JOINT TRANSPORTATION RESEARCH PROGRAM

FHWA/IN/JTRP-2009/30

Final Report

SYNTHESIS STUDY: DEVELOPMENT OF AN ELECTRONIC DETECTION AND WARNING SYSTEM TO PREVENT OVERHEIGHT VEHICLES FROM IMPACTING OVERHEAD BRIDGES

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July 2010

INDOT Research

TECHNICAL *Summary*

Technology Transfer and Project Implementation Information

TRB Subject Code: 25-1 Bridges
Publication No.: FHWA/IN/JTRP-2009/30, SPR-3237

July 2010
Final Report

Synthesis Study: Development of an Electronic Detection and Warning System to Prevent Overheight Vehicles from Impacting Overhead Bridges

Introduction

Overheight vehicle impacts with bridges are surprisingly common and are of particular concern in areas of Indiana such as the I-65 – I-70 merger location in Indianapolis. The damage from collisions can range from minor to severe, and there is evidence that some bridges are impacted multiple times, leading to the potential for cumulative damage effects. With this in mind, there is a clear need to attempt to prevent overheight vehicle collisions with bridges; and this study provides an in-depth examination of the availability and in-field performance of Overheight Vehicle Detection and Warning (OVD&W) systems that could help address this challenge.

Findings

The findings of this study indicate that most states have updated their infrastructure to account for overheight vehicles and permanently avoid collisions. The few states that still actively employ overheight vehicle detection and warning systems (OVD&W) tend to use optoelectronic single- or dual-eye infrared detection systems and report that the devices have decreased the amount of damage occurring to their structures. The initial equipment and installation costs of these systems range from a few thousand to twenty-five thousand dollars based on DOT interviews, and on-going maintenance appears minimal. Overall, considering that the only other completely effective option to avoid overheight vehicle incidents is to raise the height of affected structures, or lower the roadway surface, an (optoelectronic) OVD&W system is a relatively inexpensive and effective method for decreasing overheight vehicle accident.

Implementation

The combined insights gained through this study were used to develop a straight-forward decision tool that can be employed by INDOT personnel to identify equipment options to address site specific needs for overheight vehicle protection. This tool and its underlying principles were applied to a test case focused on the I-65 – I-70 merger location in Indianapolis, IN leading to a preliminary OVD&W system strategy for that specific location. It is recommended that the sensor characteristics and design decision logic exemplified through this case example be used for future OVD&W system deployment envisioned in the State.

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Joint Transportation Research Program
Project Number: C-36-67VVVV
File Number: 9-10-99
SPR-3237

Conducted in Cooperation with the
Indiana Department of Transportation
and the U.S. Department of Transportation
Federal Highway Administration

Purdue University
West Lafayette, IN 47906
July 2010

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/IN/JTRP-2009/30		

4. Title and Subtitle	5. Report Date
Synthesis Study: Development of an Electronic Detection and Warning System to Prevent Overheight Vehicles from Impacting Overhead Bridges	July 2010
	6. Performing Organization Code
7. Author(s) Joe Sinfield Assistant Professor of Civil Engineering, Purdue University	8. Performing Organization Report No. FHWA/IN/JTRP-2009/30
9. Performing Organization Name and Address Joint Transportation Research Program Purdue University 550 Stadium Mall Drive West Lafayette, IN 47907-2051	10. Work Unit No.
	11. Contract or Grant No. SPR-3237
12. Sponsoring Agency Name and Address Indiana Department of Transportation State Office Building 100 North Senate Avenue Indianapolis, IN 46204	13. Type of Report and Period Covered Final Report
	14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with the Indiana Department of Transportation and Federal Highway Administration.

16. Abstract

Overheight vehicle impacts with bridges are surprisingly common. The damage from collisions can range from minor to severe, and there is also evidence that some bridges are impacted multiple times, leading to the potential for cumulative damage effects. Thus there is a clear need to attempt to prevent overheight vehicle collisions with bridges.

This Synthesis Study provides a review of solutions that exist to detect and forewarn overheight vehicles and thereby prevent a collision, and specifically examines the breadth of available overheight vehicle detection technologies, the commercial availability of such equipment, and the experience of relevant DOTs with installed and functioning systems.

The findings of this study indicate that most states have updated their infrastructure to account for overheight vehicles and permanently avoid collisions. The few states that still actively employ overheight vehicle detection and warning systems (OVD&W) tend to use optoelectronic single- or dual-eye infrared detection systems and report that the devices have decreased the amount of damage occurring to their structures. The initial equipment and installation costs of these systems range from a few thousand to twenty-five thousand dollars based on DOT interviews, and on-going maintenance appears minimal. Overall, considering that the only other completely effective option to avoid overheight vehicle incidents is to raise the height of affected structures, or lower the roadway surface, an (optoelectronic) OVD&W system is a relatively inexpensive and effective method for decreasing overheight vehicle accidents.

With this in mind, this study provides a guide to the site characteristics that influence both sensor selection and overall OVD&W system design. A simple Equipment Selection Tool is presented to guide system choice, and is demonstrated through a case example centered on the I-65 – I-70 merger location in Indianapolis, IN.

17. Key Words	18. Distribution Statement
Overheight vehicle, bridge collisions, electro-optical sensors, infrared beam, detection, warning, re-routing	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	74	

Form DOT F 1700.7 (8-69)

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1.0 INTRODUCTION AND PROBLEM STATEMENT

Overheight vehicle impacts with bridges are surprisingly common. An in-depth study conducted by Fu et. al. (2004) in the state of Maryland indicated that “of the 1,496 bridges susceptible to impact by overheight vehicles statewide, 309 (20%) [had] been struck, [and] 54 (4%) required repairs.” Fu et. al. further indicate that a nationwide survey on the subject garnered response from 29 states, and 62% of these stated that overheight vehicle collisions with bridges are a significant problem. Fu et. al. also point out that few states that actually reported data also track the financial consequences of overheight vehicle impact on bridges. However, for those that did (Kentucky, Mississippi, Iowa, Louisiana), the annual average financial impact of vehicle bridge collisions amounted to $250 - $500 thousand dollars.

The damage from collisions can range from minor to severe, and there is also evidence that some bridges are impacted multiple times, leading to the potential for cumulative damage effects. Fu et. al. (2004) report that for Maryland, about half of the bridges that were known to be struck received only scrapes, about one third sustained minor damage, and slightly less than 20% required repairs.

While there is little doubt that overheight vehicle collisions result in costly damage, and that preventing these collisions is clearly an issue that must be addressed, it is also apparent that many overheight vehicle collisions with bridges go unobserved and their effects are only discovered at a subsequent time during routine inspections. Thus there is a clear need to not only attempt to prevent overheight vehicle collisions with bridges, but also to monitor susceptible bridge structures and thus alert authorities to a collision that may warrant inspection and repair.

2.0 OBJECTIVES AND SCOPE

The objective of this Synthesis Study was to examine and summarize available off-the-shelf solutions that address two challenges associated with the problem of overheight vehicle impact with overhead bridges:

1. A primary focus, particularly in the context of the issues faced by INDOT, was to conduct a thorough review of technological solutions that are readily available to detect and forewarn overheight vehicles to prevent a collision – technologies collectively known as Overheight Vehicle Detection & Warning Systems (OVD&W Systems).

2. A secondary focus was to examine and summarize the availability of off-the-shelf technologies that could detect a vehicle-bridge collision and automatically alert appropriate authorities of the incident.

3.0 RESEARCH APPROACH

This synthesis effort consisted of a multi-pronged data gathering initiative focused on understanding the breadth of available means to detect overheight vehicles and avoid structure-vehicle collisions, the commercial availability of such systems, and the experience of relevant DOTs with installed and functioning systems.

Insight into applicable technologies was gained through an evaluation of (1) literature and databases, (2) commercial vendor offerings, and (3) a survey of technologies/solutions utilized by other DOTs.

(1) Literature and databases that were examined include the following:

- FHWA Database of Priorities, Market-Ready Technologies, and Innovations
- AASHTO's Technology Implementation Group
- Technology Transfer News of the NYDOT
- The Caltrans Division of Research and Innovation
- The TRB Research In Progress (RiP) Database
- The TRB TRIS database
- The US DOT's Research and Innovative Technology Administration (RITA)
- The US DOT's Intelligent Transportation Systems unit
- The National Transportation Library
- The National Highway Traffic Safety Administration (Crash Avoidance and Intelligent Transportation Systems)
- The US DOT Research Development and Technology unit
- The US DOT Transportation Safety Institute
- The US DOT University Transportation Centers site
- The Volpe National Transportation Systems Center resource
- ITS International
- Compendex/Academic Search Premier/Omni File Mega/MetaLib technical journal review
- LexisNexis news search

(2) The evaluation of vendor offerings was facilitated by internet searches, examination of commercial directories and company websites, and conversations/correspondence with vendor sales personnel and engineering staff.

(3) In addition to the sources cited above, DOTs from other states were surveyed to understand their experience with relevant technologies and/or their knowledge of potentially applicable systems. Specific characteristics of the systems under investigation (as outlined below) were obtained when available in addition to general evidence of deployment and satisfactory performance.

For each potential solution, information was gathered that could help inform INDOT's decision to pursue the specific technology for deployment within the State of Indiana. Specifically, efforts were made to define the following parameters:

- Operating principle (e.g., optical beam, image processing)
- Core sensor performance (e.g., accuracy, precision, error)
- Deployment requirements/capabilities (e.g., lane span, power)
- Associated alert system characteristics
- Overall advantages and disadvantages
- Ability to link to communication system
- Likely field performance (e.g., performance in rain, cold, snow)
- Reliability and maintenance requirements
- Cost (e.g., purchase, installation, maintenance)
- Compatibility with existing DOT systems (to the extent available)

Once identified, the performance characteristics of available systems were related to a set of site characteristics that have particular relevance to field deployment scenarios - for example, the traffic speed limits near bridges of interest, available location to place a system ahead of the bridge, proximity of bridges to alternate routes, distance from one side of the roadway to the other – to develop a OVD&WS equipment selection guide/tool that will facilitate selection of equipment relevant to Indiana's needs.

4.0 OVERVIEW OF EXISTING/COMMERCIALLY AVAILABLE OVD&W SYSTEMS

A comprehensive literature review and database search was completed that encompasses perspectives on existing/commercially available OVD&W system technologies from the sources outlined in Section 3.0. This review led to the development of a fundamental taxonomy of strategies to avoid/limit overheight vehicle incidents (Table 1).

		Passive	Active
Target	Driver	Education/ Truck Marking	In-cab Proximity Alerts
	Structure	Protection	Alteration
	Roadway	Posting/ Marking	Detection/ Re-routing

Table 1: Strategies to Address Overheight Vehicle-Infrastructure Collisions.

As illustrated in Table 1, measures to limit overheight vehicle collisions with infrastructure can be directed toward the driver, the structure itself, or the roadway. In addition, regardless of the focus, the steps taken can be passive or active in nature. Driver education and truck height marking (on driver's side and in the cab) have been shown to be an effective component of any programmatic effort aimed at reducing overheight vehicle collisions with structures. GPS based in-cab proximity alert systems that indicate the presence of a "low bridge" on the route of travel have also been shown to be helpful in alerting drivers to potentially unsafe conditions (e.g., Bridgewatch, BRIDGESAFE systems). It is also possible, albeit expensive, to limit the damage resulting from overheight vehicle - infrastructure collisions by erecting protective structures (e.g., in-line barriers, sacrificial beams or bars) that bear the brunt of a collision, or to avoid the potential for damage by increasing the vertical clearance between road surfaces and the underside of overhead structures (e.g., raising bridges or lowering roadway surfaces). However, from a DOT perspective, the most practical and economical measures to limit overheight vehicle incidents involve a combination of posting and marking roadways to warn drivers of upcoming obstacles along with active sensor systems that detect, warn, and re-route vehicles in jeopardy of a collision (shaded area of Table 1). This latter category of integrated sensing and warning systems on the roadway represents the focus of this work.

4.1 ROADWAY DETECTION, WARNING AND RE-ROUTING SYSTEM DESIGNS AND OPERATING PRINCIPLES

A typical active OVD&W strategy involves three key elements, namely a sensor capable of detecting an overheight vehicle, an alarm or warning mechanism to alert the driver of the overheight vehicle, and, when possible, a communication mechanism that can convey an alternate route or information about other corrective action. Figure 1 provides a visual example of a typical installed configuration. The figure shows a truck passing through a single eye detection system (discussed in more detail below). In the figure both visual and auditory warning systems are utilized to alert the driver of an impending collision. Finally, the figure highlights a message board that directs the truck driver to an off ramp where the driver could exit the current roadway and avoid collision with the bridge. This is an ideal example of how a system would prevent an overheight vehicle from colliding with a structure.

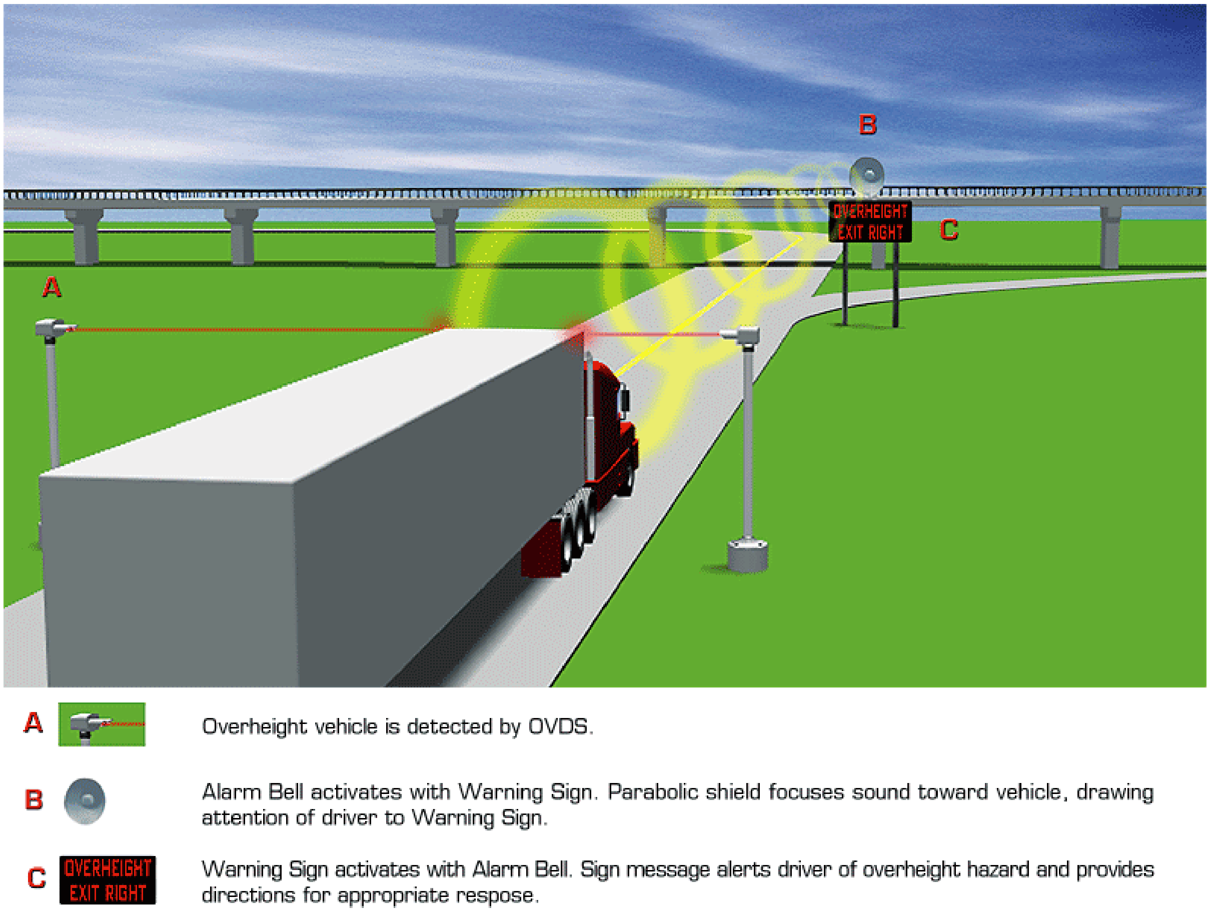

Figure 1: Typical installed configuration (Source: Trigg Industries Inc.).

Examination of the sources of information outlined in Section 3.0 indicates that currently available overheight vehicle sensing and warning systems can be organized at a fundamental level by the *sensing approach* employed in any given device or method and its specific operational configuration. Specifically, overheight vehicle detection and warning systems make use of three primary sensing mechanisms (Figure 2): 1) optoelectronic sensors that rely upon the interruption of a beam or sheet of light to indicate that a vehicle exceeds a predefined height threshold, or to construct profiles of vehicles that can be interpreted to obtain accurate vehicle dimensions, 2) ultrasonic sensors that emit and receive ultrasonic frequencies from an overhead gantry-like structure down onto passing vehicles to assess their height, and 3) mechanical systems that provide direct indications of vehicle impact with a warning structure positioned at a limiting height.

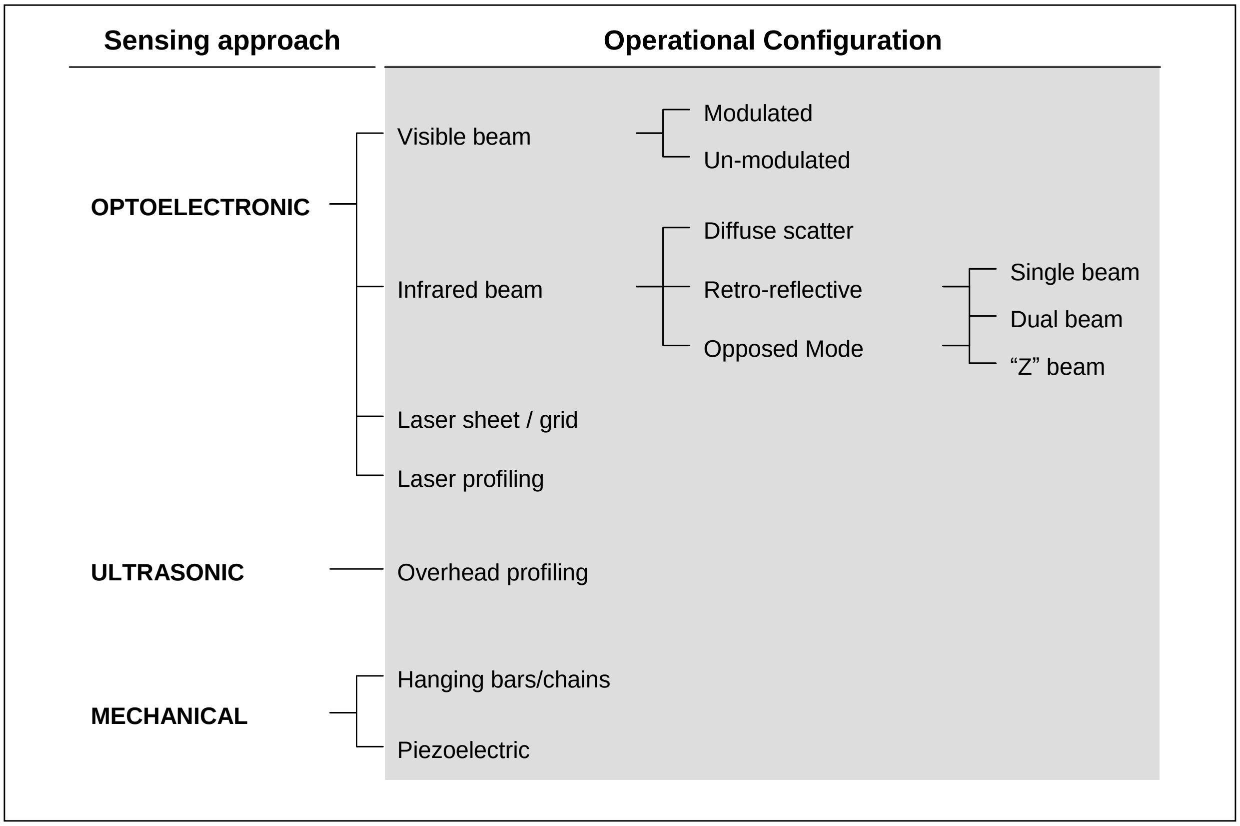

Figure 2: Taxonomy of currently available overheight vehicle sensing systems.

Each of the fundamental sensing approaches can be realized in multiple ways and offer specific advantages and disadvantages. These are discussed in detail below.

4.1.1 OPTOELECTRONIC APPROACHES

4.1.1.1 OPTICAL BEAM BASED SYSTEMS

Optical beam based systems are characterized by three key parameters: the wavelength region of the optical spectrum employed, the modulation of the optical beam itself, and the operational configuration of the transmission (Tx) and receiving (Rx) optoelectronics.

