above criteria could be met.

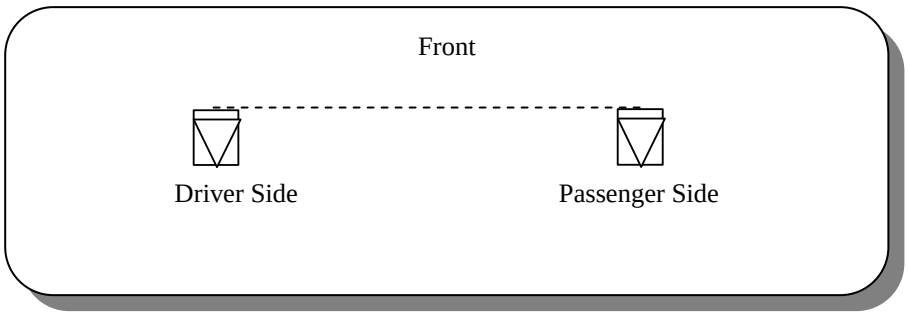
1.7 The strobe power supply shall have two external spade-type fuses mounted near the input power connector for easy field replacement.

1.8 Strobe power supplies shall have a manual High/ Low toggle switch which allows the operator to reduce the intensity for night time operation.

1.9 The strobe power supply shall be completely input reverse polarity and short-to-ground protected via diode and fuse circuitry combination. Full output short protection, which will shut down the operating power supply circuitry and not damage the power supply or strobe lamps in any manner, is required.

2.0 TOP LIGHTHEAD ASSEMBLIES:

2.1 To be mounted as high and wide on the vehicle as practical shall be two (2) lightheads, one on each side of the vehicle. Each lighthead assembly must contain three (3) linear flashtube modules, and each lighthead must produce a full 360-degree coverage. These modules should be a minimum of 6 inches in length, the xenon flash tube should be permanently affixed to the reflector. The three modules shall form a triangle as shown below.



2.2 With the use of a 8 outlet power supply, the lighthead assembly shall allow for different combinations of flashtube operation. This will outline the vehicle for quick identification even in adverse lighting conditions such as in intersections, and on vehicles such as boom or platform trucks.

2.3 The dimensions of each lighthead should be as small as practical to allow for minimum of approximately 6-inch linear flashtube modules and for each flashtube to have a minimum of approximately 21 square inches of lens covering.

2.4 All lenses shall be amber in color and have a smooth outer surface.

2.5 The lighthead assemblies shall be provided with permanent mounting capabilities.

3.0 REAR LIGHTHEAD ASSEMBLIES:

3.1 To be mounted into or on the rear of the vehicle shall be two strobe flushmount lightheads. Each lighthead shall be capable of emitting a full 180° of light in the vertical plane. These may be mounted into pockets provided in the vehicles or other locations provided, and must accommodate a minimum lens size of approximately 21 sq. inches.

Note: Include the price of a 8 gage steel box with appropriate opening for installing the described lighthead.

3.2 The two rear lightheads shall utilize the same power supply and switching unit as the top lighthead assemblies.

3.3 The flashtube modules shall be easily replaceable. A waterproof connector for each module shall be used to connect to the cable harness.

3.4 All grommet's, connectors, and strain relief items will be included in the bid.

3.5 The lighthead lenses shall be made of polycarbonate, amber in color, and have a smooth outer surface.

4.0 SWITCH CONTROL CENTER:

4.1 A 5-position switch bracket assembly shall provide for permanent mounting.

4.2 Provided shall be one High/Low toggle switch, and three heavy-duty rocker style, aircraft-type on/off switches. The 5th position shall be open for the 'light on' indicator panel if provided with the system. All switches shall be prewired with 6-inch pigtail wires.

5.0 CABLE HARNESSES:

5.1 The heavy-duty TPR foil jacketed cable shall maintain its electrical, mechanical, and environmental integrity for the life of the vehicle on which it is originally installed. In addition, it shall be of a quality that will comply with the following parameters: (Note: No substitutions will be accepted for TPR wire and no splicing will be allowed.)

5.2 Be flexible in cold weather, to minus forty degrees Fahrenheit (-40°) and tolerant of hot temperatures to 194° Fahrenheit.

