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Alerting Lights on Locomotives

SUMMARY

In 1991, the Federal Railroad Administration (FRA) Office of Research and Development initiated a locomotive conspicuity research program with the Volpe Center, to evaluate experimental locomotive alerting light devices and patterns. The FRA Office of Safety used the results in its rulemaking activity, initiated in response to a 1992 congressional mandate to issue interim regulations to improve conspicuity of locomotives to motorists. Preliminary results of the program were considered by FRA in issuing of two interim rules in 1993 and 1994. Upon conclusion of the program in 1995, the research results served as the basis for the final rule issued in 1996 and amended in 2003 and 2004.

The study consisted of two components: (1) technology assessment and (2) human perception and recognition. The technology assessment addressed the luminous intensity, flash rate, cost of auxiliary lighting components, and the potential for a selected auxiliary lighting system to reduce the number of accidents at highway-rail grade crossings. It consisted of literature reviews, laboratory tests, and 3 years of in-service testing of a triangular alerting pattern using active warning crossing lights in combination with standard headlights, shown in Figure 1. The human perception and recognition research consisted of controlled field tests to evaluate the ability of three auxiliary lighting systems to enable motorists to recognize the locomotive as a potential hazard and estimate its arrival at a grade crossing. Each system consisted of a pair of auxiliary lights (crossing lights, ditch lights, or roof-mounted strobe lights) that formed a triangle with the headlights, shown in Figure 2.

Figure 1. Alerting Light Triangle Using Auxiliary Crossing Lights

All three alerting light systems evaluated in the human perception and recognition tests were found to be more effective as warning devices than standard headlights alone. FRA regulations now require use of one of those systems.

The crossing light system provided the greatest advance warning of train arrival at the grade crossing during the human perception and recognition tests. Data from the technology assessment indicated a potential for significant accident rate reduction with use of the crossing light system.

BACKGROUND

In the 1970s, the Volpe Center conducted several studies on improving train conspicuity through use of locomotive alerting lights, such as oscillating headlights, rotating beacons, crossing lights, ditch lights, ground lights, and roof-mounted strobe lights. Field evaluations showed that two strobe lights used in a triangular configuration with a standard headlight was the most effective system. Subsequent in-service tests identified the use of roof-mounted xenon strobe lights as an effective means to alert motorists to approaching trains. FRA published rulemaking initiatives on use of auxiliary external alerting light systems in 1978, 1979, and 1982. Public comments, however, raised questions on alerting light effectiveness, cost, and reliability, and the initiatives were discontinued.

Improvements in existing locomotive alerting devices were made throughout the 1980s, and new devices were invented. In 1991, FRA initiated a locomotive conspicuity research program with the Volpe Center. This included testing of triangular patterns combining the standard headlight with different auxiliary lights. In 1992, Congress required the Secretary of Transportation to complete locomotive conspicuity research and to issue interim regulations on locomotive conspicuity. As a result, FRA continued and expanded the Volpe Center research program through the duration of the rulemaking activity, ending in 1995.

RESEARCH OBJECTIVES

Technology Assessment

- Evaluate the physical properties and performance of alerting light system components to be used on locomotives.
- Compile data on equipment, installation, and maintenance costs associated with the experimental lighting arrangements.

Human Perception and Recognition

- Collect and analyze data on the detectabiltiy of experimental lighting arrangements as a warning to motorists of an approaching train.
- Collect and analyze data on motorists' ability to estimate the arrival of an approaching train to a grade crossing.

RESEARCH METHODS

Technology Assessment

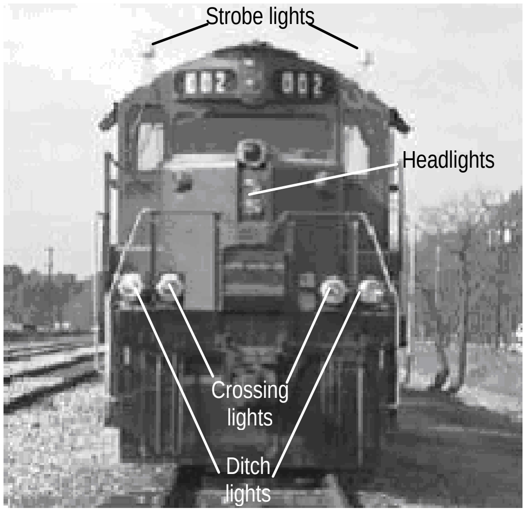
A literature survey was conducted to identify the requirements for a triangular lighting pattern combining locomotive headlights and auxiliary alerting lights in use or planned for use in the early 1990s. The survey included comparison of those requirements with Federal Aviation Administration (FAA) and U.S. Coast Guard (USCG) requirements, based on physical conditions and operational characteristics of the vehicles, aircraft, or vessels.

In November and December 1992, laboratory tests were conducted to measure the performance of three strobe lights and a steady-burn headlight identified during the literature survey. The intensity, flash rate, and pattern design of the alerting light components were measured.

A 3-year railroad in-service test program of a triangular locomotive alerting light arrangement using crossing lights was initiated in 1993 on 3 railroads: Caltran commuter service on the San Francisco Peninsula Corridor, Conrail, and Norfolk Southern. The program evaluated (1) purchase and installation costs associated with crossing lights, (2) maintenance requirements for the crossing lights, and (3) the impact of the lighting pattern on accident rates. The crossing lights were operated in steady-on mode while the locomotive was traveling, except for a 30-second alternately flashing interval following sounding of the locomotive horn. Pre-installation accident data on the test program railroads for the 3 years before the program were compared with accident data during the program.