4.1.1.2 VISIBLE BEAM SYSTEMS

Visible beam systems are the simplest types of optoelectronic sensors employed in overheight vehicle identification applications. As their name implies, a visible beam operational configuration works by directing a beam of visible light from a source unit (Tx, for Transmission) to a detection unit (Rx, for Receiver) (either directly, or through reflection). These systems are generally low cost, but also low performance. Although the visible beam configuration works well in some situations, particularly indoors, it is easily influenced by ambient light and weather conditions. The visible beam systems can take two forms based primarily on the modulation scheme of the optical source:

a.) MODULATED VISIBLE BEAM

A modulated visible beam's output intensity varies with a defined period in time. The receiver in the system can be synchronized at the modulation frequency to reject potentially interfering sources of un-modulated light. However, even when modulated, the system's reliance on visible light makes it particularly prone to ambient light interference that approaches the modulation frequency. Although it is technically feasible to modulate the light frequency as well as its phase, these steps are rarely taken in the context of an overheight vehicle sensing unit as they require sophisticated electronics that is not warranted given other available means of countering interference.

b.) UN-MODULATED VISIBLE BEAM

An un-modulated visible beam system makes use of an unmodified optical source transmitter and is thus highly prone to interference from ambient and stray light. This is the simplest type of optoelectronic system and as such is not unlike the storefront optical beam systems used to detect pedestrian traffic in retail settings.

4.1.1.3 INFARED BEAM

An infrared beam operational configuration works by directing a focused beam of light in the infrared region of the optical spectrum from a transmission unit to a reflective target or detection unit. Unlike the visible beam, the infrared beam is less subject to ambient light interference and other outside factors due to the generally lower fraction of directed and intense infrared frequencies present in the general environment. Further, this kind of system offers performance benefits in adverse weather due to the use of infrared wavelengths that penetrate moisture (rain, snow, fog) better than visible light. Infrared beam systems typically take on one of three operational configurations as outlined below.

a.) DIFFUSE SCATTER

A diffuse scatter infrared system works by directing an infrared beam at an object and expecting at least some light to return to the detector. This method is dependent on the object being detected and the reflectivity of the surface of the object. This dependency leads to a reduced effectiveness at detection. Figure 3 is an illustration of how the diffuse scatter system operates.

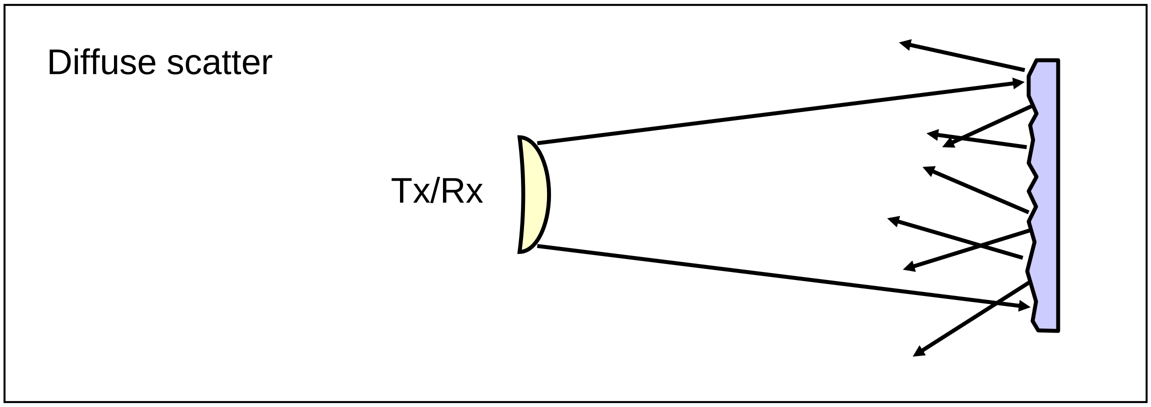

Figure 3: Diffuse scatter operational configuration of infrared optoelectronic sensor.

b.) RETRO-REFLECTIVE

An infrared retro-reflective system operates by directing an infrared beam at a mirror that re-directs a fraction of the beam back to a receiver (see Figure 4). This system is quite effective and achieves a good balance of low cost, general reliability and tolerance to outside interference. Figure 3 is an illustration of how a retro-reflective system operates.

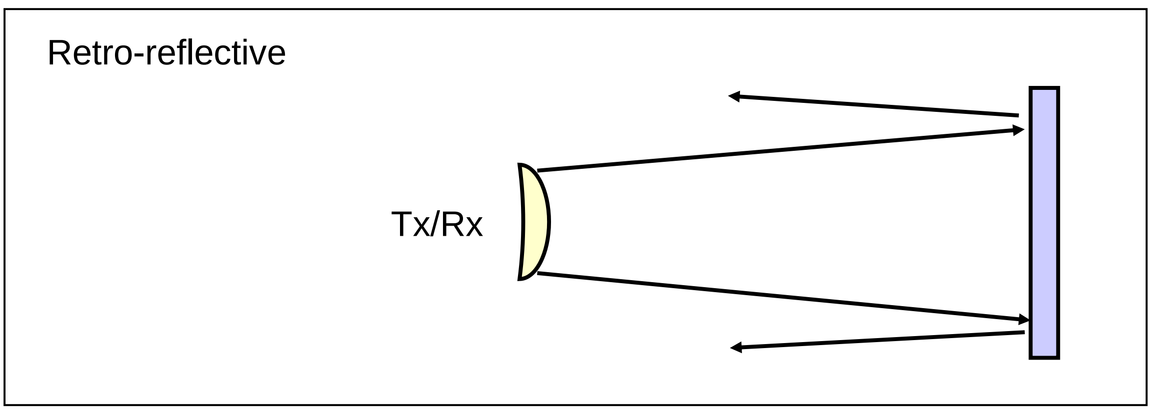

Figure 4: Retro-reflective operational configuration of infrared optoelectronic sensor.

c.) OPPOSED MODE

Opposed mode systems involve the use of pairs of aligned infrared emitters and receivers. The receiver and emitter are located on opposite sides of the roadway in a typical overheight vehicle detection scenario. This system greatly decreases the amount of outside interference as the optics of the transmission and receiver units are closely matched to optimize the collection angle of transmitted light. Figure 5 is an illustration of several opposed mode system designs.

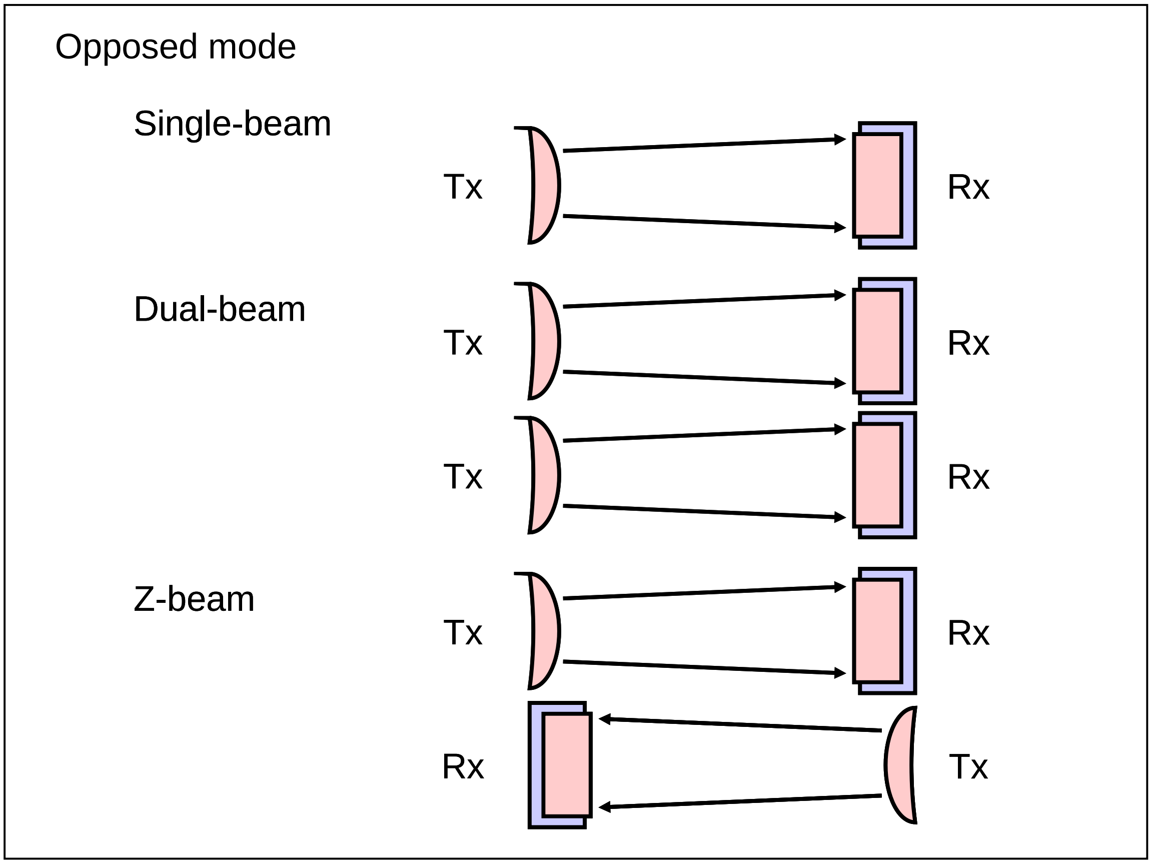

Figure 4: Optoelectronic designs for an opposed mode system.

The single beam system merely involves direction of an (infrared) light beam from a transmitter to a detector. The strength of this general approach is that the detector is positioned to receive a significant portion of the transmitted beam. The dual beam configuration builds on this benefit but provides the added ability to facilitate direction sensitive observation (based on beam break order), enabling system installation across bi-directional roadways using support posts on only the outermost edges of the road. In a simple dual beam configuration, both emitters are on one side of the roadway and both receivers are on the other. This type of system, although quite robust, could still be vulnerable to ambient light interference at some times of the day. In contrast, the “Z” beam configuration utilizes two pairs of infrared emitters and receivers oriented parallel to each other in a horizontal plane at a predefined height above the road surface, but with one emitter and one receiver located on each side of the roadway. In addition to the aforementioned benefits, a “Z” beam configuration further limits ambient light interference by ensuring that one receiver is always out of direct alignment with the Sun.

4.1.1.4 LASER SHEET / GRID

A laser sheet system makes use of one or more, horizontally stacked laser units arranged in an opposed-mode or multiple reflection geometry to form a “plane” that is interrupted by the passing of an object (see Figure 5 for a representative illustration).

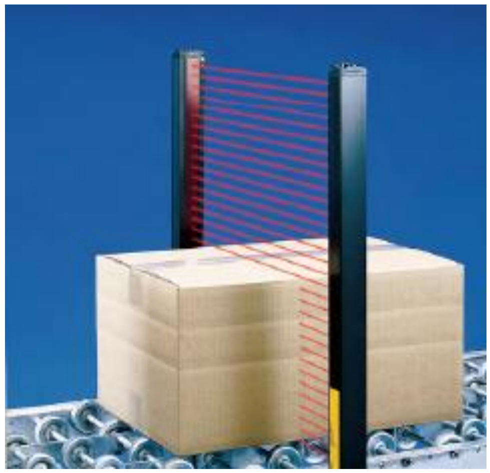

Figure 5: Representative operational design of a laser sheet system (Banner Engineering).

When applied for overheight vehicle detection, breaking a beam at a preset height in the sheet will indicate an overheight condition. The cost of these systems is quite high; and they are most effective when detecting objects passing at low speeds. These factors, coupled with the adverse effects of interference from outside light sources, make laser sheet systems an illogical choice for simply detecting overheight vehicles.

4.1.1.5 LASER PROFILING

Laser profiling systems are more advanced than general sheet designs and make use one or more lasers arranged in diffuse scatter geometry to assess the distance from the laser source to the passing vehicle based on either time of flight observations (beam source to vehicle) or scatter intensity measurement using a position sensitive detector (PSD) to develop a complete profile of a passing vehicle. While generally effective for overheight vehicle detection, these devices are typically applied for a broader set of uses including vehicle classification and calculation of vehicle spacing. Figure 6 illustrates the type of vehicle image that can be captured with a laser profiling unit.

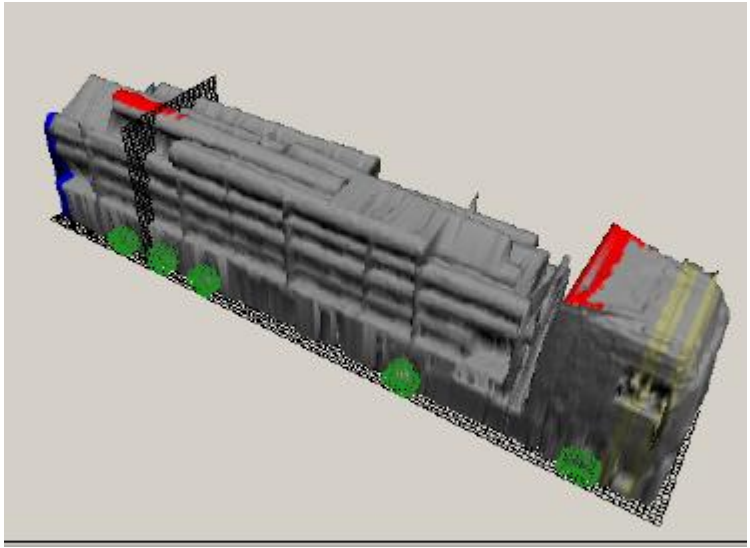

Figure 6: Representative vehicle image obtained with a laser profiling unit (ECTN AG).

Laser profiling units tend to be quite expensive, are less robust than simpler systems, and are generally limited to use on slow moving traffic. For these reasons, laser profiling systems are rarely employed solely for overheight vehicle detection.

4.1.2 ULTRASONIC OVERHEAD PROFILING

Ultrasonic overhead profiling systems make use of ultrasound emitters and detectors mounted on gantry like structures above traffic to assess vehicle height. The devices use time of flight measurements to define the distance between the emitter/receiver and the top of a passing vehicle. Unfortunately these units offer only limited coverage of the vehicle top surface profile and thus are less sensitive to non-continuous obstructions (e.g., small protruding vehicle parts) than a cross-beam optical system. While certainly a technologically feasible means to address the overheight vehicle challenge, these systems are rarely deployed in the field solely for overheight vehicle detection.

4.1.3 MECHANICAL SYSTEMS

4.1.3.1 HANGING BARS/CHAINS

Hanging bar or chain systems involve the use of a physical, “sacrificial” obstacle as an absolute indicator of an overheight condition. Effectively the obstacle, which may be mounted on a gantry a comfortable stopping distance ahead of a protected structure, provides awareness of an overheight condition when it is impacted by a passing vehicle. These types of systems of course only work if the driver realizes they have hit the bar or chains. This type of system is also only applicable when vehicles are expected to operate at low speeds to both ensure the driver is aware they are overheight, and to ensure the bar is not damaged or does not cause damage to any vehicles. For these reasons, mechanical systems of this type are rarely useful as a sole line of defense, particularly in highway scenarios.

4.1.3.2 PIEZOELECTRIC SENSORS

Piezoelectric materials are self-generating and reflexive in their behavior, meaning that an electric polarization is generated when they are subjected to stress and that they will deform when exposed to an appropriate electric field. In the context of overheight vehicle detection, piezoelectric sensors depend on the force of impact with a vehicle to generate an electrical response that can be used to trigger any of a variety of warning and signaling devices to an overheight condition (Song et al., 2007). In this regards, piezoelectric sensors are not completely preventive. For this to be effective as a means of preventing overheight vehicle-structure collisions, the sensors would have to be mounted a safe stopping distance from the structure of interest, possibly on a gantry. These types of sensors exist in research contexts but do not appear to be present in field settings.

4.1.4 OPTIMAL SENSOR CONFIGURATION

Overall, the results of this analysis indicate that infrared based optoelectronic sensors operated in an opposed mode dual or “Z” beam pattern appear to provide the greatest potential for reliability and environmental robustness at a reasonable level of cost. More advanced systems bolster the already robust capabilities of these dual beam units with an inductive loop or ferro-magnetic sensor that ensures that a triggered overheight detection sensor signal is supported by indications of the presence of a vehicle on the roadway – a method that limits false positive detection caused by birds or animals that may break the optical beams employed in the OVD unit.

Integrated systems that couple active overheight vehicle detection devices with active warning units appear to have the most merit. In these systems, detection of an overheight vehicle triggers a signal that is sent (via wireline or wireless communication) down the road, ahead of the offending vehicle and before the height limited structure, to gain the attention of the offending vehicle driver. The warning systems may consist of flashing or steady lights or variable message signs and can encourage the vehicle to stop, or, when feasible, re-direct the overheight vehicle to an alternate, safe route.

4.2 COMMERCIAL AVAILABILITY

A thorough international search for suppliers of optoelectronic OVD&W systems indicated that there are approximately 10 major suppliers. These suppliers include:

- ASTI Transportation Systems (USA)
- Banner Engineering (USA)
- Coeval Group (UK)
- International Road Dynamics Inc. (Canada)
- Measurement Devices Ltd. (Scotland)
- Peter Berghaus GmbH (Germany)
- Schuh & Co. GmbH (Germany)
- Sick-Maihak (USA)
- Trigg Industries Inc. (USA)

While there are a host of re-sellers and distributors for the products made by the above listed companies, those listed represent organizations that offer proprietary product designs. Background and offerings of these organizations have been examined in depth. Available specification sheets for systems offered by each company are presented in Appendix A and contact information for each of the companies is provided in Appendix B. Several key specifications differentiate the systems (Klein, 2001; Cawley, 2002; Kowal, 2002), including:

- Transmitter / receiver configuration - directional sensitivity
- Allowable vehicle speed
- Optical transmission / detection range
- False positive check
- Warning system sophistication
- Cost
- Availability of back-up warning system
- Video capability
- Power requirements
- Environmental robustness
- Ease and versatility of installation

Specifications for each of the major vendor offerings are provided in Table 2.

Company	Model	2-way detection	Speed Parameters	Width Range	Temperature Parameters	Backup Warning System	Video Capability	Power	Enviromentally sealed	Internal thermostat
ASTI Transportation Systems		0	0	200 ft.	(-) 25F to 150F	0	0	10 - 30 V DC	0	0
Autotron	LRML	0	0	35 ft.	(-) 40F to 55F	0	0	12 V DC or 120 V AC	yes	yes
Banner Engineering	Magnet-resistive	0	0	0	0	0	0	0	0	0
	QS30	0	0	0	0	0	0	0	0	0
	A-gage Mini Array	0	0	55 ft.	0	0	0	0	0	0
Coeval Group		0	0	165 ft.	0	0	0	0	0	0
Internaltional Road Dynamics Inc.		yes	1 to 75 (mph)	200 ft.	(-) 40F to 135F	yes	yes	24 V DC or 115 V AC	yes	yes
Measurement Devices Ltd.	Laser Ace IM	0	1 to 75 (mph)	500 ft.	14F to 140F	0	yes	9 - 24 V DC	yes	0
IDT		yes	1 to 75 (mph)	65 ft.	5F to 150F	yes	yes	UK mains	yes	no
Peter Berghaus GmbH		yes	0	200 ft.	(-)4F	0	0	12 V DC or 230 V AC	yes	yes
Schuh & Co.		yes	1 to 75 (mph)	100 ft.	(-) 10F to 140F	yes	yes	24 V DC	yes	yes
TEC Traffic Systems		0	1 to 75 (mph)	100 ft.	0	0	0	0	no	no
Sick Maihak		no	1 to 75 (mph)	300 ft.	(-) 25F to 150F	yes	no	24 V to 240 V UC	yes	no
Trigg Industries Inc.	Z-Pattern	yes	1 to 75 (mph)	200 ft.	(-) 40F to 135F	yes	yes	24 V DC or 115 V AC	yes	yes
	Double Eye	yes	1 to 75 (mph)	200 ft.	(-) 40F to 135F	yes	yes	24 V DC or 115 V AC	yes	yes
	Single Eye	no	1 to 75 (mph)	200 ft.	(-) 40F to 135F	yes	0	24 V DC or 115 V AC	yes	yes
	Metro Economy	no	1 to 75 (mph)	200 ft.	0	no	0	24 V DC or 115 V AC	yes	no

Table 2: Vendor offerings and related system specifications.

5.0 ASSESSMENT OF DOT DEPLOYED SYSTEMS

5.1 IDENTIFICATION OF STATES WITH OVD SYSTEMS

Following the literature review for this study, there were indications that 19 states and the District of Columbia may have some form of OVD system installed and/or in use (USDOT, 2006; Bretz, 2000; Hanchey and Exley, 1990; Mimbela and Klein, 2007) (Table 3).