5.3 Outside TPR insulation jacket shall be highly resistant to abrasion, corrosion, oil/grease, and normal highway chemicals or environmental abuse for the normal life expectancy of the vehicle. The minimum TPR thickness shall be approximately:
3 Conductor = .070 inch.
6 Conductor = .080 inch.
9 Conductor = .090 inch.

5.4 Each cable shall be foil jacket shielded and have a minimum sixteen (16) gauge, 16 fully tin coated stranded noninsulated pure copper wire.

5.5 Each power conductor shall be a minimum fourteen (14) gauge with 41 pure copper fully tin coated strands with a minimum .032" TPR insulation.

5.6 The cable will be supplied, without fillers, in multiples of 3 power conductors per cable (3, 6, and 9 conductor).

5.7 No splicing will be allowed

6.0 WARRANTY:

6.1 The strobe power supply shall be warranted to MoDOT directly, to be free of defects of material and/or workmanship for a period of five (5) years from the date of delivery. The flashtube modules in the cab cover lighthead assemblies shall be warranted for a period of twenty-four (24) months. The rear module assemblies shall be warranted for a period of twelve (12) months. Written proof of this warranty must be provided with bid.

Appendix E – SPECIFICATION (A *MODIFIED) SPECIFICATIONS FOR A 2 LIGHTHEAD 4 LIGHT REMOTE STROBE SYSTEM FOR MoDOT PICKUP TRUCKS, VANS, CARRYALLS / SUV'S, AND TRACTORS / BACKHOES WITH CABS

GENERAL REQUIREMENTS:

Shall include connectors, grommets, and strain relief apparatus as needed for a completed installation.

No splicing will be allowed in the wiring harness.

1.0 STROBE POWER SUPPLY:

1.1 The strobe power supply used in this system shall have a maximum input of 115 watts. The desired power output rating is approximately 90 watts. The strobe power supply shall operate on 12 volts DC and operate through the range of approximately 10-16V DC with nominal degradation of performance in either intensity or flash rate. All standard mounting hardware shall be included. A telephone type jack for a 'lamp on' indicator panel is desired.

1.2 The strobe power supply shall have RFI suppression circuit(s) to prevent radiated, as well as conducted, interference problems.

1.3 The strobe power supply(s) shall have four (4) output outlets, each using 3-pin AMP Mate-N-Lock or equivalent connectors. It shall also have two (2) other 4-pin connectors, one for input power and the other for outlet switching capability. Systems that incorporate a "lamp on" indicator panel shall provide a jack.

1.5 The strobe power supply shall produce a burst of four impulses per burst to each flashtube, at a minimum flash rate of 70 bursts per minute.

1.6 The strobe power supply shall be designed with, built-in, output switching capabilities. A minimum of two selective switching circuits, two that control two outlet pairs. These circuits shall be controlled by remote on/off switches, via external connection.

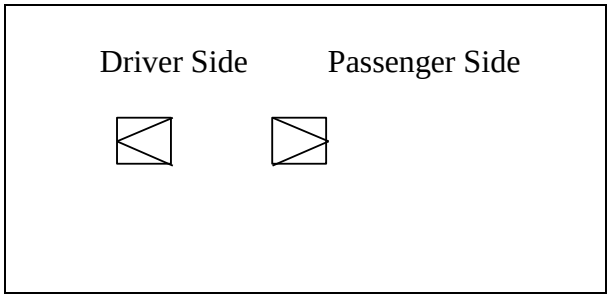
1.7 The strobe power supply shall have two external spade-type fuses mounted near the input power connector for easy field replacement.

1.8 Strobe power supply(s) shall have a manual High/ Low switch which allows the operator to reduce the intensity for nighttime operation.

1.9 The strobe power supply shall be completely input reverse polarity and short-to-ground protected via diode and fuse circuitry combination. Full output short protection, which will shut down the operating power supply circuitry and not damage the power supply or strobe lamps in any manner, is required.