Human Perception and Recognition:

In November 1993, controlled field tests were conducted to compare the detectability of three auxiliary lighting systems with a pair of conventional headlights. Each experimental system consisted of a triangular pattern combining a pair of auxiliary lights with the conventional headlights. The auxiliary lights tested were roof-mounted strobe lights, ditch lights, and crossing lights. Two locomotives, shown in Figure 2, were equipped with a pair of headlights and a pair of each type of auxiliary lights. A locomotive was operated through a simulated 90^{o}-angle grade crossing with one of the triangular patterns activated or simply with the headlights activated. Observers performed three tasks: (1) visual monitoring, (2) peripheral detection, and (3) estimation of train arrival time to the grade crossing. The tests were performed in daylight and darkness.



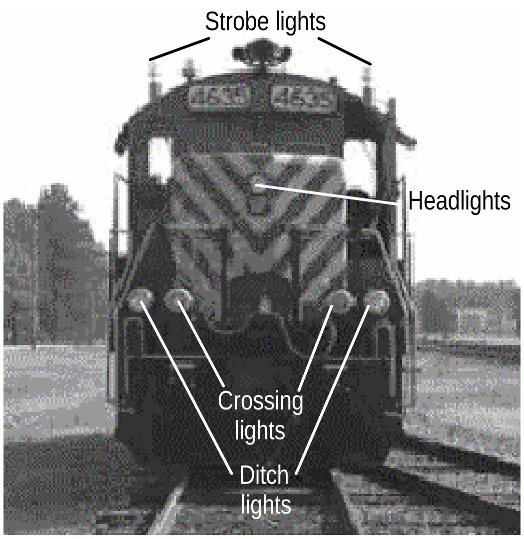


Figure 2. Locomotives Used in Controlled Field Tests

The ditch lights were pointed outward at 15^{o} from the centerline of the locomotive, and the crossing lights were pointed at 0^{o}. The crossing lights and the strobe lights were operated in flashing mode. The ditch lights were operated in steady-on mode.

FINDINGS AND CONCLUSIONS

The findings and results of both components of this study were the basis for the regulatory provisions related to locomotive auxiliary lights. Interim provisions were published on February 3, 1993, and were amended in a second interim rule issued in 1994. These provisions were issued as a final interim rule, in 49 CFR, Part 229.125 (d) through (h) and Part 229.133, in 1996. Part 229.133 established a uniform distinctive pattern by requiring spacing requirements for two ditch, crossing, or strobe lights, which (in combination with the headlight) form a three-light triangle. The provisions in Part 229.133 were later superseded by similar provisions in the revised Part 229.125, published in 2003 and amended in 2004.

Technology Assessment

Almost all of the auxiliary alerting light components used by the railroad industry at the time of testing in 1992 exceeded the criteria for intensity and flash rate that were issued as part of the first interim rule in 1993. The only exceptions were two strobe light components that did not meet the requirements for intensity.

The pattern requirements contained in the 1994 FRA Interim Rule were found to be consistent with FAA and USCG requirements based on physical conditions and operational characteristics of the vehicles, aircraft, or vessels.

The average capital (equipment and installation) costs of each of the auxiliary light systems tested were estimated at approximately $2,600 per end of the locomotive, in the mid-1990s.

The life of the flashing bulbs used in crossing lights was expected to be shorter than that of the steady-burn bulbs used in ditch lights or standard headlights, making the expected maintenance costs of crossing lights higher than those of ditch lights. The strobe lights had a very long life cycle because they had no moving parts. A strobe light, however, was not a standard replacement part, making its expected maintenance costs similar to those of crossing lights.

In-service test accident statistics for the three participating railroads show significant grade crossing accident reduction potential for locomotives equipped with the crossing light system, compared with those with standard headlights only. Analysis of accident data provided by CalTrain, Conrail, and Norfolk Southern indicated an accident reduction of 76.4 percent, 74.3 percent, and 54.6 percent, respectively.

Use of auxiliary alerting lights was expected to have only minimal impact on the workload of train operators because activation of the lights could be automated with tie-ins to other activation tasks.

Human Perception and Recognition

The results of the controlled field tests indicated that the triangular lighting pattern used with each type of auxiliary lights (crossing, ditch, and strobe) increased detectability of the locomotive compared with the use of the standard headlights alone. Each system provided a distinctive, uniform light pattern that motorists could recognize as signifying a locomotive.

The crossing light system provided the best overall performance. The increase in detection distance provided by the crossing light system (over that of the ditch and strobe systems and the standard headlights alone) was statistically significant, providing a greater safety margin.

Table 1. Mean Detection Distance and Time

Alerting Light System	Detection Distance	Time to Crossing at 25 mph
Crossing Lights	464 ft (1548 m)	42.2 sec
Ditch Lights	417 ft (1391 m)	37.9 sec
Strobe Lights	413 ft (1377 m)	37.6 sec
Headlight Alone	377 ft (1257 m)	34.3 sec

REFERENCES

Use of External Alerting Devices To Improve Locomotive Conspicuity. Carroll, A.; Multer, J.; Markos, S. Final Report. July 1995. DOT/FRA/ORD-95/13; DOT-VNTSC-FRA-95-10.

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KEYWORDS:
Alerting lights, human perception and recognition research, locomotive, grade crossing, auxiliary light system