States	Metropolitan Area
CA	Bakersfield, Fresno, San Diego, San Francisco, Oakland, San Jose
CO	Denver, Boulder
CT	Hartford, New Britain, Middletown
DC	Washington
KY	Louisville
LA	Baton Rouge, New Orleans
MD	Baltimore
MI	Detroit, Ann Arbor
NY	Albany, Schenectady, Troy, Buffalo, Niagara Falls, New York, Northern New Jersey, Southwestern Connecticut, Syracuse
OH	Cleveland, Akron, Lorain
OK	Oklahoma City
OR	Portland
PA	Philadelphia, Wilmington, Trenton
TN	Knoxville
TX	Dallas, Fort Worth, San Antonio
VA	Hampton Roads
WA	Seattle, Tacoma
WI	Milwaukee, Racine

Table 3: States with reference to an OVD&W system.

Each state DOT was contacted to confirm or refute the existence of an OVD&W system in the state. The results from the state confirmation calls can be seen in Table 4. Table 4 highlights the point of contact as well as their contact information and the status of any overheight vehicle detection system(s).

State	Contact Person	Phone Number	Findings
CA	Operator	510-286-4444	No response
	Nadal Ebrahimi	916-654-6914	
	James Anderson	916-654-5548	
CO	Operator	303-757-9011	System in use
	Permits	303-757-9011	
	Thersea Lawser	303-757-9843	
	Rod Henderson	303-512-5735	
CT	Operator	860-594-2000	System no longer in use
	Linda Hope	860-594-2878	
DC	Operator	202-673-6813	No response
	Livett Williams	202-673-6813	
KY	Nancy Albright	502-564-3730	System no longer in use
LA	Peter Holland	225-242-4631	System no longer in use
MD	Permits	410-865-1000	System no longer in use
	State Highway	410-545-0300	
MI	Operator	517-373-2090	No response
	Mark Dianese	517-373-2121	
	John Goke	517-373-2123	
NY	Operator	518-457-5826	No response
	Sreenivas Almapliai	518-457-4544	
	James Patterson	845-431-5771	
	Jane Alexander	845-575-6071	
OH	Operator	330-786-4940	System in use
	Dave Holstein	614-644-8137	
	Turnpike	440-234-2081	
	Gary Calley	440-234-1273	
	Bill Keaton	440-234-2081	
OK	Bruce Jeffcoat	580-332-1526	System no longer in use
OR	Operator	888-275-6368	System no longer in use
	Mike dunning	503-986-3059	
	Donn Wence	503-986-3594	
TX	Operator	214-320-6100	System not yet operational
	Tony Oakafer "Mainenance Director"	214-320-6171	
VA	Operator	757-925-2500	System in use
	Jessy Niel	757-727-4811	
	Joe Reed "Electronic Technichian Supervisor"	757-592-8088	
WA	Operator	360-705-7099	System in use
	Permits	360-705-7000	
WI	Permits	262-548-5903	System no longer in use

Table 4: Summary of DOT confirmation phone calls.

Out of the 19 states believed to have an OVD&W system, 4 were found to still have a system in use, 8 were found to no longer use a system and one was not yet operational.

The eight states that no longer employ the system had different reasons for stopping use of the system. Maryland for example decided to switch back to a height pole, in which a truck travels ahead of the oversize load and checks for possible height interferences. Oklahoma had one system in use that became obsolete after the bridge was raised to accommodate overheight vehicles. Connecticut also raised the structure that was being monitored by the sensor system. Michigan utilized the sensor during a construction project and removed the system once construction was complete. Wisconsin now relies on signage and operator awareness instead of the sensor system. The Texas DOT was in the bidding phase of their sensor system setup when this survey was conducted.

The four states that were confirmed to have an active OVD&W system include OH, WA, VA, and CO.

5.2 SURVEY OF ACTIVE SYSTEM USERS

Specific DOT experiences with active OVD&W systems were explored in the latter half of this project through a structured interview and survey process. A survey (shown in Figure 7) was administered via phone to knowledgeable DOT personnel in each state to learn what equipment was in use, how well the system worked in the field, and if any major problems arose with the system.

Survey Questions

- From which company did you purchase your OVD&W system?
- What were the costs of this system?
- What were the costs for supporting structures and installation?
- Was the system easily integrated into the DOT's information system?
- To-date has the system failed to maintain any of its specified performance?
- To-date how would you grade the overall system in-field performance (on a scale of 1 to 10)?
- To-date have there been any incidents in which the weather directly interfered with the system?
- What were the conditions of the incident (rain, snow, sunny)?
- How often is system maintenance needed (given)? What does maintenance entail?
- Since implementing the OVD&W system, has there been an increase or decrease in over height vehicle incidents?

Figure 7: Survey administered to each state DOT with an OVD&W system.

The results of enquiries with the four states possessing active systems are summarized below.

Washington's DOT uses a Trigg Industry single eye sensor purchased from International Road Dynamics Inc. for $5782. The system is installed before an overpass. The system took two people, three days to install. No lane closure was needed which kept installation costs down to $2500. A four inch diameter pole was set in concrete and the sensor was placed at the top. IRD was able to easily integrate the sensor into the DOT's information system. A representative from the Washington DOT rates the system as 8 out of 10 for field performance. There are some weather conditions that affect the system, such as heavy fog and a few minutes of direct sunlight. Both heavy fog and direct sunlight obscure the beam of light and therefore trigger the system. There are covers that extend over the lens and could help keep out direct sunlight. Maintenance is only needed once a year to ensure the sensor is aligned properly. Alignment is generally checked by taking a wooden paddle and passing it in front of the sensor. Since installing the system there has been no recorded incident with an overheight vehicle striking the protected structure. The installation of more systems is being heavily considered for other locations.

Colorado's DOT also uses a Trigg Industry single eye sensor purchased from Tripp Lite for $3000. The lane closure, alarms, and video sensing cost a total of $25,000. There were no problems integrating the system in the DOT's information system. Colorado DOT gave 8 out of 10 for field performance. There are some weather conditions that affect the system, such as heavy snow and ground heave. The heavy snow will sometimes build up and block the lens of the sensor. The snow blocks the lens and causes the system to trigger a false alarm. Generally a worker is sent out to check the problem and clean off the lens. There are covers that extend over the lens to keep out the snow. Ground heave sometimes alters the alignment of the system and therefore maintenance is done every three months to ensure the sensor is aligned properly. Like in Washington, maintenance is simply conducted with a wooden paddle. The Colorado DOT has a manned station by the monitored bridge to stop overheight vehicles from continuing. The need for the station was based on the volume of collisions the bridge was experiencing. The amount of incidents has greatly decreased since system installation, however illegal late night drivers still hit the bridge.

Virginia's DOT uses Cutler Hammer (patent assignee Trigg Industries) dual eye sensors purchased from Jo-Kell Inc. for $2000. Installation for this unit cost approximately $2000. The system was easily integrated into the DOT's new tunnel information system (NEWTIN). Minor technical problems were encountered with the system including a light source failure and a problem with AC powering of the sensing unit. Jo-Kell Inc. rapidly addressed the problems and the sensing units have been working fine ever since. A representative from the Virginia DOT rates the system as 8 out of 10 for field performance. There are some weather conditions that affect the system, such as ice forming over sensor and a few minutes of direct sunlight. The ice and direct sunlight results in the system being triggered. Generally a worker is sent out to check on the system and identify the problem. The ice is removed manually from the lens, and the sun is only a problem for a few minutes. Maintenance is done on a quarterly basis to ensure alignment. As with the other DOTs, the maintenance is done with a wooden paddle. The light sources in the sensor are replaced every 9 to 12 months and the lenses are cleaned every 3 months due to cloudiness. The sensor for the unit is tested every 8 hours to ensure it is working properly. At the Hampton Roads Bridge-Tunnel, forty to forty-five overheight vehicles are stopped every weekday, approximately seventy-five overheight vehicles are stopped on Saturday and Sunday. The Hampton Roads Bridge-Tunnel connects the cities of Norfolk and Hampton, Va. Though the number of overheight vehicles is high, there has been a decrease in the number of tunnel impacts since installation of the OVD system. Virginia DOT also has systems at Memorial Bridge in Arlington, Elizabeth Tunnel, and the Monitor-Merrimac Bridge-Tunnel, and is considering placing a system at Big Walker Mountain in Southwest Va.

Ohio's DOT uses single eye Autotron sensors purchased from Trans Corporation. This system allows for the entire car to be scanned. This can tell the height of the vehicle, what type of vehicle it is as well as the distance between it and the car in front of and behind it. The system was easily integrated into the DOT's information system. The Ohio DOT rates the system 10 out of 10 for field performance, stating the system is "very user friendly". There are some weather conditions that affect the system, such as snow collecting on top of trucks and causing false alarms. To counteract the snow accumulation on the trucks the motto "if its snow let them go" has been implemented in the state. Preventive maintenance is conducted once a month to ensure stability and alignment. Ohio's preventative maintenance involves a single worker checking calibration and tightness of bolts on the unit and its mountings. Since implementing the system there has been a decrease in the amount of hits on the protected structure.

5.3 CONCLUSIONS

Based on the data collected from DOT's, it is clear that most states have updated their infrastructure to account for overheight vehicles. Some states continue to check for height limitations using escort vehicles for oversized loads. While this method is effective most of the time, it does not account for the illegal trucks traveling through the state. The few states that still actively employ OVD&W systems have stated that the systems have decreased the amount of damage occurring to their structures, but have not been able to provide solid quantitative data to support these assertions. The initial equipment and installation costs of the active systems range from a few thousand to twenty-five thousand dollars based on DOT interviews, and on-going maintenance appears minimal. Overall, considering that the only other completely effective option to avoid overheight vehicle impact with structures is to raise the height of the structure, or lower the roadway surface, an (optoelectronic) OVD&W system is a relatively inexpensive and effective method for decreasing structural damage due to overheight vehicles.

6.0 RECOMMENDATION FOR SYSTEM SELECTION PROCESS

Findings from the review of available and in-use systems provide valuable information for the selection of OVD&W systems. Site characteristics define the parameters by which a system is selected.

6.1 OVD&W SYSTEM SELECTION CONSIDERATIONS

Relevant site characteristics that influence both sensor selection and overall OVD&W system design are described below.

Sensor selection considerations:

- **ONE-WAY/TWO-WAY HIGHWAY:** A select few sensors found in this project are bi-directional, which allows a single sensing unit to be used for a two-way highway. The bi-directional sensors offer an opportunity to place support systems at the far edges of a two-direction highway, yet only trigger warnings for a single direction of traffic flow.
- **NUMBER OF LANES**: The number of lanes across which a sensing system must span is important because it defines the optical range parameters of the system. Certain systems can work properly over longer ranges and are therefore ideal for multi-lane highways.
- **WEATHER:** As with many electronic devices, an OVD&W system can be influenced by the weather. The degree to which each system is affected can be seen in Table 2. The most common problems stem from direct sunlight, fog, and heavy snow. The Z-beam system by Trigg Industries almost completely eliminates these concerns. Beyond weather interference effects, a system exposed to the elements should likely be weather proof and may benefit from an on-board thermostat that can actively compensate for environmental temperature fluctuations and maintain sensor performance.
- **USABLE SPACE 1000 FT. BEFORE STRUCTURE:** The usable space before the structure influences placement of the sensors. In settings where there is limited distance available between the placement of an overheight detector and the structure to be protected, it can be valuable to install a backup warning system that is likely to gain the attention of those driving overhead vehicles and help avert a collision. Warning signs should be placed 100 to 150 ft. after the sensors, to ensure the driver has time to see

them and stop, or exit the highway, if possible. More distance could be needed for the warning system, depending on the type of signage used.

- **SECURITY:** In some circumstances, particularly when monitoring structures on roadways prone to off-hour traffic, interference from wildlife, or where remote locations preclude easy access and physical monitoring, it may be valuable to install a video monitoring system in conjunction with an overheight sensing unit.
- **SPEED LIMIT:** All of the sensors identified through this effort can successfully monitor traffic traveling at up to 75 mph. Therefore it is important to keep in mind the speed around the structure and account for people who may travel slightly over the posted speed limit.

Macro design considerations:

- **ACCESS TO OFF RAMP:** Access to an off ramp is a convenience characteristic and can influence the need or desire to make use of message boards to inform drivers of alternate routes. If an off-ramp is not present it is possible to have warning signs that stop the vehicle instead of directing it off the highway. With this option however the truck must then be removed from the highway via u-turn or reverse, often with police supervision. The lack of an off ramp should not however be a determining factor in not investing in an OVD&W system. The truck will still be stopped and the damage averted.
- **NUMBER OF POSSIBLE ENTRY POINTS TO REACH STRUCTURE**: Considering the number of possible entry points to reach the structure is important when considering how many warning systems are needed. It is sometimes more beneficial to go further out from the structure to more easily direct traffic in a different direction. The distance between warnings and a structure should be kept within a mile due to some reports indicating OVD&W systems are ignored when no structures are visible.

6.2 OVD&W SENSOR SELECTION GUIDE

Building on the site characteristics outlined above, a simple MS Excel based Equipment Selection Tool has been developed to guide selection of optoelectronic OVD equipment models. The tool provides the designer with a set of 7 questions and associated answer options. Changing any of the responses to this set of characterization questions alters an accompanying list of viable equipment alternatives based on manufacturer specified performance capabilities. The user interface for this OVD Equipment Selection Tool is illustrated in Figure 8. The tool can be easily updated with new equipment characteristics as they become available by entering specific performance parameters on data sheets in the Excel file.

Please select an answer for each question from the drop-down menu provided.

Is 2 way detection a requirement?	No
What is the maximum range, in feet, required for the system?	35
What is the minimum temperature, in degrees F, required for the system?	15
Is a backup warning system a requirement?	No
Is video capability a requirement?	No
Is it required that the system be enviromentally sealed?	No
Is an internal thermostat required?	No

Recommended System(s)
Trigg Industries 'Z Pattern'
Trigg Industries 'Double Eye'
Trigg Industries 'Single Eye'
Trigg Industries 'Metro Economy'
Sick Maihak
Schuh & Co.
Peter Berghaus
Integrated Design Techniques Limited
Measurement Devices Ltd. 'Laser Ace IM'
International Road Dynamics
Autotron 'LRML'
ASTI Transportation Systems

Figure 8: User interface for this OVD Equipment Selection Tool.

7.0 CASE EXAMPLE

A case example has been developed to illustrate implementation of an OVD&W system and highlight the logic behind the sensor selection process outlined above. The case centers on the I-65 – I-70 merger location in Indianapolis, IN (known as the south-split). A detailed schematic of the proposed solution to limit overheight bridge impact in this region is provided in Appendix C and a simplified schematic of this same solution is illustrated in Figure 9 herein for convenience. This solution makes recommendations on where to place sensors, warning signs, and prevention signs. The sensors were selected using the "system selection process" discussed earlier in this report. The type of signage used to warn drivers of overheight limitations is not specified in this report. It is recommended that the signage be large enough to ensure driver awareness, and if possible both visual and auditory signaling should be used close to the protected structures. The following sub-sections describe in detail the specific site, as shown in Figure 9.

7.1 LEGEND

The legend and compass for the map provided in Figure 9 can be found in the upper left corner of the page. There are six components of the legend. Two parallel lines represent one complete sensor unit. A sensor unit consists of a transmission and receiver unit. The transmission unit will be placed on one side of the roadway and the receiver unit on the opposite side of the roadway, in an opposed-mode configuration. The arched line represents a bridge marker. Located beside each bridge marker is the respective bridge number.

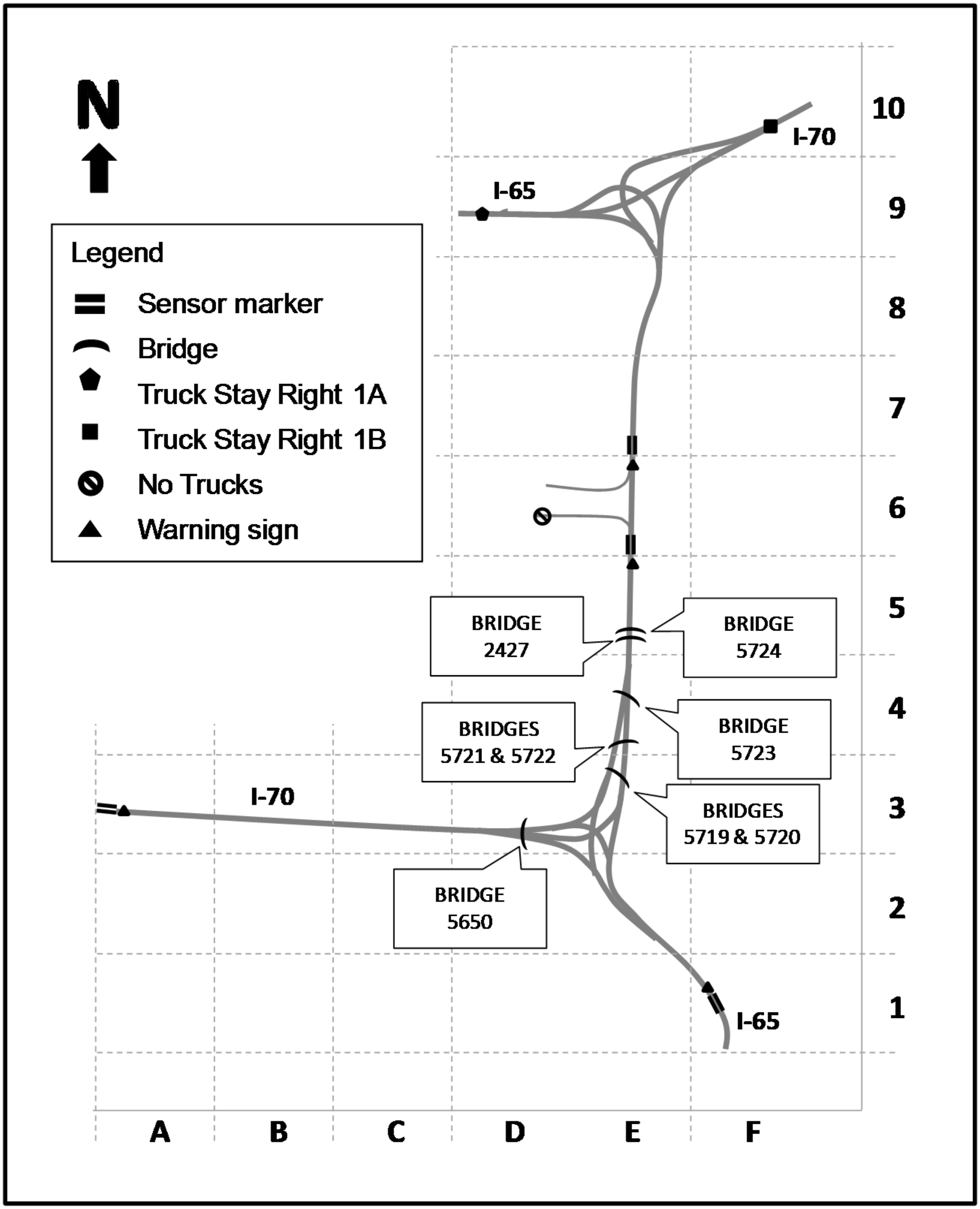

Figure 9: Schematic of I-65 – I-70 merger location in Indianapolis, IN and proposed OVD&W system deployment plan (Illustrative – see Google Earth rendering in Appendix for details).

The “Trucks Stay to the Right” 1A and 1B signs are marked with a pentagon and a square, respectively. The “No Trucks Allowed (over 14’ 6”)” symbol is a circle with a diagonal line through it. The “Warning Sign” symbol is a solid triangle. These signs are associated with the sensors. They are located 100 ft behind the sensor locations. Each sensor should be equipped with two warning signs, except for the sensor in southern region of quadrant E6 on the map, which should have three warning signs. The number of warning signs is related to how many lanes a sensor must cover and the driver’s ability to see the warning signs.

7.2 Prevention Signs

There are three prevention signs for the area indicated on the map. The first prevention sign is located in quadrant D6. This prevention sign is a No Trucks Allowed prevention sign. This sign is intended to stop trucks over a specified height defined by the related bridge clearance from gaining access onto the interstate. This sign could be replaced with a height warning sign or with another sensor. However, if a sensor were placed at this location the truck would not be able to exit the on ramp and would be forced to turn around.

The second prevention sign is located in quadrant D9. This sign is the Trucks Stay to the Right 1A in the legend. The purpose of this sign is to ensure the trucks stay in the right two lanes on I65. I65 S is composed of four lanes separated in the middle by a wall. If the trucks stay to the right, the sensor in quadrant E7 will read the height of the truck and they will be able to exit via an off ramp if they are indeed over height. If the trucks ignore this, the sensor in quadrant E6 will catch any overheight vehicle. However, there will be no place to turn the truck around.

The third prevention sign is located in quadrant F10. This sign is the Trucks Stay to the Right 1B in the legend. The purpose of this sign is the same as the for prevention sign, 1A. Sign 1B is simply meant to keep trucks from the east to stay in the right two lanes of the road. Again, if the trucks ignore the signage, the sensor in quadrant E6 will catch any overheight vehicle. However, there will be no place to turn the truck around.