2.0 LIGHTHEAD ASSEMBLIES:

2.1 To be mounted on the cab / body shall be two lightheads, one on each side of the vehicle. Each lighthead assembly must contain a minimum of two strobe modules, the xenon flash tube should be permanently affixed to the reflector. One strobe module shall face diagonally to the front, and the other shall face diagonally to the rear. These shall be placed in a outward < position and each pair will provide 270 degrees coverage. When one lighthead is placed on the driver side and one on the passenger side of the vehicle in a diamond (<>) configuration the combination of the two will provide 360 degrees coverage for the vehicle. Additional flashtube per lighthead is not a disqualification but is not desired.



2.2 With the use of a 4 outlet power supply with selective output switching capabilities, the lighthead assembly shall allow for front flashtubes operation, rear flashtubes operation, or both front and rear flashtubes operation. The two front flashtubes may flash simultaneously, and the two rear flashtubes may flash simultaneously or they may flash alternately. These circuits shall be controlled by manual on/off switches.

2.3 The dimensions of each lighthead should be as small as practical to allow for minimum of approximately 6-inch linear flashtube modules and for the lens of each flashtube to have a minimum of approximately 21 square inches.

2.4 All lenses shall be amber in color and have a smooth outer surface.

2.5 The lighthead assemblies shall be provided with permanent mounting capabilities.

3.0 SWITCH CONTROL CENTER:

3.1 A 4-position switch bracket assembly shall provide for permanent mounting.

3.2 Provided shall be one High/Low toggle switch, and two heavy-duty rocker style, aircraft-type on/off switches. The 4th position shall be open for the 'light on' indicator panel if provided with the system. All switches shall be prewired with 6-inch pigtail wires.

4.0 WIRING:

4.1 The heavy-duty TPR foil jacketed cable shall maintain its electrical, mechanical, and environmental integrity for the life of the vehicle on which it is originally installed. In addition, it shall be of a quality that will comply with the following parameters: (Note: No substitutions will be accepted for TPR wire and no splicing will be allowed.)

4.2 Be flexible in cold weather, to minus forty degrees Fahrenheit (-40°) and tolerant of hot temperatures to 194° Fahrenheit.

4.3 Outside TPR insulation jacket shall be highly resistant to abrasion, corrosion, oil/grease, and normal highway chemicals or environmental abuse for the normal life expectancy of the vehicle. The minimum TPR thickness shall be approximately:

6 Conductor = .080 inch.

4.4 Each cable shall be foil jacket shielded and have a minimum sixteen (16) gauge, 16 full tin coated stranded uninsulated pure copper wire.

4.5 Each power conductor shall be a minimum fourteen (14) gauge with 41 pure copper fully tin coated strands with a minimum .032" TPR insulation.

4.6 The cable will be supplied without fillers.

4.7 No splices will be accepted.

5.0 WARRANTY:

5.1 The strobe power supply shall be identified by serial number and warranted to MoDOT directly, to be free of defects of material and/or workmanship for a period of five (5) years from the date of delivery. The flashtube modules in the lighthead assemblies shall be warranted for a period of twenty-four (24) months.

Appendix F – SPECIFICATION FOR A FOUR LIGHTHEAD 6 LIGHT REMOTE STROBE SYSTEM FOR 12 VOLT LOADERS (SEE APPENDIX A,B, AND F)

Appendix G – SPECIFICATIONS FOR A 360 DEGREE SELF-CONTAINED STROBE BEACON FOR USE ON TRACTORS, AND BACKHOES WITHOUT CABS

The following specifications detail a 360 degree self-contained strobe beacon and shall come complete with all standard mounting brackets and accessories.

1.0 The lighthead shall be designed with solid-state circuitry, and will incorporate features to insure a structural and power supply warranty life of 5 years.

1.1 The base, shall contain the power supply, and have both pipe and permanent/flat mounting provisions.

1.2 The heavy-duty strobe power supply shall have capability of dual voltage, 12 or 24 volts DC operation, and operate through the range of 10 to 28 volts DC with no degradation of performance in either intensity.

1.3 The strobe power supply must produce a burst of four impulses per burst at a minimum flash rate of 70 bursts per minute. A output rating of 30 watts or greater is required.

1.4 The strobe power supply shall have a remote manual High / Off / Low switch which allows the operator to reduce the intensity for night time operation. The switch must remain in the High / Off / Low position so the operator can see which mode is selected. A automatic photocell dimming system is acceptable.

1.5 The strobe light shall have RFI suppression circuits built-in/hard wired within the electronic assembly to prevent radiated, as well as conducted, interference problems.

1.6 The system shall be completely reverse polarity and short-to-ground protected via diode and fuse circuitry combination.

1.7 The amber lens shall have a smooth outer surface for self-cleaning purposes. A top and bottom polished reflector to reflect the light, down and out, and up and out is desired.

2.0 <u>WARRANTY</u>

2.1 The strobe beacon shall be warranted by the manufacturer to the end user directly to be free from defects of material or workmanship for a period of five (5) years from the date of delivery. The strobe tube shall be warranted for a period of two (2) years. The strobe power supply shall be warranted for a period of five (5) years. Written proof of this warranty by the manufacturer must be furnished by the bidder and attached to this bid.

Appendix H – SPECIFICATIONS FOR A TWO LIGHT MINIBAR FOR MoDOT POOL - CARS, PICKUPS, AND MINIVANS

GENERAL REQUIREMENTS:

The lightbar shall be a strobe type. All electronics, including the power supply, shall be contained inside the lightbar.

1.0 BASIC STRUCTURAL DESIGN OF LIGHTBAR:

1.1 Size and weight shall be suitable for mounting on the dash, rear window, or rear deck, and suitable for mounting on the sun visor is desired.

1.2 Must have linear flashtubes.

1.3 Must provide wide angle visibility

1.4 Must come with power cord long enough to reach from the power point to the rear window of any full size car. Must come with cigar lighter (power point) adaptor or remote on off switch. Exact number of each will be supplied with the bid request.

2.0 POWER SUPPLY FOR THE STROBES:

2.1 The strobe lightbar should have a minimum of 20 watt output power supply and shall operate on 12 volts DC.

2.2 The power supply shall produce a minimum of 60 double flashes, and should produce 70 quad flashes per flashtube per minute with the left and right sides of bar alternately flashing.

3.0 INTERNAL COMPONENT SYSTEMS:

3.1 Flashtubes and reflectors should be modular in design for ease of replacement.

4.0 WARRANTY:

4.1 The lightbar and all modules shall be warranted by the manufacturer to the user to be free of defects of material or workmanship for a period of two (2) years from date of delivery. Flashtube modules shall be warranted for a period of twenty-four (24) months. Written proof of this warranty by the manufacturer must be furnished by the bidder and attached to the bid.

Appendix I – SPECIFICATIONS FOR A THREE LIGHT MINIBAR FOR MoDOT ATTENUATOR TRUCKS

GENERAL REQUIREMENTS:

The lightbar shall be a strobe type. Amber shall be the only color emitted from this unit. All electronics, including the power supply, shall be contained inside the lightbar.

1.0 BASIC STRUCTURAL DESIGN OF LIGHTBAR:

1.1 The lightbar should be no greater than 24" in length and shall be suitable for permanent or temporary mounting.

1.2 Must be designed for three flashtubes.

1.3 Must provide wide angle visibility.

1.4 Must have self contained power supply.

1.5 Must have a power cord suitable for a remote on / off power control switch.

2.0 POWER SUPPLY FOR THE STROBES:

2.1 The strobe lightbar shall have a minimum of 60 watt output power supply and shall operate on 12 volts DC.

2.2 The power supply shall produce a minimum of 60 quad flashes per flashtube per minute.

3.0 INTERNAL COMPONENT SYSTEMS:

3.1 Lamp modules should be modular in design for ease of replacement.

4.0 WARRANTY:

4.1 The lightbar and all modules shall be warranted by the manufacturer to the user to be free of defects of material and or workmanship for a period of two (2) years from date of delivery. Written proof of this warranty by the manufacturer must be furnished by the bidder and attached to the bid.

Appendix J – SPECIFICATIONS FOR A MASTER/SLAVE, OR 4 LIGHT REMOTE STROBE WARNING SYSTEM THAT WILL PROVIDE 360 DEGREE COVERAGE FOR USE ON TRACTORS AND BACKHOES WITHOUT CABS

Appendix J – AND SPECIFICATIONS HAVE BEEN DELETED

Appendix K – SPECIFICATION FOR A EIGHT STROBE LIGHT LIGHTBAR FOR MOTORIST ASSIST PICKUPS

GENERAL REQUIREMENTS:

The lightbar shall be a strobe type. All electronics, including the power supply, shall be contained inside the lightbar.