7.3 Sensors and Warning Signals

There are four recommended sensors for the area indicated on the map. Based on conditions at the site appropriate OVD sensors for sensor locations in quadrants F1, A3, and E7 are available from any of the manufacturers listed in Figure 10.

Please select an answer for each question from the drop-down menu provided.

Is 2 way detection a requirement?	No
What is the maximum range, in feet, required for the system?	65
What is the minimum temperature, in degrees F, required for the system?	-40
Is a backup warning system a requirement?	Yes
Is video capability a requirement?	No
Is it required that the system be enviromentally sealed?	Yes
Is an internal thermostat required?	Yes

Recommended System(s)
Trigg Industries 'Z Pattern'
Trigg Industries 'Double Eye'
Trigg Industries 'Single Eye'
International Road Dynamics

Figure 10: Viable sensor vendors for sensor locations 1, 2 and 4 in I-65 – I-70 merger location.

The first sensor is located in quadrant F1. This sensor is located 1000 ft before the start of the upcoming off ramp. The warning signs or signals are located 900 ft before the start of the off ramp. The significance of the 100 ft differential is to ensure the driver has time to see the warning signs and recognize that he or she is the truck in violation of the height restrictions. The significance of the 900 ft spacing from the off ramp is the approximate distance needed for an 18-wheeler to come to a complete stop under wet road conditions when traveling at highway speed. The detour routes for this sensor have been drawn in red on the map in Appendix C. Truck drivers traveling north and west will need to exit immediately off the same off ramp. The driver would then need to follow the appropriate detour route, depending on which direction of travel is desired.

The second sensor is located in quadrant A3. The sensor is located 1000 ft before the start of the upcoming off ramp. The warning signs or signals are located 900 ft before the start of the off ramp. The detour routes for this signal have two separate off ramps. The first off ramp is intended for truck drivers traveling south. The second off ramp is the detour drivers traveling north would need to take. Two sets of warning signs may be needed for this area to take into consideration separate off ramps.

The third sensor is located in quadrant E6. The sensor is located 1000 ft before bridge 5724. This is the first bridge with a height restriction. The warning signs or signals are located 900 ft before bridge 5724. The span of traffic for this sensor is four lanes and therefore would need a sensor capable of handling that distance. This limitation alters the inputs to the Sensor Selection Tool as illustrated in Figure 11, but in this case, does not change the set of viable vendors.

Please select an answer for each question from the drop-down menu provided.

Is 2 way detection a requirement?	No
What is the maximum range, in feet, required for the system?	100
What is the minimum temperature, in degrees F, required for the system?	-40
Is a backup warning system a requirement?	Yes
Is video capability a requirement?	No
Is it required that the system be enviromentally sealed?	Yes
Is an internal thermostat required?	Yes

Recommended System(s)
Trigg Industries 'Z Pattern'
Trigg Industries 'Double Eye'
Trigg Industries 'Single Eye'
International Road Dynamics

Figure 11: Viable sensor vendors for sensor location 3 in I-65 – I-70 merger location.

Three locations for signs or signals would be needed to ensure driver awareness of the upcoming bridge. Unlike the other sensors, this sensor is put in place as a last chance prevention. There are no off ramps available if the truck driver has arrived at this location. The truck driver would need to stop and inform local authorities of the height restriction and inability to proceed without damaging the bridge. There is an off-ramp available after RR Bridge 2427. This would however involve the driver passing under two bridges before exiting the interstate. The slower speed accompanied with a police escort could however decrease the amount of damage done on the bridge, as well as decrease the potential threat to other drivers. Tire deflation could potentially enable safe passage.

The fourth sensor is located in quadrant E7. The sensor and signage are placed 1000 and 900 ft before the upcoming off ramp, respectively, the same as the other sensors. Although there are four lanes of traffic traveling southbound only two lanes are connected to an off ramp. This is due to the wall separating the two sets of roadway. Truck drivers driving in the west set of lanes (collector/distributor lanes) will trigger the sensor and be able to exit via the off ramp. After exiting, drivers will be able to take a detour to continue their route, either southbound or westbound. For truck drivers traveling in the east set of lanes (mainline lanes), the sensor in quadrant E6 will detect them if they are over height. The drivers in the east set of lanes will not however have the option to exit via an off ramp before encountering a low bridge.

8.0 BENEFITS OF STUDY AND RECOMMENDATIONS FOR USE OF FINDINGS

The work performed in this study provides a guide to available and in-use overheight vehicle detection systems and suppliers of such equipment. In addition, the review outlines the underlying technologies that enable these sensors as well as the performance attributes that define their relevance for field deployment under various installation scenarios. The combined insights gained through this review were used to develop a straightforward decision tool that can be employed to identify equipment options to address site specific needs for overheight vehicle protection. This tool and its underlying principles were applied to a test case focused on the I-65 – I-70 merger (south-split) location in Indianapolis, IN leading to a preliminary overheight vehicle detection and warning system strategy for that specific location.* It is recommended that the sensor characteristics and design decision logic outlined herein be used for any future OVD&W system deployment envisioned in the State. Ultimately, implementation of such systems could reduce vehicle-bridge collisions and prevent associated injuries and repair costs, prevent emergency bridge closures, and potentially prevent catastrophic bridge failures.

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APPENDIX A

OVER-HEIGHT VEHICLE DETECTION SYSTEMS

PURDUE UNIVERSITY
SCHOOL OF CIVIL ENGINEERING

Joint Transportation Research Project
SPR-3237

Table of Contents

THE

SAFETY PASS™

Overheight Vehicle Detector

Helps Prevent Bridge & Underpass Damage

Safety Pass™ alerts drivers if their vehicles are overheight for an upcoming bridge, overpass, overhead walkway, etc. The Safety Pass™ is an optical instrument that uses infra-red light which is non-invasive, completely safe, and invisible to the naked eye. As such, it can operate day and night in virtually all weather conditions to detect vehicles that are overheight, giving drivers time to turn back or take alternate exits or turns. With today's extremely high construction costs and downtime rerouting problems, the Safety Pass™ becomes a very cost-effective alternative to even one bridge repair.

The Safety Pass™ consists of a transmitter and receiver which are typically mounted on posts or poles at the same height as an upcoming overpass. The transmitter projects a narrow beam to the receiver located across the roadway. It can be aligned to match the exact slope of an unlevel overpass. LED's located at the top of the sensors tell the installer when the units are aligned, making setup a breeze. The sensor heads are designed so that objects less than 1 1/2" (such as antennas) will not trigger the unit. The Safety Pass™ is lightweight, compact and extremely rugged. All parts are modular and can be replaced onsite in less than 15 minutes.

The Safety Pass™ can be used in conjunction with the Computerized Highway Information Processing System (CHIPS™) from ASTI Transportation Systems, Inc. to automatically notify DOT personnel, incident management teams, etc., when a vehicle has not cleared an overpass.

SAFETY PASS IS A TRADEMARK OF:

ASTI

18 Blevins Drive
New Castle, DE 19720
Phone: (302) 328-3220 - Fax: (302) 328-4051

www.asti-trans.com

THE

SAFETY PASS™

SPECIFICATIONS

Method of Operation........................	Narrow, pulsed dual beam infrared with background noise rejection
Range	200' @ 2X margin / 250' @ 1X margin
Input/Power Consumption................	10 to 30 vdc or 110 to 240 vac, 4VA maximum
Timer Range	1 second to 100 seconds - adjustable rotary dial
Ambient Temperature	-25 to +150 degrees F -30 to +70 degrees C
Dimensions..	Transmitter .... 4"H x 2"W x 3.25"D Receiver .... same as transmitter Electronics Enclosure.... dependent upon system package - NEMA rated
Weight	1 lb. each (receiver and transmitter heads)
Mounting	Ball & swivel joint with 12" of vertical adjustment

SAFETY PASS IS A TRADEMARK OF:

ASTI

Transportation Systems, Inc.
A DIVISION OF STADLER COMPANIES INC.

18 Blevins Drive
New Castle, DE 19720
Phone: (302) 328-3220
Fax: (302) 328-4051
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Members of:

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Autotron

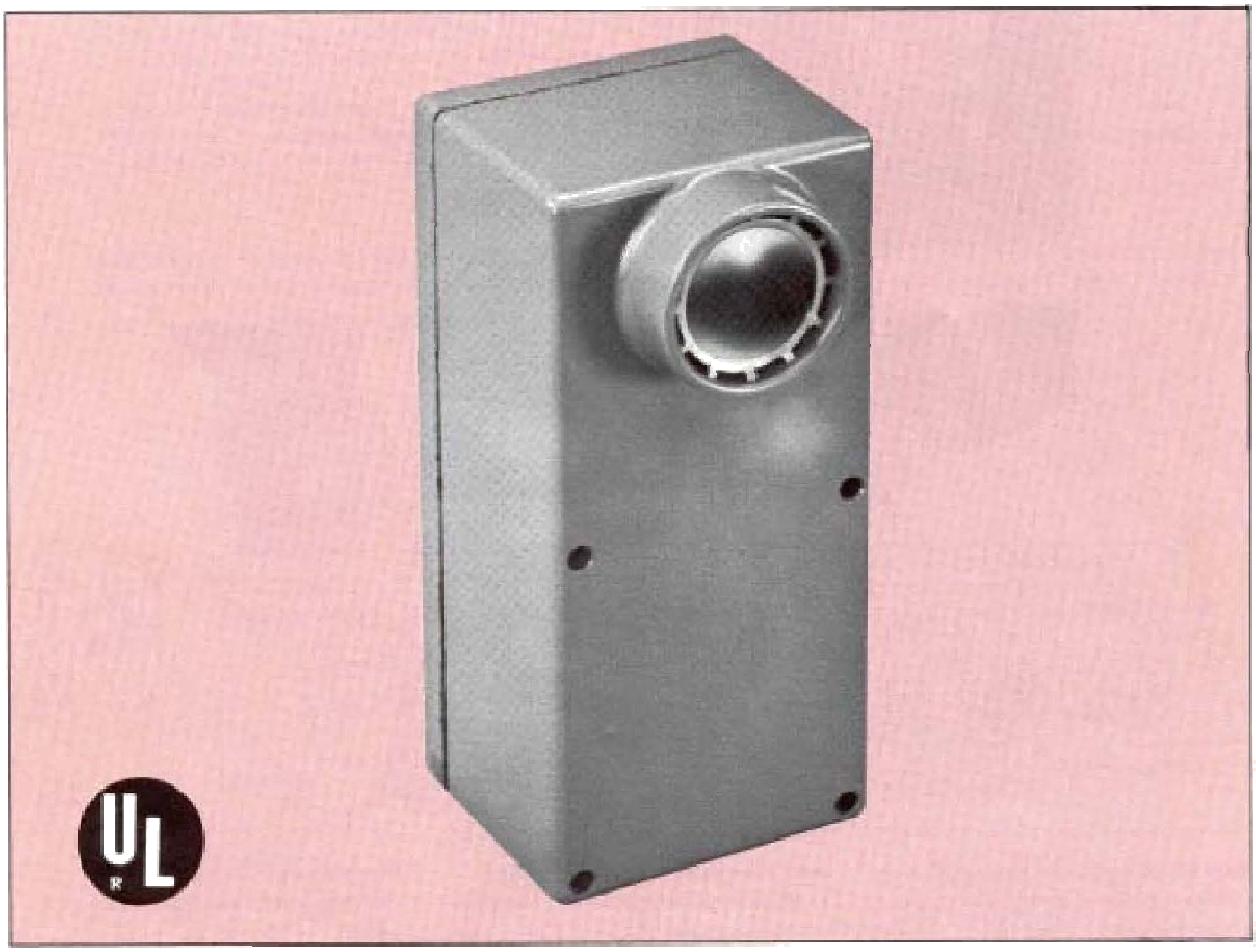
R Series General Purpose LED Controls

The R Series controls from Autotron represent the finest in general purpose photoelectrics. The rugged die cast metal case takes up only 57 cubic inches, making positioning and installing to best serve your production requirements a snap, as well as insuring long life. The R Series circuitry is field-tested with highly engineered solid state technology which provides years of trouble-free operation.

Modulated LED light allows uninterrupted operation under the brightest ambient light conditions. The indefinitely long life of the LED is unaffected by shock or vibration.

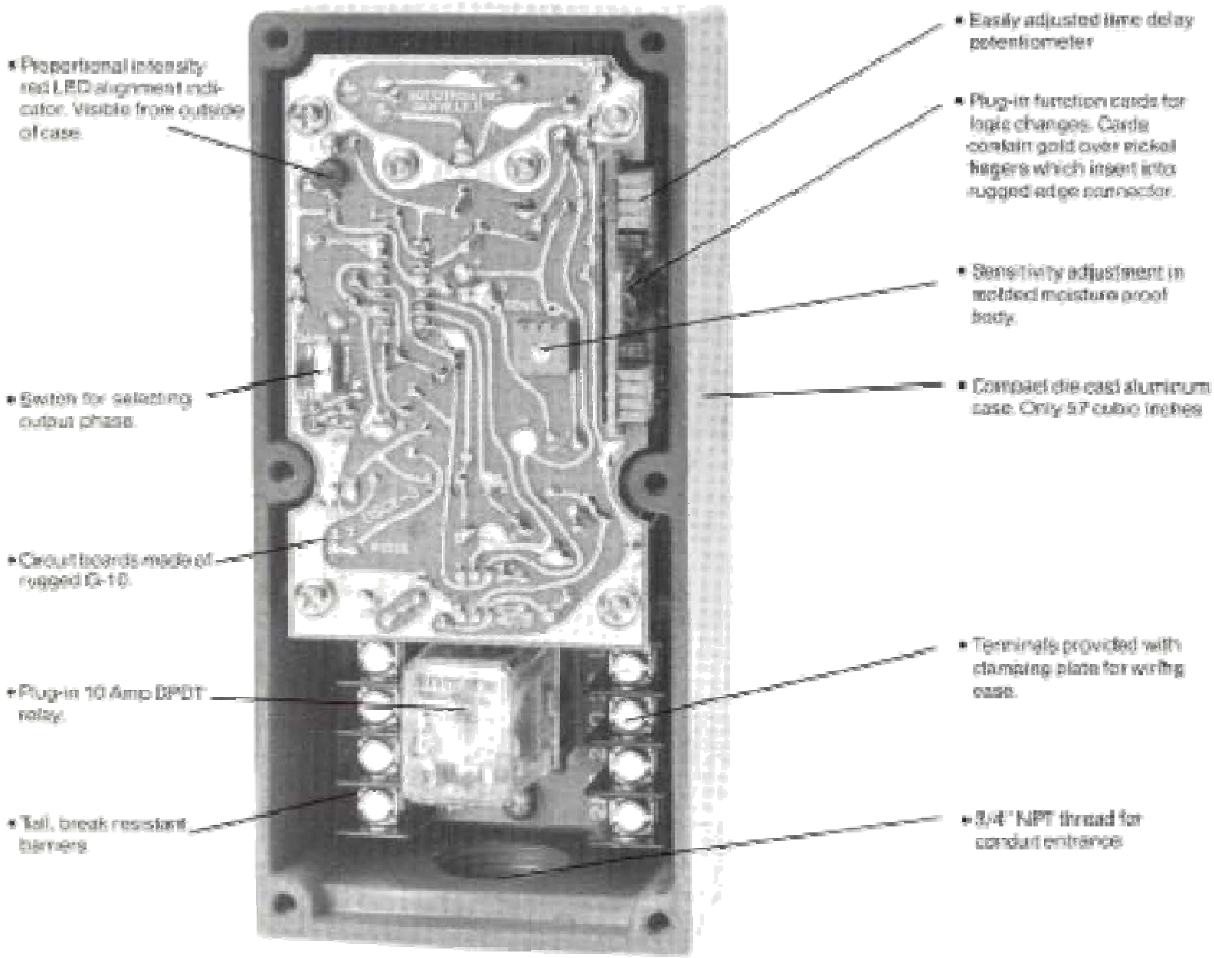
The flexibility and operation of the R Series is guaranteed through engineering thoroughness which has gained UL listing. LED alignment is made simple by a visible proportional intensity indicator. Lens wear is reduced, and lens efficiency is enhanced through the use of recessed scratch resistant glass. Control functions are changeable through a series of plug-in cards. These cards along with a choice of plug-in output options make the R series the ultimate in modular flexibility.

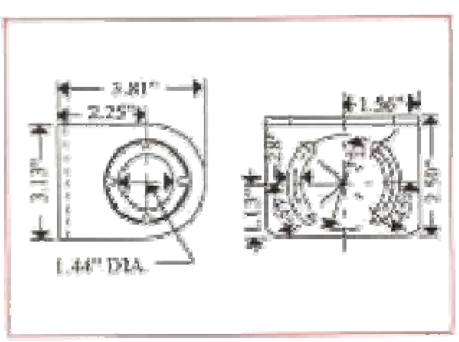
All of these elements go into making R Series controls from Autotron a dependable and cost efficient work horse, whatever your counting, measuring, or sorting needs might be.



Modulated LED Beam • Versatile

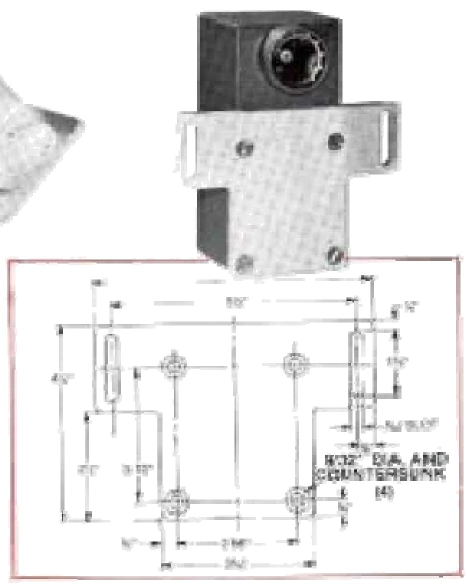
R Series Engineering Puts You in Control





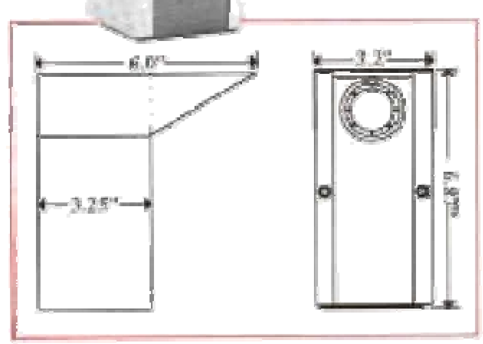
P875 Universal Swivel Bracket Option

- Allows rotation of control in all planes.
- 360° horizontal rotation.
- Made of heavy 7GA cad-plated steel.



P961 Flange Mount Bracket Option

- Allows a additional mounting capability.
- Acts as adapter bracket to A990 Series mounting.
- Made of 3/16" cad-plated steel.

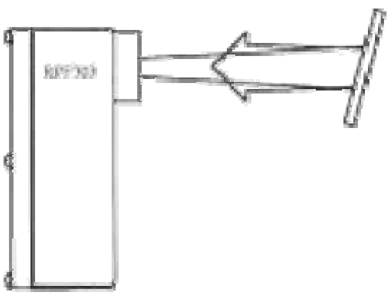


P1193 Weather Shield

- Inhibits accumulation of rain, ice and snow on lens.
- Made of lightweight gold anodized aluminum.
- Stainless steel mounting bolts provided.

METHODS OF DETECTION

RETRO-REFLECTION



A retro-reflective control generally provides a surer, simpler and more positive detection in applications where a reflector can be used.

Retro-reflective controls project light through the control lens to a retro-reflective surface, which reflects the light directly back to the control lens. The reflective surface may be up to 15° from perpendicular, and may even be vibrating. Reflective discs are more efficient reflectors than retro-reflective tape.

The gain of the control is set so that the control will *not* respond to light reflected off of the object breaking the light beam. If the object is shiny or glossy, it may be necessary to angle the light beam so that it does not strike the object at right angles.

Retro-reflective models currently offered are —

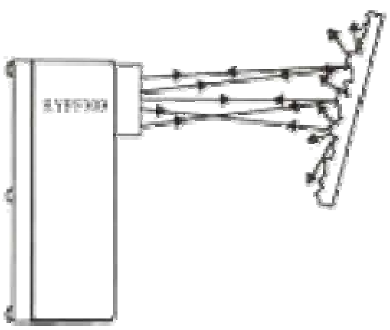
Model No.	Operation	Range Off 3" Diameter Reflector†
RPF303	On/Off	0-35 feet

(See ORDERING INFORMATION on back page for list of optional plug-in function cards.)