1.0 BASIC STRUCTURAL DESIGN OF LIGHTBAR:

1.1 The lightbar should be a minimum of 58 inches and a maximum of 62 in length, and shall be supplied for permanent mounting.

1.2 The four (4) end flashtubes shall be placed in a diamond < > configuration which will give 360 degree visibility for each lightbar. These four flashtubes shall be switched so the two front facing can be on or off, and the two rear facing can be turned on or off.
Two additional flashtube shall be facing the front and can be turned on or off. The remaining two flashtubes, which must face the rear, can be turned on or off depending on traffic and specific needs.

1.3 The lightbar shall be equipped with brake/turn signal lights facing the rear, and two (2) clear halogen work lights facing the front and 2 facing the rear.

1.3 The main structural material should be of heavy gauge aluminum.

2.0 POWER SUPPLY FOR THE STROBES:

2.1 The strobe lightbar shall have two power supplies, each shall have a minimum of 90 watts output power, and shall operate on 12 volts DC.

2.2 The power supply shall be able to supply power to four pair of two flashtubes, at the rate of 70 quad flashes per flashtube per minute.

2.3 The power supply shall have a high/low intensity feature which allows the operator to reduce the intensity for night time operation. The high/low switching circuit shall utilize positive voltage to switch the unit into the low intensity mode and must remain in the High / Off / Low position so the operator can see which intensity is selected.

3.0 INTERNAL COMPONENT SYSTEMS:

3.1 All internal components such as flashtube modules and power supplies shall be modular in design for ease of replacement without removing the lightbar from the

vehicle.

4.0 SWITCH CONTROL CENTER:

4.1 A 6-position bracket assembly containing five on/off aircraft-type switches and one High / Off / Low switch shall be provided for permanent mounting and shall be permanently marked for identification purposes. All switches shall be heavy-duty rocker style switches and prewired to 6 inch pigtail wires.

5.0 WARRANTY:

5.1 The lightbar and all modules shall be warranted by the manufacturer to the user to be free of defects of material or workmanship for a period of two (2) years from date of delivery. Flashtube modules shall be warranted for a period of twenty-four (24) ` months. Written proof of this warranty by the manufacturer must be furnished by the bidder and attached to the bid.

Appendix L – SPECIFICATIONS FOR A TWELVE LIGHT ARROW FOR MoDOT MOTORIST ASSIST PICKUPS

GENERAL REQUIREMENTS:

The arrow may be a strobe or halogen type.

1.0 BASIC STRUCTURAL DESIGN OF ARROW:

1.1 The arrow shall be approximately 23 inches high and 4 feet in length.

1.2 The arrow shall have side mounting studs

1.3 The arrow housing shall be extruded aluminum

1.4 The light/reflector, and lens shall be rectangular in shape

2.0 POWER SUPPLY FOR THE ARROW:

2.1 The arrow shall operate on 12 volts DC.

2.2 The power supply shall produce a solid flashing arrow to the left, right, or both sides.

3.0 INTERNAL COMPONENT SYSTEMS:

3.1 Strobe units shall have minimum of 270 watts (22.5 watts per flashtube) output.

3.2 Halogen lamps shall be a minimum of 35 watts.

4.0 WARRANTY:

4.1 The arrow board and all modules shall be warranted by the manufacturer to the user to be free of defects of material or workmanship for a period of two (2) years from date of delivery. Written proof of this warranty by the manufacturer must be furnished by the bidder and attached to the bid.

Appendix M – SPECIFICATIONS FOR CABLE HARNESSES FOR USE ON DUMP TRUCKS, DISTRIBUTOR TRUCKS, MOTORGRADERS, LOADERS, AND ALL OTHER REMOTE POWER USES.

CABLE HARNESSES:

No splicing will be allowed.

The cable shall maintain its electrical, mechanical, and environmental integrity for the life of the vehicle on which it is originally installed, without the need for re-wiring at any future time.

The heavy-duty TPR-foil jacketed cable shall be of a quality that will comply with the following parameters.

A. Be flexible in cold weather, to minus forty degrees Fahrenheit (-40°) minimum and tolerant of hot temperatures to 194° Fahrenheit.

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B. Outside TPR insulation jacket shall be highly resistant to abrasion, corrosion, oil/grease, and normal highway chemicals or environmental abuse for the normal life expectancy of the vehicle. The minimum TPR thickness shall be approximately:

3 Conductor = .070 inch.
6 Conductor = .080 inch.
9 Conductor = .090 inch.

C. Each cable shall be foil jacket shielded and have a minimum sixteen (16) gauge, 16 fully tin coated stranded uninsulated pure copper wire.

D. Each power conductor shall be a minimum fourteen (14) gauge with 41 pure copper fully tin coated strands with a minimum .032" TPR insulation.

E. The cable will be supplied, without fillers, in multiples of 3 power conductors per cable (3, 6, and 9 conductor).

WARRANTY

The heavy-duty TPR-foil jacketed cable shall be warranted by the manufacturer to the end user directly to be free from defects of material or workmanship for a period of five (5) years from the date of delivery. Written proof of this warranty by the manufacturer must be furnished by the bidder and attached to this bid.

Appendix N – Work Plan

RI97006
WORK PLAN FOR DEPARTMENT WORK VEHICLE SAFETY

June 1997

Introduction:

The goal of this investigation is to provide MoDOT with recommendations for lighting on Department vehicles, which will be in contact with the traveling public. Construction work zones, right of way mowing, roadway and bridge surveys, snow removal, bridge washing and sweeping, are some duties department vehicles will be involved in. Lighting systems must meet industry requirements for maximum and minimum brightness and comply with uniform state and department codes for color. Dependability, maintenance requirements, usage flexibility, and cost are among the items for consideration before any recommendations could be made. Trucks with innovative lighting have been field tested in Iowa, Minnesota and possibly other states with highly recommended functional results. Cost-effectiveness would have to be considered and include reliability, maintenance cost, liability risk reduction, installation costs, and additional productivity.

The scope of this investigation is primarily to evaluate, report, and recommend lighting systems for MoDOT vehicles. Features that will provide safe, reliable visibility, to the traveling public, and provide the operators with affective vehicular lighting in adverse conditions will be considered.

Expected Benefits:

Benefits will be improved motorist recognition of department work vehicles, and improved visibility of the work area for vehicle operators, this should reduce costs of accidents and liability. By reducing liability, down time, and repair costs, productivity should be improved and the initial cost, of the improved lighting equipment, should be recovered over the life of the vehicles.

Background & Significance of Work:

Iowa and Minnesota have installed warning light systems utilizing photo optic cables with high intensity light sources, on a number of trucks. They are now evaluating these systems for overall functional and cost effectiveness. The preliminary operator assessment was very positive. The strong points from the operators standpoint was it was trouble free, provided light at eight different locations around the truck, which allowed the driver to monitor functions without leaving the drivers, seat. The bottom line was the truck stayed in the field nonstop for 2 days during a major snow fight, with out any lighting problems, and that was very unusual.

On the basis of these findings, Research, Development & Technology (RDT) has decided to initiate an in-depth investigation.

At this time, equipment operators need to be polled for thoughts they believe to be important in regard to equipment operation the main thrust of the investigation will be directed toward snowplows. By requesting input from part time operators, regular operators, maintenance supervisors, risk management, and management personnel we should ascertain the shortcomings of the present light systems and the needs of future systems.

Action Plan:

1. Determine the lighting needs of MoDOT work vehicles by interviewing department employees, and observing prototype vehicles from Iowa and or Minnesota.
2. Prepare specifications for a small number of trial vehicles to be placed in service in selected areas for evaluation by MoDOT personnel
3. Evaluate all aspects of function, cost, and risk reduction for a final recommendation

After completion of this analysis, the results and findings will be collected in the form of a final recommendation

Staffing:

The anticipated staffing for this project will be a Materials Research Engineer, and a Field Testing Technician.