RANGE OFF OTHER RETRO SURFACES†

Surface	Part No.	Max. Range
3" dia. reflector	P380	35 feet
1 5/8" dia. reflector	P380A	16 feet
1 1/4" dia. reflector	P380AB	14 feet
7/8" dia. reflector	P380B	12 feet
5/8" dia. reflector	P380C	10 feet
1 1/4" x 3" reflector	P380E	20 feet
1 1/4" x 4" reflector	P380F	20 feet
1" x 1" retro tape	7610	4 feet
1" x 1" retro tape	3870	3 feet
1" x 1" retro tape	7800	2 feet

PROXIMITY (Diffuse Reflection)



Proximity controls are primarily used in applications where retro-reflectors can not be used. They sense the presence of objects by bouncing light off of the object and detecting the diffuse reflected light. They are best suited to detect the presence or absence of objects, but can be used for color detection if there is enough contrast.

Proximity models currently offered are —

Model No.	Operation	Range Off 90% Diffuse White Surface†
RXPF303	On/Off	0-6 feet
RYPF303	On/Off	0-14 inches

(See ORDERING INFORMATION on back page for list of optional plug-in function cards.)

HOW REFLECTIVITY AND DIRT AFFECT RANGE

The table below shows the typical reflectivity of various materials. This determines the minimum Excess Gain required for operation in clean air. Add additional Excess Gain for dirty environments.

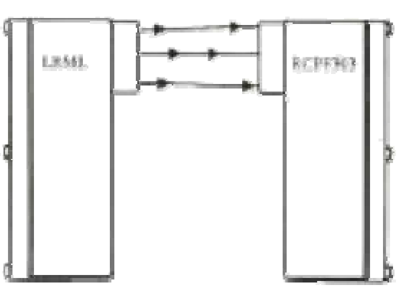
Example: If material reflectivity requires an excess gain of 2 in clean air and your dirty environment requires an excess gain of 5, then you need an excess gain of 10 (2 x 5) to detect your material in your dirty environment.

Control operating range can then be determined from the RXPF303 and RYPF303 Excess Gain graphs on page 8.

Material	Typical Reflectivity	Required Excess Gain For Clean Air
Kodak White Test Card	90%	1.0
White Bond Paper	82%	1.1
Kraft Paper	80%	1.1
Clear White Pine Wood	75%	1.2
Black Polyester Cloth	25%	3.6
Old Black Conveyer Belting	16%	5.6
New Black Conveyor Belting	9%	10.0
3M Nextel Flatblack Paint	4%	22.5

RULE OF THUMB: When distinguishing one material from another, the ratio of one reflectivity to another should be 2:1 minimum.

THROUGH BEAM



Through beam detection is generally considered better than retro or proximity detection because of greater sensing range and freedom from false detection of shiny objects. However, because of difficulty in alignment and the necessity of locating a separate light source, this method of detection is not used as often.

Through beam models currently offered are —

Model No.	Operation	Range†
RCPF303	On/Off Control	0-300 feet
LRML	Light Source	

(See ORDERING INFORMATION on back page for list of optional plug-in function cards.)

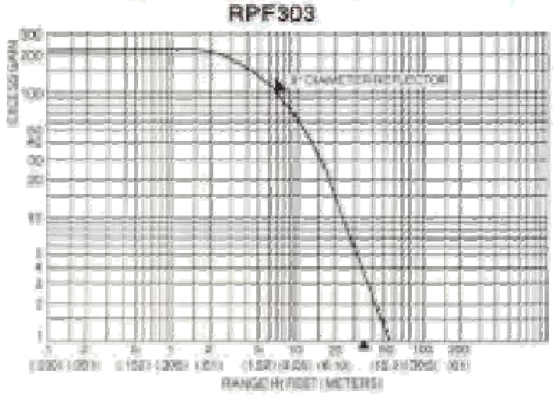
†Maximum ranges apply for clean indoor conditions only. Contact the factory for dirty or outdoor applications.

EXCESS GAIN

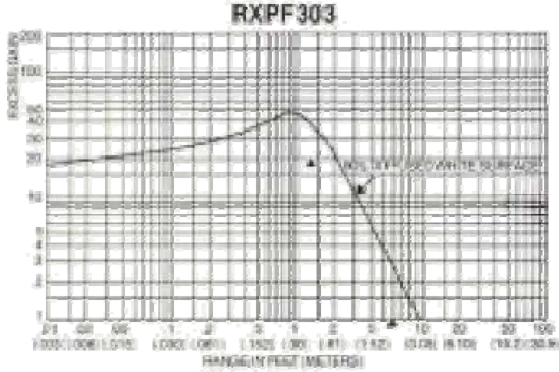
How well a photoelectric control can perform under less-than-ideal conditions is measured in terms of Excess Gain. Excess Gain is the ratio of the light signal available to the light signal necessary for the control to barely work. The graphs below plot this factor versus range from specific targets. If degrading factors such as dirt, a poorly reflective surface, or misalignment exist, an Excess Gain greater than one (1) is required. How much Excess Gain is required for the application is determined by the customer. An Excess Gain of 3-5 should be allowed for light industrial environments, and 5-8 for moderately dirty environments.

TYPICAL EXCESS GAIN vs. RANGE

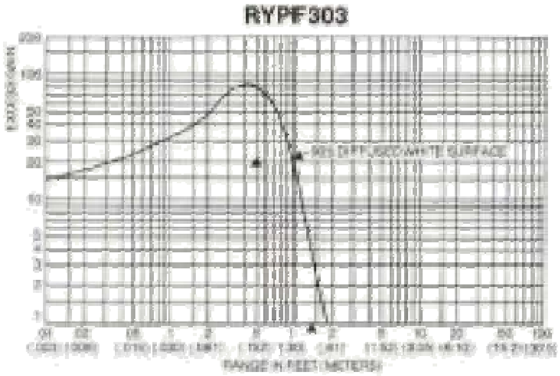
RPF303



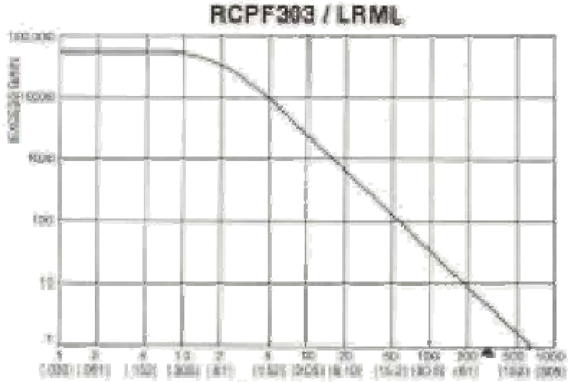
RXPF303



RYPF303

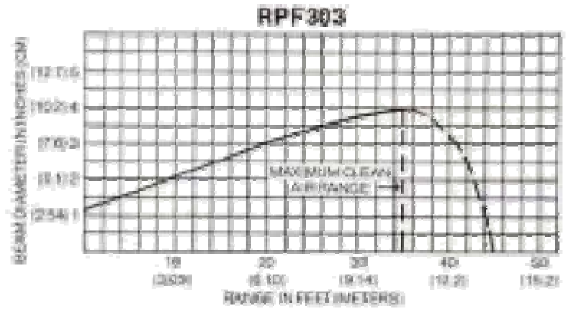


RCPF303 / LRML

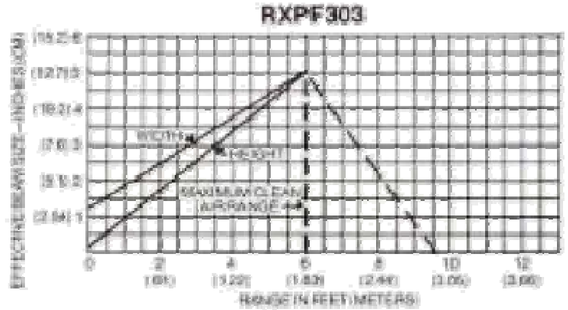


EFFECTIVE BEAM DIAMETER* vs. RANGE

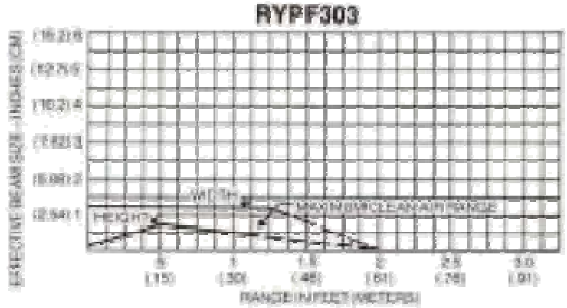
RPF303



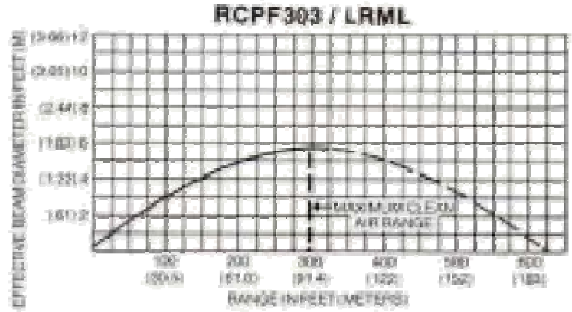
RXPF303



RYPF303



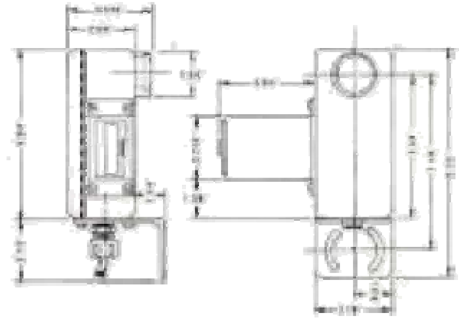
RCPF303 / LRML



* EFFECTIVE BEAM DIAMETER is defined as that portion of the radiation pattern that is sufficiently intense for detection.

A878R Counting Control Pak

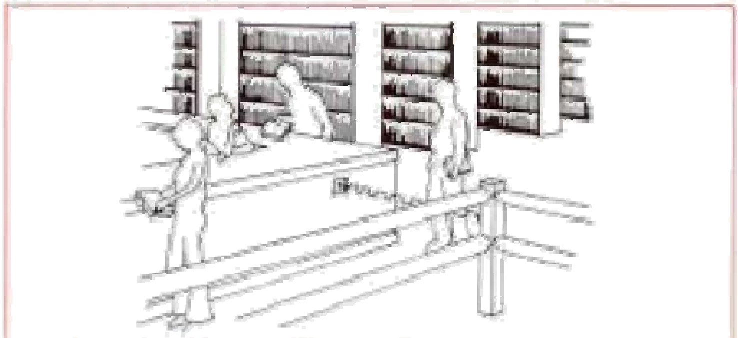
A high performance counting package with instant installation capability. Long life combined with plug-in flexibility provides a unique counting system all rolled into one neat package. The all solid-state design (including the counter) eliminates moving parts that can wear out.



FEATURES

- Packaged system comes ready to use-no wiring to do.
- Plugs into standard 120V outlet.
- Counter is 8-digit, push button reset. Counter life is independent of the total number of counts.
  Self-contained Power Supply: 8 years typical
  Maximum Count Speed: 3000 CPM
- Complete package consists of:
  RPT365 Control (logic output)
  P875 Universal Swivel Bracket
  P380 Reflector
  P1106 Solid-State Counter Assembly
  6' Cord Set with Ground
- Retro-Reflector makes alignment easy. Beam can strike reflector up to a 15° angle and still activate.
- Adjustable control sensitivity.
- Light beam distance a maximum of 35'.
- Adjustable time delay. Range is from .02 to 2.5 seconds. Provided to slow response and prevent "double counting."
- Shipping weight of 5 lbs.
- Other features and options same as R Series.
- Not UL listed.

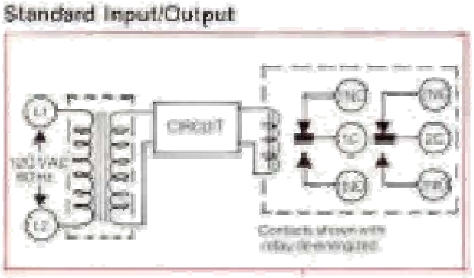
APPLICATION



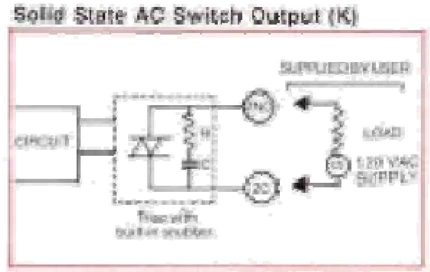
INPUT and OUTPUT OPTIONS

In addition to the standard input and output, the R Series can be supplied with any of the options shown to make the control compatible with practically any power supply and load. The optional inputs and outputs are not UL listed.

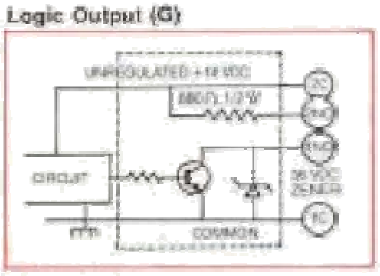
Standard Input/Output



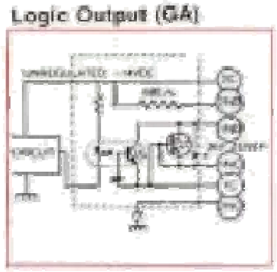
Solid State AC Switch Output (K)



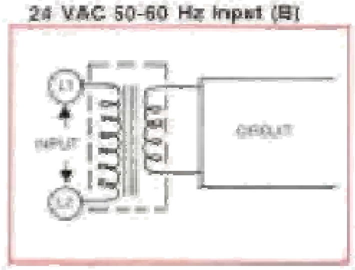
Logic Output (G)



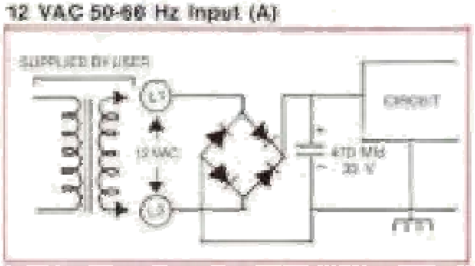
Logic Output (GA)



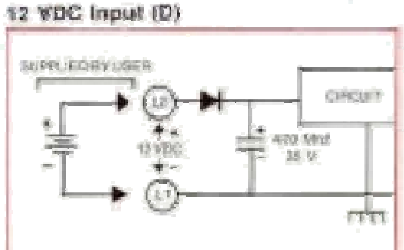
120 VAC 50-60 Hz Input (T)
230 VAC 50-60 Hz Input (E)
24 VAC 50-60 Hz Input (B)



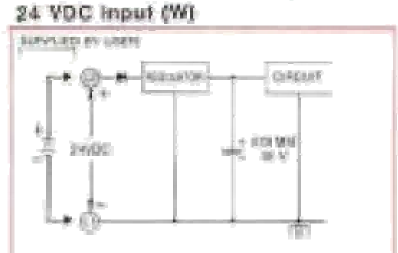
12 VAC 50-60 Hz Input (A)



12 VDC Input (D)



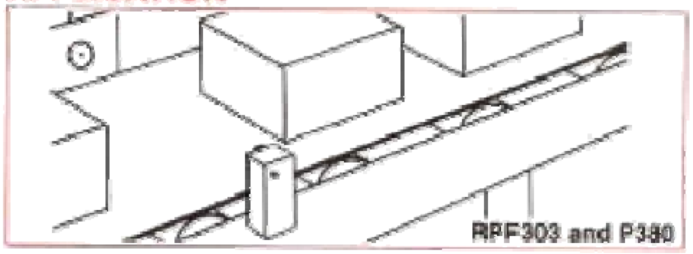
24 VDC Input (W)



FEATURES

- Multitude of industrial uses.
- Modulated LED beam. Highly immune to ambient light. Indefinitely long life.
- Plug-in relay and function cards interchangeable with other AUTOTRON Series. No card required for ON/OFF.
- Unique proportional intensity red LED alignment indicator. The better the alignment-the brighter it glows. Visible from outside of case.
- Compact, rugged die cast metal case, gasket sealed. Provides maximum shielding from electrical noise. Heavy epoxy paint protects against solvents and corrosive agents.
- Cover held tightly by six captive screws. Lip on cover prevents gasket "blow in" by external high pressure wash down.
- Metal case holds shape. Does not deform when hot or shatter when cold.
- Recessed glass lens resists scratching.
- False trip protection when power is turned on.
- Adjustable sensitivity is standard.
- Output phase selection is standard.

APPLICATION



OPTIONS

- P875 Universal swivel bracket.
- P961 flange mount bracket.
- Plug-in logic or solid state AC switch output.
- P960 weather shield.
- Anti-fog lens heater for extreme environments.
- Optional input voltages:
  - 12 VAC 50-60 Hz
  - 12 VDC
  - 24 VAC 50-60 Hz
  - 24 VDC
  - 230 VAC 50-60 Hz
  - 120 VAC 50-60 Hz

SPECIFICATIONS

Light Beam Distance - See page 3.

Input - 120V ± 10% 60Hz

Power Consumption - 5VA

Response Time - .01 sec. for circuit .03 including relay.

Output-Relay: DPDT Contacts Rated 10A, 120 VAC resistive

Lamp - GaAs infrared LED, Life-indefinitely long

Sensor - Silicon phototransistor

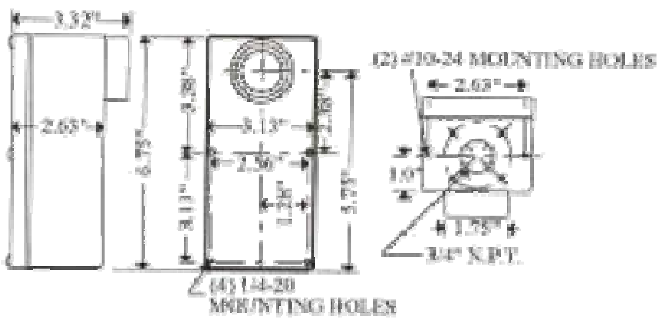
Ambient Operating Temperature Range -40°F to +131°F (-40°C to +55°C)

Ambient Light Tolerance - 10,000 foot candles

Enclosure - Die cast aluminum epoxy gray painted gasket-sealed, NEMA 1, 3, 4, 5, 12, 13, tapped in bottom for ¾" conduit

Shipping weight - 3 lbs.

For more details ask for R Series Owner's Manual (Bulletin 178)



ORDERING INFORMATION

CONTROLS

Model No.	Description
RPF303	ON/OFF Retro. Control
RXPF303	ON/OFF Prox. Control
RYPF303	ON/OFF Prox. Control
RCPF303	ON/OFF Long Range Control
LRML	Long Range Light Source
A878R	Counting Control Pak

For ordering and pricing above Model Nos. with plug-in function cards installed, substitute the Function Card No. for "F303" and add the card price.

For example, the RPF 303 On/Off Control with the T360 Single Timer Card installed is ordered as:

RPT360 Timing Control

PLUG-IN FUNCTION CARDS

Model No.	Function
T360	Single Timer, OFF Delay
T310	Single Timer, ON Delay
T320	Dual Timer
T330	One-Shot Timer
T300	Five Function Timer
T342	Two-Digit Batch Counter
T370	Delayed One-Shot Timer
T380	Shift Register
T390	Over or Under Speed Detector
T399	Output Latch
T1330	Repeat Cycle Timer
T349	Single-Digit Toggle Batch Counter

For time delays from 30 secs. to 40 hrs. Consult factory for time ranges.

T320	Long Delay One-Shot Timer
T3600	Long Delay Single Timer, OFF Delay

For more Function Card details, see Bulletin 979.

TIMING RANGES (Do not use for T3200 or T3600) Timing Ranges are specified in the last digit of the model number. The standard ranges are shown.

Range			
No. 0	.1-10 sec.		
No. 2	.005-.5 sec.	No. 6	.04-5 sec.
No. 3	.01-1 sec.	No. 7	.2-23 sec.
No. 5	.02-2.5 sec.	No. 8	.9-90 sec. (additional charge)

Others available upon request.

ACCESSORIES (ORDER SEPARATELY)

Reflectors

Model No.	Diameter
P380*	3"
P380A	1 5/8"
P380AS	1 1/4"
P380B	7/8"
P380C	5/8"
P380MH*	3" (metal housing)
P380E	1 1/4" x 3" rectangle
P3880F†	1 1/4" x 4" rectangle
3870 Tape	2" wide

*Has center mounting hole. †Has end mounting holes

Brackets and Shield

Model No.	Description
P875	Swivel Bracket
P961	Flange Mount Bracket
P1193	Weather Shield

OPTIONAL FEATURES (Consult factory for model designation)

Description

12VAC 50-60 Hz Input (A)
12VDC Input (D)
24VAC 50-60 Hz Input (B)
24VDC Input (W)
230VAC 50-60 Hz Input (E)
120VAC 50-60 Hz Input (T)
Plug-in AC Switch Output (K)
Plug-in Logic Output (G or GA)
Anti-fog Lense Heater (H)

Autotron

ELWOOD CORP.-AUTOTRON GROUP
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more sensors, more solutions

Banner Engineering - Industrial Sensors for Vehicle Detection, Overheight Detection, Parking Control and Toll Booth Applications

Email Article Print

Banner Engineering is a leading manufacturer of industrial sensors, using opto- electronics, ultrasonic, laser and magnetic-resistive technologies.

Sensor applications include vehicle detection and profiling for the traffic and rail industry. Typical applications include vehicle detection (cars, trucks, forklifts, etc.), overheight detection for tunnels and bridges, parking access control, measuring and profiling in toll booth applications and train and tram detection.

Expand Image

Multiple sensors such as optical, ultrasonic or magneto-resistive are being used for vehicle detection at a toll booth lane.

M-GAGE MAGNETIC VEHICLE SENSORS (PATENTED TECHNOLOGY)

This innovative sensor uses 3-axis magneto-resistive technology to sense large ferro-magnetic objects (such as motorcycles, cars and trucks). Its compact size allows easy mounting and installation, either above or below ground.

A simple "click-&-teach" routine stores the ambient background conditions into a non- volatile memory, after which the sensor will detect stationary or dynamic vehicles within its detection range. This makes the M-GAGE the ideal sensor to replace inductive loop technology at a much lower installed cost. In addition, this self- contained sensor requires only power, and it has a standard PNP and NPN switching output on-board.

Sensors that are mounted below ground are not required to be removed in case of rework of the road surface. A simple background re-teach is sufficient to get the sensor going again!

Expand Image

A powerful QS30 optical sensor with a 200m range, immune to direct sunlight, is being used for overheight alarm.

QS30 HIGH POWER PHOTOELECTRIC SENSORS

Banner's QS30 optical sensor is built for extreme temperature fluctuations and for high humidity conditions. With its IP69K sealing degree it can be submerged indefinitely, or exposed to high pressure cleaning at 120bar. Its optical power has been specially tuned to look through mist or fog but not miss any cars or trucks blocking its beam. It is also unaffected by direct sunlight or from optical crosstalk with other sensors.

A-GAGE MINI-ARRAY MEASURING LIGHT SCREEN SYSTEMS

Reliable information is needed for tolling applications if a car is entering the toll booth station, or if it has cleared the station. The main difficulty is that a wide variety of vehicles can come through the station: motorcycles, cars, cars with caravans, cars with trailers, light pick-ups, trucks, etc.

Expand Image

The Mini-Array measuring light curtain is ideal for

The MINI-ARRAY measuring light curtains are the standard solution for these problems. Composed of an array with multiple synchronized emitter / receiver pairs, hey will detect the car or truck starting with its bumper, but sense even the smallest parts like the towing hook. This ensures reliable sensing, or even processing the car / truck profile for automated fee calculation.

U-GAGE ULTRASONIC SENSORS

Ultrasonic sensors are unaffected by rain, fog, snow, mud, extreme lighting conditions or colour of the object to be sensed. Many of these sensors have analogue outputs (voltage or current), discrete switching outputs, or both. All sensors have a compact housing and are completely sealed for harsh environmental conditions. Sensors can be easily set up using a simple "click-&-teach" routine. Most ultrasonic sensors have built-in temperature compensation sensors to avoid any drift in sensing distance due to temperature differences.

Expand Image

Car wash sensors need to have extreme sealing degrees (such as IP69K). Banner offers optical and magneto-resistive (M-Gage) sensors.

TYPICAL APPLICATION EXAMPLES: VEHICLE DETECTION, OVERHEIGHT DETECTION AND DOCKING GUIDANCE

Car wash vehicle detection. This type of application requires sensors that correspond to the highest sealing degree possible, to avoid liquids entering the housing and affecting the electronics. Banner offers various optical, ultrasonic and magnetic vehicle detection sensors with an IP69K sealing degree. These resist continuous exposure to liquids, even at high pressure cleaning levels.

Doc

king station detection. A truck driver can be helped when backing his truck in a docking station. Ultrasonic sensors indicate the distance from the back of the truck to the docking station. Magnetic vehicle detection and optical sensors indicate that the truck is docked. After the truck drives away, the docking doors will be automatically closed.

Expand Image

For docking large trucks, ultrasonic sensors offer measuring outputs. Magneto-resistive sensors are built into the ground for detection.

Forklift entry / exit. Where forklift trucks are entering or leaving an area frequently, pull cords or transponders can be avoided by mounting multiple magnetic vehicle detection sensors below the concrete for invisible installation. These doors will only open when a forklift truck is in front of the door, and will not react to people. This avoids doors being opened by unauthorized personnel.

Toll booth detection. Banner offers measuring light curtains for vehicle detection and measurement (e.g. detecting trucks). Overheight detector optical sensors warn the tollbooth operator that the car or truck is too high. A magnetic vehicle detector can sense a vehicle to issue a ticket from an automatic ticket dispenser machine.

Please also see [Railway Technology - Banner Engineering - Industrial, Radar-Based Sensors for Train Detection]

Contact Details **Banner Engineering BVBA**
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Fax: +32 2 456 0789
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URL: www.bannereurope.com

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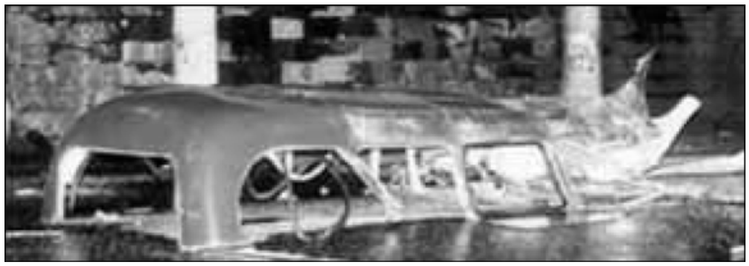
Web: http://www.coeval-group.com

Coeval
"Customers are our Business"



Overheight Vehicle Detection

Hundreds of low headroom locations throughout the world now benefit from the installation of Coeval overheight vehicle detectors. The infra-red based system, coupled with high intensity "secret" signing offer great reliability in detecting and warning drivers of high vehicles to "DIVERT or TURN BACK"

Type approved to UK Highways Agency specifications, the post mounted twin infra-red beams are normally set at the same height as the height restriction some distance farther down the road. The overheight vehicle harmlessly breaks the infra-red beams, causing the high intensity secret sign to illuminate for a short period of time. The driver then is fully aware that they are too high to pass under the obstacle ahead and takes the action to divert or turn back as the sign instructs.

Inductive loops installed in the carriageway beneath the infra-red beams can also form part of the detection logic. The loop proves that a vehicle is actually present when the beams are broken.

Several lanes of traffic can be covered as the detectors can span up to 50 metres.

IDT

Integrated Design Techniques Limited

Low Bridge Warning Systems

Minimise the risk of high vehicles striking low bridges and other structures

Each year in the United Kingdom over 1500 bridges or other low str ures are struck by overheight vehicles. Although, fortunately, most of t n do not cause injury, delays to road and rail traffic can be considerable.

IDT's overheight vehicle warning system is designed to help local authorities minimise delays caused by bridge strikes by providing dri rs of overheight vehicles with an immediate, highly visible warning that ey risk hitting a low structure.

Through careful placing of the sign, drivers are given the c

Key Information

Operational features

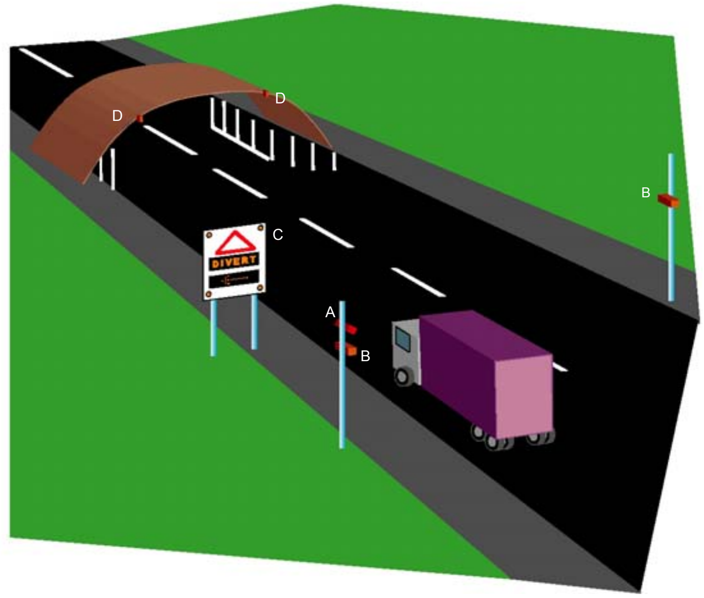
- Radio link between detector and sign means no ducting required
- Remote monitoring by mobile phone
- Distinguish between arched or girder structures
- DOT73 amberwarn lanterns

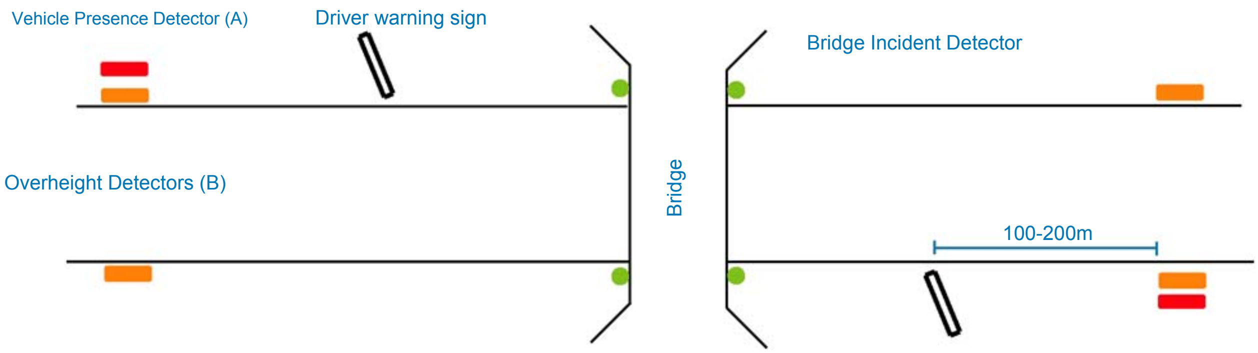
Options

- 100mm or 160mm character
- heights Bridge Incident Detection
- UTMC network interface

How the system works

The system consists of a vehicle presence detector (A) and an overheight vehicle sensor (B) installed upstream of the low structure. When an overheight vehicle is detected, a signal is transmitted by secure radio link to a variable message sign which then displays a message advising the driver to take an alternative route. A slightly more complex arrangement is required for arched bridges (see below).





Arched bridges

Where the low bridge is an arched structure, some high vehicles can pass through the bridge provided they use the centre of the highway.

In this situation, the system uses a second set of detectors at B to distinguish between 'high' vehicles (ok to pass but must use the centre of the highway) and 'overheight' vehicles (must divert).

The 'high vehicle detector' detects high vehicles and directs them through the centre of the arch. The VMS on the opposite side of the bridge simltaneously displays a warning message such as "Vehicle in centre of road".

Bridge Incident Detection

In the unfortunate event that a bridge is still struck by an overheight vehicle, a Bridge Incident Detection unit (D) installed on the bridge (or as close as possible) will detect the event.

For further information on IDT's Low Bridge Warning Systems contact us at:

Integrated Design Techniques Ltd, Endurance House, Seventh Avenue, Team Valley, Tyne & Wear, NE11 0EF

t: 0191 491 0800 f: 0191 491 0799 e: info@idtuk.com www.idtuk.com

LaserAce® IM

2
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0

OEM LASER MODULE

The LaserAce® IMunits are compact class 1 eye safe, rugged, multipurpose laser distance meters for integration into OEM applications. These laser distance measuring modules have been specifically designed for additional integration each giving a reflectorless range of up to 700m (2300ft), 300m (1000ft), 150m (500ft) and 35m (114ft) for the IM 700, IM300, IM150 and IM35 respectivly. The sensors can be integrated into a number of suitable system applications requiring, primarily distance measurement.

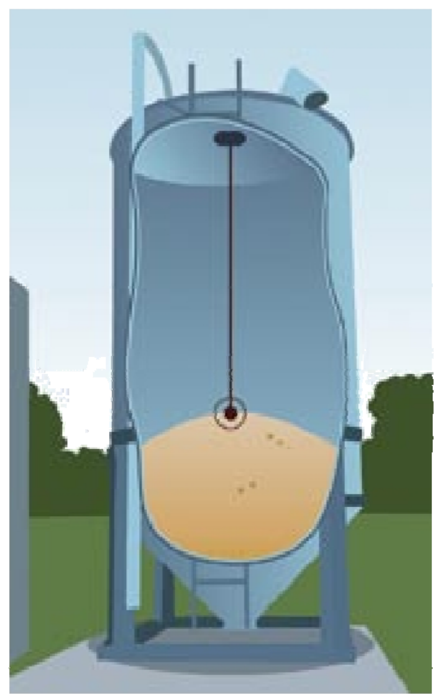
LaserAce®IMmodules can be configured to output range, speed and height of vehicles or objects and may also be set to trigger cameras in Tollbooth or Law Enforcement applications. The sensors can also be further integrated to produce vehicle profiles and scans, classify and identify them, count axles, over height detection and much more.

Alongside traffic applications the LaserAce®IM is used in Military, Security, Construction and Aviation markets. From a target designator, motion detector, surveying tool and altimeter, each market segment has its own special requirement. Here at MDL we are aware that no two applications are exactly the same so we work with our OEM partners to provide unique solutions to their individual applications and are always willing to help. LaserAce®IM is cost effective, accurate, fast and environmentally sealed to IP67 making it the most robust sensor on the market today!

The laser modules use time-of-flight technology, put simply, it measures the time taken for a very short pulse of infrared laser light to travel from one window in the module, to a very low noise detector in a second window. The distance to the target is calculated from the time taken to make the round trip.

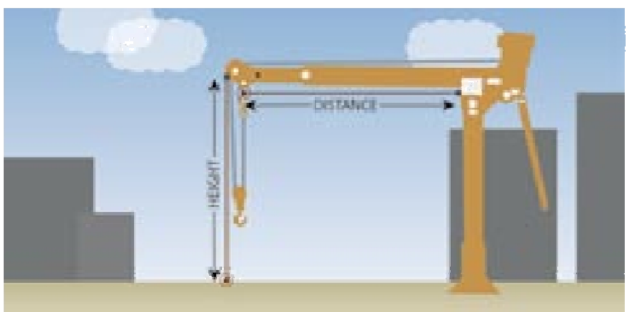
The reflected light signal levels are very low, so the greater the reflectivity of a target, the longer the range over which this target can be 'seen'. Therefore, reflective targets will increase the range of each of the LaserAce®IM modules.

Elevator Position Measurement

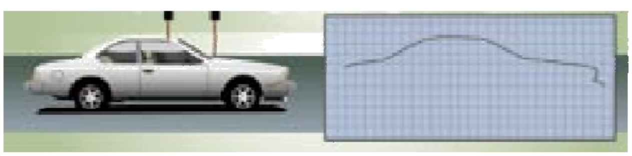


Silo Measurement

Ship Docking Measurement

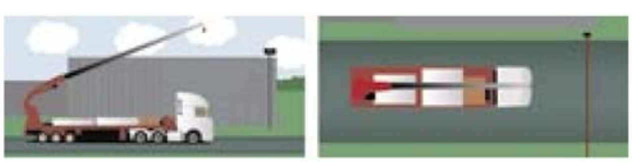


Load Height Measurement

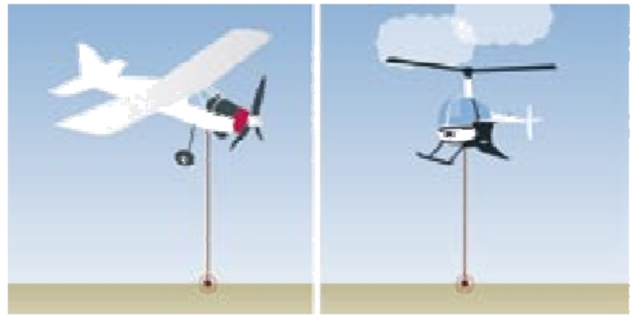


Vehicle Profiling / Height Detection

Axle Counting



Overheight / Height detection

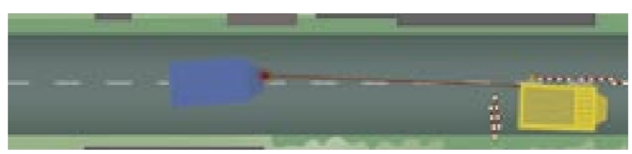


Altimetry

Car-to-Car Speed Measurement

Active Sign

Camera Trigger



Safety for Roadside Workers

Overhead Cable Measurement

We provide a set of standard systems which are designed for easy integration in all applications based on commonly required specifications. Other variations are available and customisations can be provided for OEM integrators. Please talk to us about your application and needs so that we can show you how our LaserAce®IM modules can help you.

Accessories

- Sighting Scope: Aligned to the laser beam to visually see where the target currently being ranged is located.
- Red Dot Pointer: An additional red laser pointer, aligned to the mesuring beam to locate the current target.

LaserAce® IM-R

MDL's standard laser module with a repetition rate of 9Hz. This unit is used in airborne laser altimetry, distance measurement and collision avoidance.

The LaserAce® IM-HR

The high repetition rate distance meter, with a rep rate of up to 1000Hz. This unit is faster than the standard 'R' version and is also used in airborne laser altimetry, distance measurement, excess height measurement and traffic applications.

The LaserAce® IM-T

A Fixed distance high-speed camera trigger. This unit is ideal for integration into a camera system for vehicle recognition, vehicle classification, profiling and speed detection.

The LaserAce® IM-S

An OEM speed and distance meter used to detect speeding vehicles.

High repetition rates of measurement allow continuous distance measuring and speed calculation.

Please note that for our OEM customers we can customise the modules output information and repetition rate.

MDL

Agent:

For more information on **LaserAce® IM** please visit **www.laserace.com**

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www.mdl.co.uk

LaserAce®IMRev-0106/02/06

P. BERGHAUS

Fachbetrieb und Mitglied im
Verein für Verkehrstechnik
und Verkehrssicherung e.V.

HM Height measuring system PB 12/230

Technical data:

Care tension:
12 V DC and 230 V AC

Reach of the light barrier: 0 to 60 m

Protection kind: IP 67

Equipment of the light barrier: front heating and weather protection bonnet

Our new height measuring system was conceived for such areas with which it can come by disregard of heights and way through limitations to serious accidents. The measuring system HM PB 12/230 with direction recognition grasps with the two special light barriers oversized vehicles.

If such is grasped, the system for five seconds releases an acoustic signal. Two about 30 meters ahead put up 300 mm of high-luminous two-aspect signal heads (LED) are switched about yellow to long-term-red. The oversized vehicle is stopped.

The transfer to reserve of the system occurs according to option by means of key, about time module, radio or SMS. The height measuring system can be built up with our mobile stand system simply and fast at every place. The care tension occurs about 12 V accumulator or 230 V net. The control is accommodated in a watertight (IP 66) lockable case and owns serially net battery changeover, under voltage and polarity reversal protection.

All parts, like light barriers, horn, signal head and key tracer are connected about watertight plug connectors IP 67.

Areas of application are, for example: underpasses, bridge building works, tunnel entrances, halls entrances or multi-storey car- park entrances.

P. BERGHAUS

SAM

Sensing and Activating Module Laser Sensor for Vehicle Detection

- **Over height detection**
- **Determination of vehicle height**
- **Determination of traffic lanes**
- **Drawbar Identification**

SAM

SCHUH&CO SYSTEMTECHNIK VERKEHRSTECHNIK

SAM

Application Area

Modern systems for traffic surveillance , traffic guidance and control require reliable sensoring. In contrast to conventional methods, laser sensors offer distinctive advantages. Owing to the optical mode of functioning of the laser detectors, the road construction remains untouched, in addition they can be installed and serviced without interferring with the flow of traffic.

SAM

SAM (Sensing and Activating Module) is an infrared laser detector offering various possibilities for traffic surveillance. Due to the exceptional technology used for analysis SAM recognises objects in 12 selective range slots. Presence and distance information together result in a markedly fail-save and more precise analysis. The tightly focussed and modulated infrared laser beam, in connection with the employed narrow band filters, is insensitive to sunlight, fog and snow fall. These are considerable advantages over other optical detectors. SAM is able to detect stationary as well as moving vehicles, cyclists, pedestrians and objects up to a minimal size of 5 cm.