Budget:
The anticipated costs are as follows:

Materials Research Engineer	3 weeks * $1,200/wk	= $ 3,600
Field Testing Technician	16 weeks * $750/wk	= $12,000
TOTAL		= $15,600
Including Salary Additive	$15,600 * 1.676	= $26,000
Lighting Equipment 5 units		= $12,000
Travel Expense		= $ 2,000
	Total	**= $40,000**

Funding:

This investigation will be funded by 910/SPR/1997/45/Y.

Method of Implementation:

Our final recommendation will be sent to the Procurement Division for future purchases of MoDOT equipment.

STEPS TO TAKE

DO LITERATURE SEARCH AND CHECK WITH OTHER STATES

CHECK WITH DEPARTMENT PERSONNEL ON IDEAS WITHIN OUR STATE

TO BE UNDER DIRECTION OF DON DAVIDSON AND CONSIST OF:

NELSON COOK
IVAN CORP

I CALLED WISCONSIN 6/4/97 FOR ANY INFO THEY MIGHT HAVE

June 13, 1997 at the Blue Ridge shed in KC I attended Federal Signal Demonstration of the Lighting system on the Iowa, and Minn., demonstration trucks.

June 25, 1997 talked to Randy at garage vibration and corrosion are major problems he was very positive

June 25, 1997 talked to signal shop, what happens when stepping motor goes out?

July 7, 1997 talked to Stan Grant (GRANTS) made appt. to meet with Dist. 2 Maintenance at 10:30 Wed. July 23, 1997.

July 7, 1997 called for Leland Smithson at Iowa DOT he is out of town thru July 23, I need to call him then to discuss the Iowa demo truck.

July 8, 1997 talked to Randy at garage. Maintenance personnel have freedom to try innovative ideas in directing airflow around snowplow.

July 8, 1997 talked to Matt Cowell in Risk Management. Maintenance personnel have freedom to try innovative ideas in directing airflow around snowplows. Matt will get me cost of snowplowing related accidents, also he will discuss this subject with Larry Misel. They may get back with me. I need to discuss light colors with them.

July 8, 1997 I called, Office of the Legislative Auditor, State of Minnesota, Centennial Office Building, St. Paul inn. 55155. 612 - 296 - 4708. They will send a copy of "Snow and Ice Control May 1995 A Best Practice Review". Tom Johnson suggested I do this.

Received in July 1997

July 15, talked to Hwy Patrol about colors Yellow and White are O.K. (need to verify)

July 16 1997 had meeting with Bob Lannart Larry Meisel, George Bochwinkel and Randy Fitch Larry Meisel will go to Minnesota.

July 16, 1997 called Brian Grooms 417-629-3317 Dist. 7. He will schedule meeting with districts 7,8 and 9 at Springfield sometime in Aug. or Sept.

July 16, 1997 gave work plan to Lannert, Fitch, and Meisel

Appendix O – MoDOT WARNING LIGHT POLICY

10/04/00

Purpose: To increase the visibility of MoDOT Vehicles by upgrading the Warning Lights on MoDOT equipment, to increase the safety of our employees, and establish an implementation schedule.

1. All vehicles identified in this policy shall have yellow strobe lights except signal trucks or lighting trucks, which on a regular basis are working in signalized intersections can be supplied with red lenses for working in emergency situations. These signal trucks or lighting trucks shall have a four lighthead, eight light strobe system.

2. Dump trucks shall be equipped with a four lighthead, six-light strobe system, with flush mount tailgate area rear strobes.

3. Dump trucks with mounted arrow boards in moving operations or fixed locations shall sequence the strobe flashes from top to bottom on each side of the vehicle. They shall be sequenced so the top on one side and the bottom on the opposite side flash simultaneously. The strobes shall be flashing at all times the arrow board is flashing.

4. Trucks equipped with attenuators may have a 3-light random minibar located at the rear of the truck or attenuator.

5. Motor graders/loaders shall have a four lighthead, six light remote strobe system.

6. Specialty vehicles such as but not limited to striper trucks, sweepers, step vans, bridge maintenance box trucks, field mechanics trucks, and the ARAN van shall use approved systems, with mounting specifics dictated by the physical characteristics of the vehicle.