Application

SAM is excellently suited for the following application purposes:

Over height detection
to control vehicle heights before bridges and tunnels

Identification of vehicle classes
to distinguish passenger cars from trucks / buses / street cars

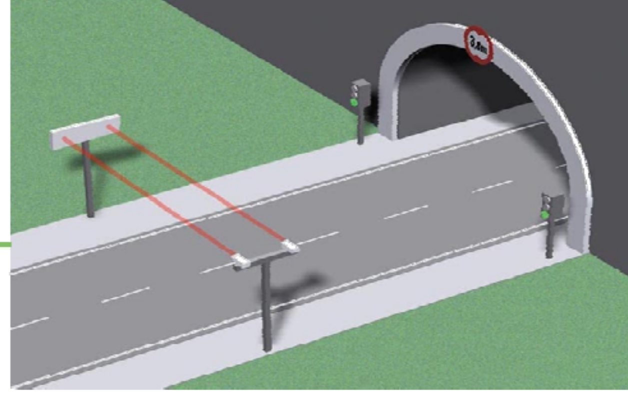
2-range-detection
lane distinction of vehicles based on distance measurements

drawbar detection
drawbar detection between truck and trailer, to distinguish from close individual car traffic.

The Company

The technical expertise of **Schuh & Co. GmbH** is complemented with sound organisational and economical know-how. More than 30 years of experience in the realisation of complex projects in traffic engineering are the sound basis for the successful management of new customer oriented tasks.

Please feel free to contact us. We would like to advise you without obligation to win you as a satisfied customer.



SAM-S over height control

To prevent damages on the structure or equipment of tunnels (lighting, signals, ventilation), it is advisable to control the height of all vehicles at tunnel access for exceeding the headroom. In the normal case, height control at two positions is recommended. At the first position the driver of a vehicle with over height is requested by an active warning sign to leave the road at the next exit. At the second position, light signals will block tunnel access in case of alarm.

Advantages

The SAM over height control system recognises even small objects (minimum of 5 cm) at a speed of up to 100 km/h. Roads with a width of up to 32 meters can be controlled for height with an accuracy of 2 cm. Two SAM-S sensors work as reflection light barriers in this appliance. This way, only one electrical installation is required on one side. On the opposite side a passive reflector is to be mounted. Due to special beam widening, adjustment is very simple and there are no problems to be expected from percussions or the swaying of the supporting pole.

The Controller

The signals of both sensors - and inductive loops, if they exist - are logically combined in the controller to avoid false alarms that could be caused by birds or falling leaves. Additionally, the signal quality of the sensors is constantly monitored and an event of fault will be reported by a separate output. The over height alarm output allows to activate warning signs, flashing lights or traffic signals. All events will be logged in the controller to allow the complete documentation of SAM operation.

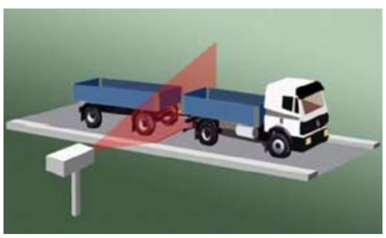
SAM

Vehicle Detection

Owing to the sharply focussed laster beam, SAM detects objects reliably even at great distance and in adverse weather conditions. Pointing across the direction of traffic, SAM detects - dependent on the height it is mounted at - all vehiclies or only vehicles starting at a minimum height. This way, light-signal systems,barriers or gates can be selectivly operated and controlled.

2-Range-Detection (Lane Detection)

SAM is able to recognize that part of its own laser beam that has been reflected by an object. The distance of the reflecting object can then be determined from the travelling time of the light. Being mounted pointing across the direction of traffic and across two lanes, SAM is able to determine the lane a vehicle is on. In this configuration, SAM is able to control light signal system, for instance at bus terminals and factory exits. Dependent on the lane they are on, vehicles can request a left or right turn.



Drawbar Detection

SAM-E is equipped with lenses, that widen the laser beam by 12º to a line. This way, a large area can be scanned optically. Objects inside the laser beam triangle reflect part of the light and will be detected. This configuration is mainly employed in fully-automatic tollgates where SAM is used to distinguish truck trailers from individual vehicles by detecting the drawbar between truck and trailer.

SAM Technical Data

Dimensions ex. tube	180 x 135 x 105 mm
Dimensions tube incl. heating	456 x 135 x 105 mm
Weight	1,8 Kg
Enclosure rating	IP67
Operation temperature	- 25° C bis +60° C
Laser	850 nm pulsed, 10 mW ,safe to the eye
Power supply	24V +/- 10%
Power consumption	100 mA
Heating power supply	24V +/- 30%
Heating current	max. 1A
Output signals	2 x RS485
Communication Interface	RS485
Operating mode display	ultra bright LED

SAM-S (Overheight Detection)

Operation method	reflex sensor
Beam (spot)	0,5 °
Detection range	3 m – 32 m
Reaction time	2 ms

SAM (Vehicle Detection)

Operation method	proximity sensor
Beam (spot)	0,5 °
Detection range	3 m – 20 m
Reaction time	10 ms

SAM-E (Drawbar Detection)

Operation method	proximity sensor
Beam (line)	12 °
Detection range	1 m – 10 m
Reaction time	10 ms

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Internet: www.schuhco.de

SCHUH & CO
SYSTEMTECHNIK
VERKEHRSTECHNIK

HiSic450

overheight Vehicle detection in front of Bridges and tunnels

detection of vehicles with overheight

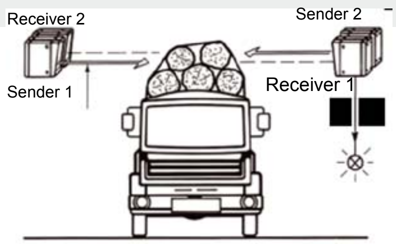
The HISIC450 detects vehicles which are too high – at tunnel entrances, low underpasses or bridges, for exam- ple. Stop and alarm signals are imme- diately activated when a vehicle in- fringes the light beam.
The HISIC system is typically of a re- dundant design consisting of two sub- systems, installed parallel to each other. Each are fitted with a sender and a receiver. The light beams across the road at required monitoring height. Any interruption of the light beam by an overheight vehicle sets off an alarm signal, and trafficlights switch to red for instance. Response- and OFF-delay times are selectable across a wide range allow- ing moving obstructions with a mini- mum diameter of 100 mm, travelling at a speed of up to 100 km/h to be reliably detected.

The usual operating distance of the HISIC450 is 100 m (330 ft) with a scanning range of 300 m (980 ft). As a rule, the width of carriageways is less than 25 m (80 ft), so the received signal strength is enhanced and there is sufficientlightin reserve to cope with difficult weather conditions, i.e. rain, snow or dust clouds. However, these atmospheric influences can not cause a false alarm.

complete systems from one source

Our measurement systems for use in traffic, road or tunnel control are ba- sed on the perfect combination of pre- cise optics and high speed intelligent electronics.
The systems are characterized by:

- high reliablity
- robust and weather proof construc- tion,
- easy to operate and low mainte- nance requirements
- modular and extendable design



Key features

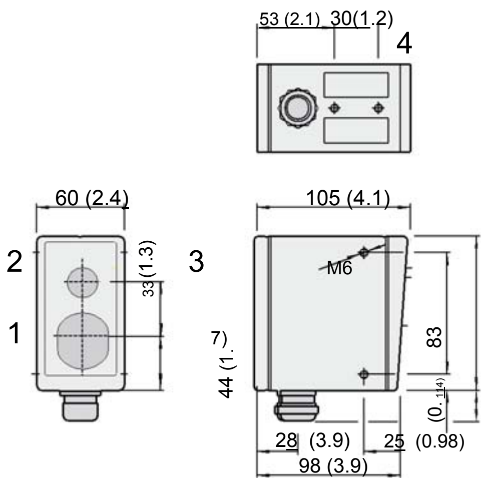
- Robust cast aluminium housing, sealed to IP 67
- Built-in lens heaters to prevent condensation or icing (option)
- Weather protection against snow, rain and dust clouds
- Optical alignment equipment
- Sensitivity adjustment
- Ambient light insensitivity
- Wide power supply range from 24 up to 240 V UC (universal)

SICK | MAIHAK
Analyzers and Process Instrumentation

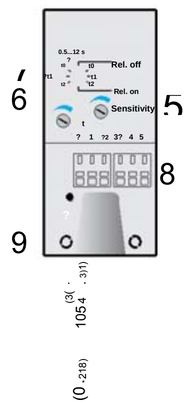
8006248/2006-01 • DIV03/BW • Printed in Germany (2006-02) · Subject to change without prior notice

HiSic450 components

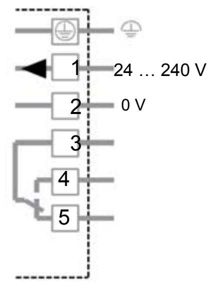
dimensions HiSic450 in mm (in)

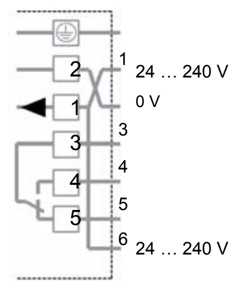


Possible adjustments



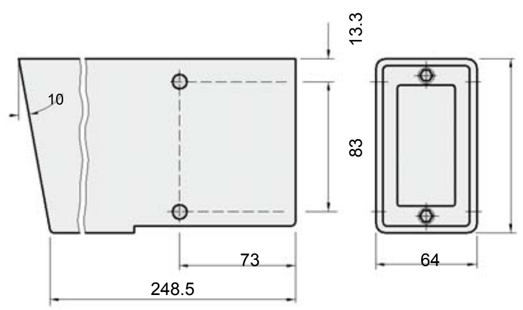
connection diagramm



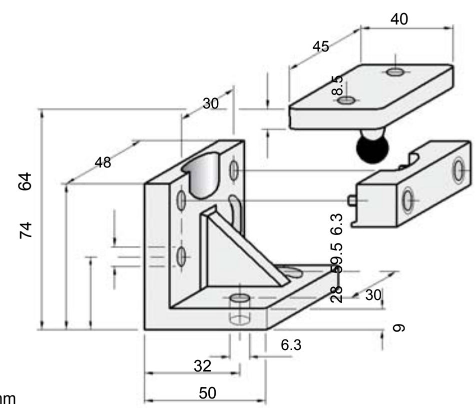


1 Center of optical axis, sender, center of optical axis, receiver
2 View finder
3 LED signal strength indicator
4 Threaded mounting hole M6 x 8
5 Sensitivity adjustment
6 Time adjustment
7 Time delay selector switch; left light-switching, right: dark-switching
8 Terminal strip
9 Status indicator

dimensions dust protection



dimensions Ball joint bracket



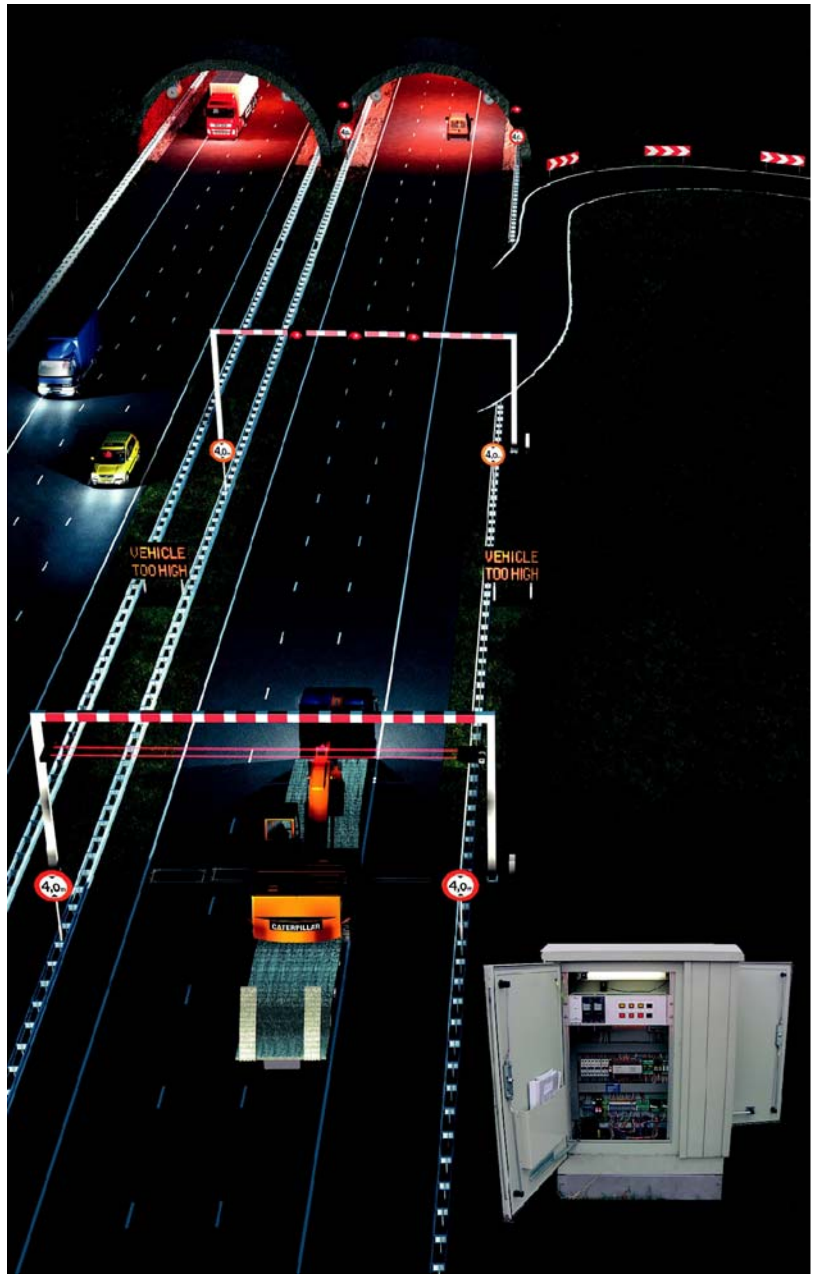
Dimension in mm

technical data	HiSic450 (WS/WE45)	HiSic450 (WS/WE transistor)
Scanning range	300 m (980 ft)	300 m (984 ft)
Supply voltage	24 … 240 V UC (universal)	10 ... 60 V DC
Current/power consumption	250 mA/6 VA	≤ 500 mA
Light transmitter	LED, infrared, pulsed	LED, infrared, pulsed
Average life time	100,000 h	100,000 h
Switching outputs	SPDT, electrically isolated	PNP, Q and $\bar{Q}$
Max. switching voltage	120/250 V AC/DC	
Max. switching current	2/4 A AC/DC	200 mA
Max. braking capacity	120 W/750 VA AC/UC	
Max. response time	≤ 10 ms; max. switching frequency 10/s	≤ 500 µs, max. switching frequency 1000/s
Protection class	IP 67	IP 67
Weight	approx. 800 g (1.7 lb)	approx. 800 g (1.7 lb)
Contamination signal		100 mA, open collector

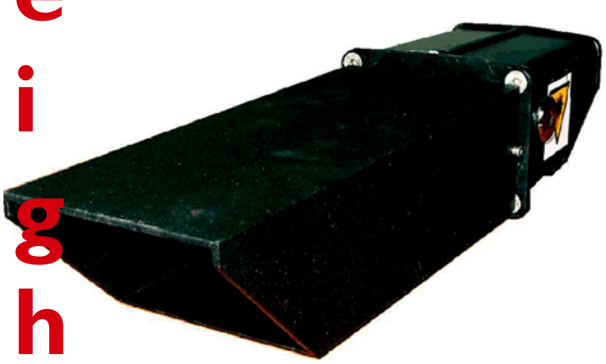
P

L a s e r o v e r H e i g h

To prevent vehicles that are too high for tunnels or low overpasses to cause severe damage,a reliable of these vehicles is necessary.TEC Traffi c Systems supplies and installs, for this application specifi cally developed laser detectors.The alarm contact is used to give early warning to operators or to set a number of automatic measures in action.



The basic principle is that a pulsating laser beam, which is projected at a certain height above the road surface, gets interrupted when (part of) a vehicle passes through it. An important plus of the detector is that it needs only to be installed on one side of the road, with a refl ection plate on the opposite side of the road. It has a reach of approximately 30 meters.
The laser is capable of detecting objects no smaller than 5 centimeters, traveling at 100 km/h, regardless of shape or colour. The laser is usually applied in a double confi guration, in combination with an inductive loop on each lane underneath the laser beam, as to maximize accuracy.
Consequently birds e.g. fl ying through the beams will not generate an alarm.



Neither mist nor snow will influence the operation signifi cantly.The lenses are equipped with heating elements to prevent condensation.Lengthened sun visors prevent the lenses from being obstructed by snow.
One installation consists of a roadside cabinet,a double laser detector and mounting constructions on existing gantries which provide for a variable height adjustment.

industries
TRIGG
international

Traffic Engineering Products

Overheight Vehicle Detection and Warning Systems

Overheight Vehicle Detection and Warning Systems (OVDS)

What Does Trigg Industries OVDS Do?

- Detects overheight vehicles and warns drivers of an impending problem.
- Directs the driver via warning signs and warning bells to take corrective action.
- Provides secondary warning beyond existing signage in the interest of public safety.
- Reduces exposure to costs associated with incidents or accidents.
- Proven to minimize or eliminate the occurrence of accidents and incidents caused by overheight vehicles.

Industry Standard

- The standard for quality and performance in all environments for thirty-five years.
- Integral to hundreds of state, county and municipal infrastructures coast to coast.
- SystemofchoiceforBostonCentralArteryTunnelProject,Cumberland Gap Tunnels, Queens Tunnel and 25 DOTs.
- We provide technical support and documentation from the planning stage through installation.

Applications

- Bridges
- Tunnels
- Overpasses
- Airport Overhangs/Walkways
- Temporary Falsework
- Parking Structures
- Equipment Yards
- Railroads
- Car Carriers
- Logging Trucks

Cost Benefit

One accident usually exceeds the cost of a complete detection and warning system. Trigg Industries OVDS adds an additional layer of protection and helps to minimize or eliminate costs associated with:

- Injury or loss of life
- Emergency Response
- Traffic Delays
- Administrative costs
- Structural Repair
- Insurance Premiums
- Dispute or Litigation
- Media Publicity

Highest Reliability and Quality Control Standards

Installed in some of the most adverse conditions worldwide. Proprietary cabinet design and internal environmental control allows continuous operation in fog, ice, snow, dust and heat. Systems meet ISO/IEC Guide 22 Compliance, CE Mark, NEMA 3R Cabinet Enclosure Rating, CALTRANS lightning and hi/lo voltage parameters. We provide extensive documentation and Factory Acceptance Testing protocols.

Innovation

The Trigg Industries Patented Z-Pattern™ Red/Infrared dual beam array provides the most advanced ability to reject ambient light and virtually eliminates false overheight alarms. Fault Detection and Alert Function notifies Central Control Facility when system is operating in Single Eye Mode (temporary condition) or has experienced a line power failure. Double and Single Eye systems also offer Fault Detection and Alert Function.

Ease of Use

Trigg Industries provides specialized mounting brackets for all systems and all elements of the system that allow it to be attached to any sturdy structure. Installation instructions are direct and easy to follow.

Descriptions

Device	Description
OVDS	Point of detection and direction discernment. Four categories of systems, encompassing ten different models for a wide range of applications. Sweep
Audible Alarm	of sight is attracted by alarm. First alarm after detection and second above message sign.
Warning Signs	Standard Warning Sign with alternating flashers includes custom message providing directions to drivers of overheight vehicles.
Extras	Variable LED Message Signs (VMS) available in two, three and four line formats. PC programmable.
	Poles, sirens, bells, strobes, solar power, loop detector, radio frequency link and alternate mounts available.

Concept

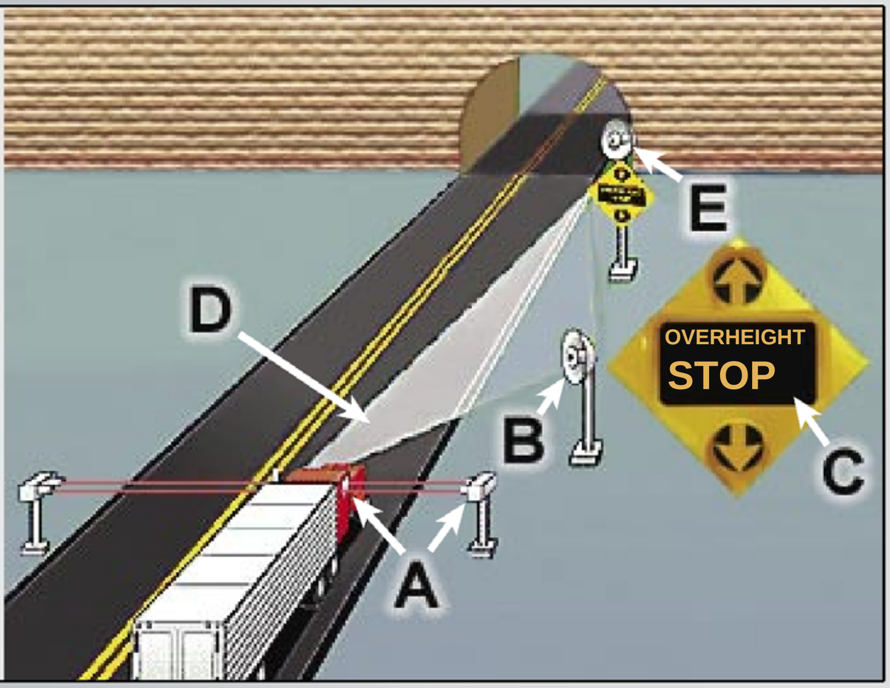
A. Overheight vehicle is detected by OVDS

B. First Alarm Bell activated

C. Warning Sign activated

D. Vehicle driver is alerted - first by sound, then by sight

E. Second Alarm Bell activated

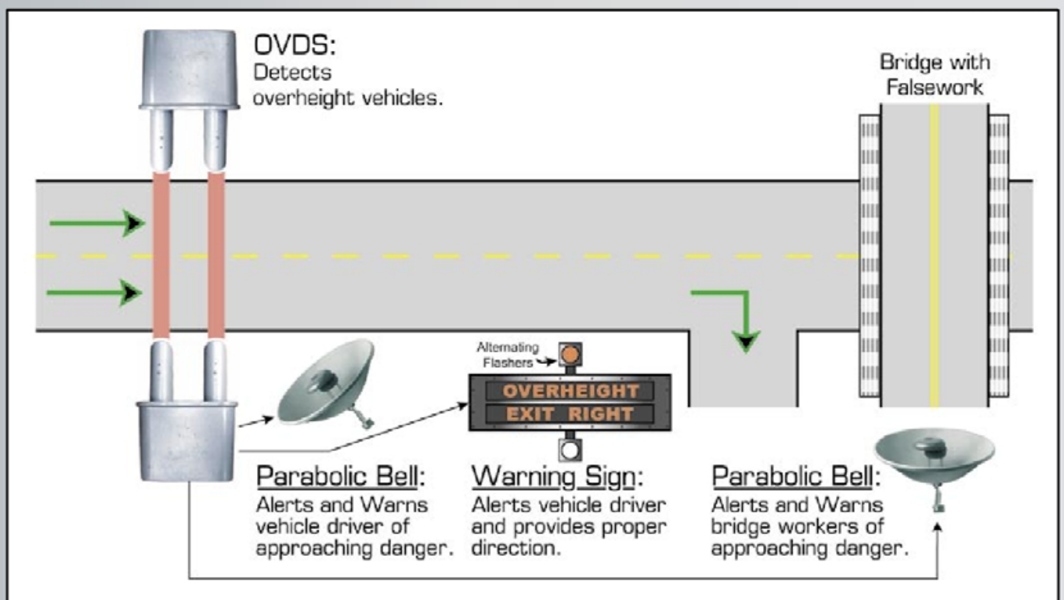


Applications

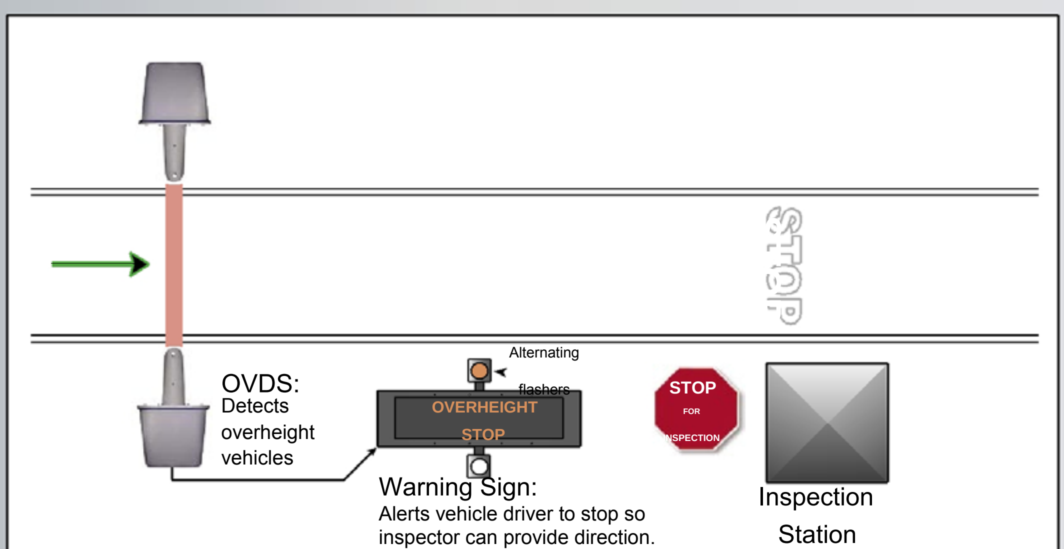
Trigg Industries manufactures complete systems, including detectors, warning signs, alarms, mounting poles and all needed accessories. We build to meet US and International power requirements, as well as AC and solar (DC) configurations.

Trigg Industries offers technical options to meet varying requirements and can provide cost effective solutions for virtually any overheight warning requirement. Custom systems can be provided as required.

- Bridges
- Tunnels
- Overpasses
- Temporary Falsework
- Railroad Tunnels
- Airport passenger drop-off overhangs and pedestrian walkways



- Weigh Stations
- Load Height Verification for:
  - Equipment Yards
  - Car Carriers



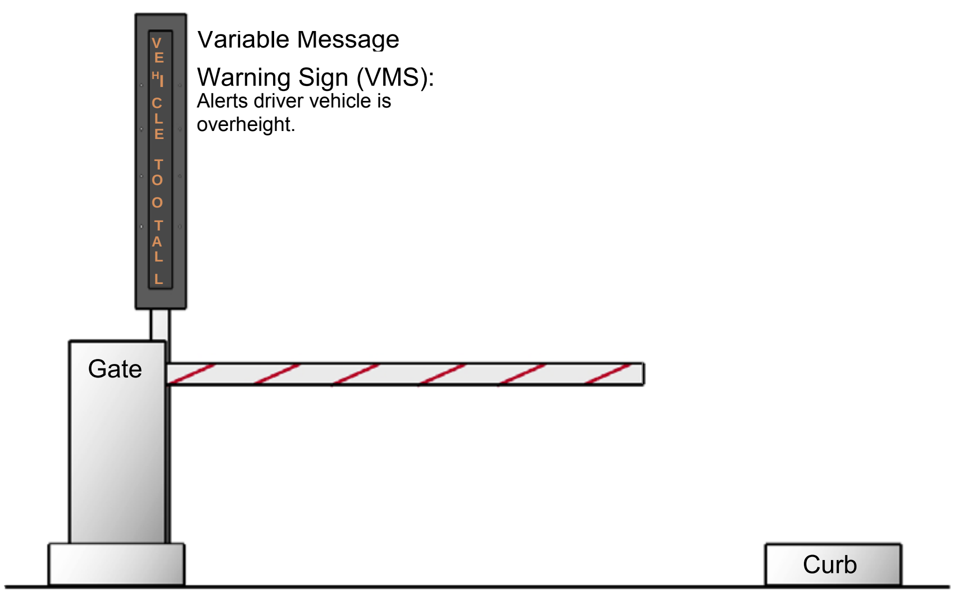
Metro Economy OVDS installed inside parking structure detecting a single height.

Dual Single Eye OVDS installed outside parking structure detecting two different heights.

EXAMPLE:
- If vehicle is detected by OVDS #1, driver is instructed by VMS to park where clearance is adequate.
- If vehicle is detected by OVDS #2, driver is instructed by VMS to stop and await further direction.

If a vehicle is overheight, the Variable Message Sign (VMS) displays a sequence of messages instructing driver where or where not to park. The gate can be delayed from opening while messages are displayed.

EXAMPLE:
- Message 1: STOP
- Message 2: “VEHICLE TOO TALL”
- Message 3: “PARK LEVEL 1 ONLY” or “DO NOT ENTER”



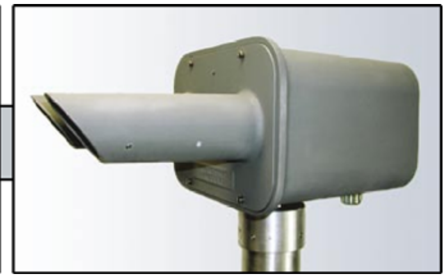
Double Eye Z-Pattern •

Visible Red and Infrared

Model #: 3400-Z, 3401-Z, 3402-Z, 3403-Z

- *Patented Visible Red / Infrared Mixed
- Environmental control
- Enhanced rejection of ambient light
- Fault detection and reporting
- Nema 3R cabinet rating
- Direction discerning
- Proprietary ALMAG cabinet design


Remote

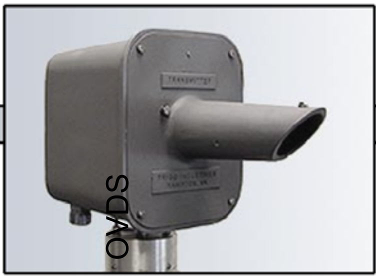

Master

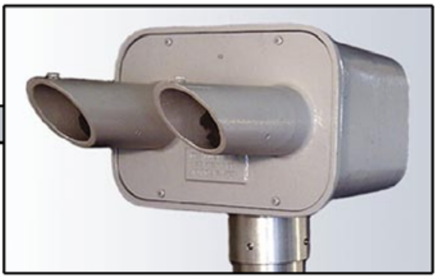
INPUT POWER	115VAC, +/- 10%, 50/60HZ. Other options include 24VDC solar or 230VAC, +/-10%, 50/60HZ operation.
OUTPUT	Two Form C, dry relay contact closures for Overheight Alarm Functions. One Form C, dry relay contact closure for Fault Reporting. Contacts rated 115VAC 10A, protected by 8A circuit breakers.
FAULT REPORTING	**DE-Z/3400** - Fault reporting output upon loss of source/detector power or total failure. **DE-Z/3401, 3402, 3403** - Fault reporting output upon loss of source/detector power or total failure. Fault Relay toggles at one-second intervals during Single Eye Mode of operation.
ALARM TIME	**DE-Z/3400** - Adjustable by customer from 2 to 30 seconds. **DE-Z/3401, 3402, 3403** - Adjustable by customer from 5 to 60 seconds.
ELECTRONICS	Sensors are NEMA 6P enclosure rated.
EFFECT OF AMBIENT LIGHT	Use of Dual Beam “Z” Pattern provides automatic switch to Single Beam Detection Mode of Overheight Protection if the sun or other interference saturates one detector.
MAXIMUM RANGE	700 feet (213 m). Suggested maximum range 200 (61 m) feet to allow for bad weather and lens contamination.
DIRECTION SELECTION	Selection switch. No tools or adjustment required.
ALIGNMENT	Four LEDs and meter (GO-NOGO functions) provided for ease of alignment and testing.
REACTION SPEED	1 to 75 MPH (1 to 121 km/h) for a 2 inch (50 cm) diameter object 1 inch (3 cm) above the detection height. Custom speed/size available.
TEMPERATURE RANGE	-40° to +135° F (-40° to +57° C).
ENVIRONMENTAL CONTROL	Internal thermostat controls air flow which reduces moisture and maintains internal temperature during cold weather.
HOUSINGS	External housing is heavy ALMAG casting and sheet aluminum (not less than 1/8 inch or .318 cm thickness) for rugged durability and extended life. Cabinet design minimizes effects of vandalism and provides rigid mounting. The pole cap serves as a mounting bracket and sighting base with our poles. NEMA 3R Certified.
DIMENSIONS	Remote Cabinet: 12¾ x 16½ x 8½ inches (32 x 42 x 22 cm). Master Cabinet: 12¾ x 18¾ x 8½ inches (32 x 48 x 22 cm).
SHIPPING WEIGHT	60 lbs (27 kg).

Double Eye

Visible Red or Infrared

Model #: DE-R/3110 or DE-IR/3111


Transmitter


Receiver

- Visible Red or Infrared systems
- Fault detection and reporting
- Environmental control
- Meets Nema 3R Intent
- Direction discerning
- Proprietary ALMAG cabinet design

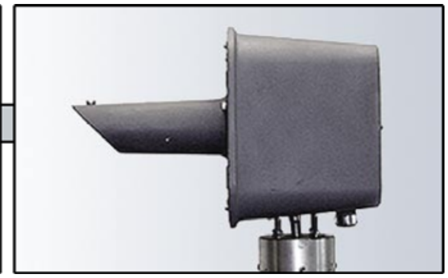
INPUT POWER	115VAC, +/- 10%, 50/60HZ. Other options include 24VDC solar or 230VAC, +/-10%, 50/60HZ operation.
OUTPUT	Form C, dry relay contact closure, contacts rated 115VAC 10A, protected by an 8A circuit breaker. System switches to Single Eye Mode of operation upon loss of either detector.
FAULT REPORTING	Optional fault reporting output upon loss of power, transmitter failure or either eye blocked for more than 13 seconds. Single Eye mode of operation implemented.
ALARM TIME	Adjustable by customer from 1 to 30 seconds. Custom alarm times available.
ELECTRONICS	Sensors are NEMA 6P enclosure rated. Electronic printed circuits for years of reliable operation.
EFFECT OF AMBIENT LIGHT	**DE-R/3110** - Sunlight immunity of 10,000 foot-candles. **DE-IR/3111** - Very high noise immunity.
MINIMUM RANGE	10 feet (3 m).
MAXIMUM RANGE	**DE-R/3110** - 800 feet (244 m). Suggested maximum range 200 feet (61 m) to allow for bad weather and lens contamination. **DE-IR/3111** - 700 feet (213 m). Suggested maximum range 200 feet (61 m) to allow for bad weather and lens contamination.
DIRECTION SELECTION	Selection switch. No tools or adjustment required.
ALIGNMENT	Two LEDs and meter (GO-NOGO functions) provided for alignment. No special tools required.
REACTION SPEED	1 to 75 MPH (1 to 121 km) for a 2 inch (5 cm) diameter object 1 inch (3 cm) above the detection height. Custom speed/size available.
COUNTER	Records the number of activations.
TEMPERATURE RANGE	-40° to +135° F (-40° to +57° C).
ENVIRONMENTAL CONTROL	Internal thermostat controls air flow which reduces moisture and maintains internal temperature during cold weather.
HOUSINGS	External housing is heavy ALMAG casting and sheet aluminum (not less than 1/8 inch or .318 cm thickness) for rugged durability and extended life. Cabinet design minimizes effects of vandalism and provides rigid mounting. The pole cap serves as a mounting bracket and sighting base with our poles. Meets NEMA 3R intent.
DIMENSIONS	Transmitter: 15½ x 10 x 8¾ inches (39 x 2 x 22 cm). Receiver: 12¾ x 16½ x 8½ inches (32 x 42 x 21.59 cm).
SHIPPING WEIGHT	45 lbs (20 kg).

Single Eye

Visible Red or Infrared

Model #: SE-R/3310 or SE-IR/3311

Transmitter



Receiver

- Visible Red or Infrared systems
- Environmental control
- Fault protection and reporting
- Non-direction discerning
- Meets Nema 3R Intent
- Proprietary ALMAG cabinet design

INPUT POWER	115VAC, +/- 10%, 50/60HZ. Other options include 24VDC solar or 230VAC, +/-10%, 50/60HZ operation.
OUTPUT	Form C, dry relay contact closure, contacts rated 115VAC 10A, protected by an 8A circuit breaker.
FAULT REPORTING	Optional fault reporting output upon loss of power, transmitter failure or either eye blocked for more than 13 seconds.
ALARM TIME	Adjustable by customer from 1 to 30 seconds. Custom alarm times available.
ELECTRONICS	Sensors are NEMA 6P enclosure rated. Electronic printed circuits for years of reliable operation.
EFFECT OF AMBIENT LIGHT	**SE-R/3110** - Sunlight immunity of 10,000 foot-candles. **SE-IR/3111** - Very high noise immunity.
MINIMUM RANGE	6 feet (2 m).
MAXIMUM RANGE	**SE-R/3110** - 800 feet (244 m). Suggested maximum range 200 feet (61 m) to allow for bad weather and lens contamination. **SE-IR/3111** - 700 feet (213 m). Suggested maximum range 200 feet (61 m) to allow for bad weather and lens contamination.
ALIGNMENT	One LED and meter (GO-NOGO functions) provided for alignment. No special tools required.
REACTION SPEED	1 to 75 MPH (1 to 121 km) for a 2 inch (5 cm) diameter object 1 inch (3 cm) above the detection height. Custom speed/size available.
COUNTER	Records the number of activations.
TEMPERATURE RANGE	-40° to +135° F (-40° to +57° C).
ENVIRONMENTAL CONTROL	Internal thermostat controls air flow which reduces moisture and maintains internal temperature during cold weather.
HOUSINGS	External housing is heavy ALMAG casting and sheet aluminum (not less than 1/8 inch or .318 cm thickness) for rugged durability and extended life. Cabinet design minimizes effects of vandalism and provides rigid mounting. The pole cap serves as a mounting bracket and sighting base with our poles. Meets NEMA 3R intent.
DIMENSIONS	Transmitter: 15½ x 10 x 8¾ inches (39 x 25 x 22 cm). Receiver: 12¾ x 16½ x 8½ inches (32 x 42 x 22 cm).
SHIPPING WEIGHT	40 lbs (18 kg).

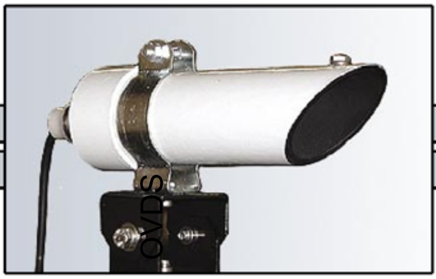
Metro Economy

Visible Red

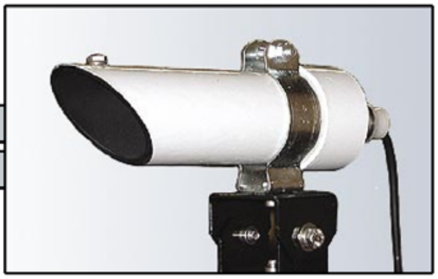
Model #: ME-R/301

Model #: ME-R/305 or ME-R/310

- Visible Red system
- Nema 6P rating
- Light weight PVC cabinet



Transmitter



Receiver

INPUT POWER 230VAC, +/-10%,	115VAC, +/- 10%, 50/60HZ. Other options include 12/24VDC solar or 50/60HZ operation.
OUTPUT protected by 5A fuses.	Two form C dry relay contact closures. Contacts rated 115VAC 5A,
ALARM TIME Other times available	**ME-R/301 & ME-R/305** - Adjustable by customer from 2 to 30 seconds. on request. **ME-R/310** - Duration equal to time beam is broken.
ELECTRONICS Electronics use printed circuit	**ME-R/301 & ME-R/305** - Sensors are NEMA 6P enclosure rated. board for reliable operation. **ME-R/310** - Sensors are NEMA 6 enclosure rated.
EFFECT OF AMBIENT LIGHT	Sunlight immunity of 10,000 foot candles.
MINIMUM RANGE	**ME-R/301** - 6 feet (2 m). **ME-R/305 & ME-R/310** - 1 foot (.3 m).
MAXIMUM RANGE feet to allow for bad	**ME-R/301** - 800 feet (244 m). Suggested maximum range 200 (61 m) weather and lens contamination. **ME-R/305 & ME-R/310** - 80 feet (24 m). Suggested maximum range 40 (13 m) feet to allow for bad weather and lens contamination.
ALIGNMENT required.	GO-NOGO green LED indicator provided for alignment. No special tools
REACTION SPEED object 1 inch (3 cm)	**ME-R/301** - 1 to 75 MPH (1 to 121 km) for a 2 inch (5 cm) diameter above the established height of detection. **ME-R/305 & ME-R/310** - 1 to 11 MPH (1 to 121 km) for a 2 inch (5 cm) diameter object 1 inch (3 cm) above the established height of detection.
HOUSINGS	Schedule 40 PVC shell and NEMA 6P eye enclosure.
HIPPING WEIGHT	20 lbs (9 kg)

APPENDIX B

Company	Phone Number	Fax Number
ASTI Transportation Systems	302-328-3220	302-328-4051
Autotron	800-637-2546	414-764-4296
Banner Engineering	322-456-0780	322-456-0789
Coeval Group	(+)44 1875-814 555	
Internaltional Road Dynamics Inc.	306-653-6600	306-242-5599
Measurement Devices Ltd.	281-646-0050	281-646-9565
IDT	191-491-0800	191-491-0799
Peter Berghaus GmbH	(+)49 2207-9677-11	(+)49 2207-9677-80
Schuh & Co.	(+)49 (0) 89 89 41 31-0	(+)49 (0) 89 84 02 226
TEC Traffic Systems	(+)31 30-6023-000	(+)31 30-6023-029
Sick Maihak	952-941-6780	952-941-9287
Trigg Industries Inc.	323-845-9390	323-845-9503

APPENDIX C

Proposed Solution to Limit Over-height Bridge Impact

Indianapolis, In