7. Pickups-Vans-Carryalls-SUV'S shall have a two lighthead, four light remote strobe system.

8. Tractors/backhoes with enclosed cabs shall have a two lighthead, four light remote strobe system. Tractors, backhoes, and other field equipment without cabs which would include but not be limited to rollers, wheels saws and skid steer loaders, shall have 360° coverage with self contained strobe units.

9. Cars and minivans that may be used in the field shall have two, fixed 2- linear flashtube strobe units in back window and, as an option, one or two additional units in front.

10. Motorist Assist vehicles shall have a multi functional arrow 4 feet long with 12 lights, either strobe or halogen. The arrow shall be enhanced by a strobe 8 light lightbar system with turn signals and forward and rear work lights.

NOTE: . All remote power controllers shall have a minimum of 22.5 watts output per flashtube (4 outlet = 90 watts output) & (8 outlet = 180 watts output), on high intensity, and shall have a two level (marked high-low) intensity switch so low can be used when dark. All strobes except items 4 and 9 shall have a minimum of 22.5 watts output per flashtube.

All four wiring cables for the 6 and 8 light systems shall be, three wires per flashtube, encased in one cable, continuous and without splices from the controller unit to four individual lightheads. All cables shall be shielded and have an uninsulated ground wire. All wire should be tin-coated copper, and all insulation and covering should be Thermal Plastic Rubber, from the controller to the light

Appendix P – TASK FORCE FOR WARNING LIGHTS FOR MODOT FLEET

District 1:	Steve Norman - Maintenance Darrel Butcher - General Services
District 2:	Phil Scott - Maintenance Roger Davis - Maintenance
District 3:	Lloyd Davidson - Maintenance Rodney Colbert - General Services
District 4:	Chuck Craig - General Services Tom Fleming - Maintenance
District 5:	Bob Simmons - General Services
District 6:	Denis Bigley - Maintenance Jim Collier - Traffic
District 7:	Daryl Weinkein - Traffic Tim Houdyshell - Maintenance
District 8:	Dave Bybee - Fiscal Services, Safety Officer Bill Hager - General Services
District 9:	Denzil Hill - Maintenance Darren Petrus - Fiscal Services, Safety Officer
District 10:	Dave Kitchens - Maintenance Superintendent Elgy Brown - Maintenance
Construction:	Bill Moreland Vince Imhoff
Risk Management:	Duane Amos
RDT:	Nelson Cook Don Davidson Ray Purvis
Materials:	Dale Glenn
Design:	Sam Masters Don Martin

Transportation Management:	Dave Schmitz
Preliminary Studies:	Bob Hoard
Chief Counsel:	Jay Smith
Maintenance:	George Bockwinkel Jim Jackson
Traffic:	Rick Bennett
General Services:	Bob Lannert
Facilitator:	Mike Stephenson - Construction

Appendix Q – Acceptance Team Members

Specification Team:

1. Nelson Cook	RDT
2. Len Dedrick	General Services
3. Steve Norman	District 1
4. Jim Colier	District 6
5. Rick Bennett	Traffic

Warning Light Field Evaluation Team and Who Each Represented:

1. Steve Norman	District 1
2. Roger Davis	District 2
3. Butch Mundle	District 3
4. Tom Flemming	District 4
5. Bob Simmons	District 5
6. Jim Colier	District 6
7. Tim Houdyshell	District 7
8. Jim Folk	District 8
9. Darren Petrus	District 9
10. Darrel Barnes	District 10
11. Larry Meisel	General Services & Risk Management
12. Doug Struemph	RDT, Materials & O.T.M.S.
13. Tim Jackson	Maintenance & Construction
14. Rick Bennett	Traffic & Bridge Maintenance

Statistical team:

1. Bill Smith	RDT
2. Len Dedrick	General Services

General Workmanship, Quality, and Durability Team:

1. Steve Norman	District 1
2. Jim Colier	District 6
3. Jon Miller	General Services
4. Rodney Colbert	General Services
5. Tim Jackson	Maintenance
6. Doug. Struemph	O.T.M.S.

Overall Evaluation and Implementation Coordinator – Bob Lannert

Note: In cases where named individuals are no longer available to serve, the named Business Unit is responsible for filling the position. In some cases the individuals have transferred but could still serve.