To the Graduate Council:

I am submitting herewith a thesis written by Chau L. Pham entitled "Subjective Evaluation of Retroreflective Conspicuity Markings: Marking Systems to Aid in Increasing Visibility of Coal Hoppers at Passive Railroad Grade Crossing". I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Industrial Engineering.

John C. Hungerford

Dr. John C. Hungerford, Major Professor

We have read this thesis
and recommend its acceptance:

John N. Lincoln

Wayne Claycombe

Robert E. Ford

Accepted for the Council:

Carolyn Winkel

Associate Vice Chancellor
the Dean of The Graduate School

SUBJECTIVE EVALUATION OF RETROREFLECTIVE CONSPICUITY MARKINGS: MARKING SYSTEMS TO AID IN INCREASING VISIBILITY OF COAL HOPPERS AT PASSIVE RAILROAD GRADE CROSSING

A Thesis

Presented for the

Master of Science

Degree

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ABSTRACT

This project had two primary objectives. The first objective was to design and administer a single questionnaire as part of a modified Delphi technique to obtain expert evaluations of eleven experimental retroreflective railroad car conspicuity marking systems. The second objective was to use the collected data and apply three different statistical techniques to evaluate what the expert respondents "perceive" to be the most effective marking system to increase the visibility of coal hoppers. The application of retroreflective markings to railcars is a novel idea, based on research that has shown retroreflective markings applied to large trucks improve conspicuity.

Results from the study found that there was a definite consensus on which markings were the most and least effective passive retroreflective hopper car markings to be used as a warning device. The results of this study have reduced the number of marking designs to be laboratory tested. The most effective hopper car marking was #8 followed by #3, and #6 respectively. Each of the three were yellow markings on a black coal hopper. The least effective marking was #11 followed by #7. The #11 was the standard non-retroreflective marking. The results seem to indicate that yellow markings are preferred on black coal hoppers.

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CHAPTER I

INTRODUCTION

The Problem

Since the early 1980's, the number of fatalities and injuries caused by collisions between motor vehicles and railroad cars has remained relatively constant (Accident Facts, 1991). Literature indicates a correlation between the number of casualties and available funding for the installation of active warning systems at railroad grade crossings (Richards and Hungerford, 1993).

In 1992, a total of 500 deaths and 2000 nonfatal injuries was attributed to collisions between motor vehicles and railroad cars. Motor vehicles deaths occur more frequently in rural areas, while nonfatal injuries occur more frequently in urban areas (Accident Facts, 1993). Statistics show that: 1) over 50% of the accidents occur at railroad grade crossings with active warning systems, 2) approximately 50% occur at night, 3) nearly 80% occur in good weather, 4) passenger cars are involved in 80% of the accidents, versus 20% for trucks, and 5) the vehicle driver is typically familiar with the crossing.

Six basic crossing accident types have been identified. They are: 1) a motor vehicle is hit by a train, 2) a motor vehicle hits a stopped train, 3) a motor vehicle hits a moving train, 4) a motor vehicle hits a stationary object at the crossing, 5) motor vehicles collide at the crossing, and 6) a pedestrian comes in contact with a moving train (Richards and Hungerford, 1993). Railroad car conspicuity enhancement has been proposed as a cost-effective means of reducing grade crossings accidents described as type 2 and 3 that occur at night. It is believed that railroad car conspicuity enhancement will improve vehicle driver detection, recognition, and reaction when the railcar is illuminated by an

approaching motor vehicle's head lamps. While this application may benefit all crossings, the greatest accident reduction may occur at rural crossings with passive controls. The application of retroreflective markings to railcars is a novel idea, based on research that has shown retroreflective markings applied to large trucks improve conspicuity (Richards and Hungerford, 1993).

Objectives of the Research

The objectives of the overall research were: 1) creation of expert generated candidate designs for further evaluation, 2) evaluation of candidate designs using a questionnaire (modified Delphi technique) and jury techniques, to reduce the number of designs, and 3) evaluation of design characteristics such as patten, color, and placement using a laboratory, computer-based, real time designed experiment to study detection, recognition, and errors. Ultimately all phases of the research would lead to recommendations concerning the effectiveness of various hopper car conspicuity markings. The research process consists of four distinct phases. They are: 1) the selection of participants and the application of the nominal group technique to generate retroreflective markings for railcars, 2) the application of the modified Delphi technique (a single questionnaire) and jury technique to evaluate and validate the candidate conspicuity markings, 3) the application of scaling techniques to determine the "best" markings to railcars, 4) the "static" evaluation of markings in a laboratory setting. The overall report describes the research process and the results obtained. Figure I-1 shows the complete research process.

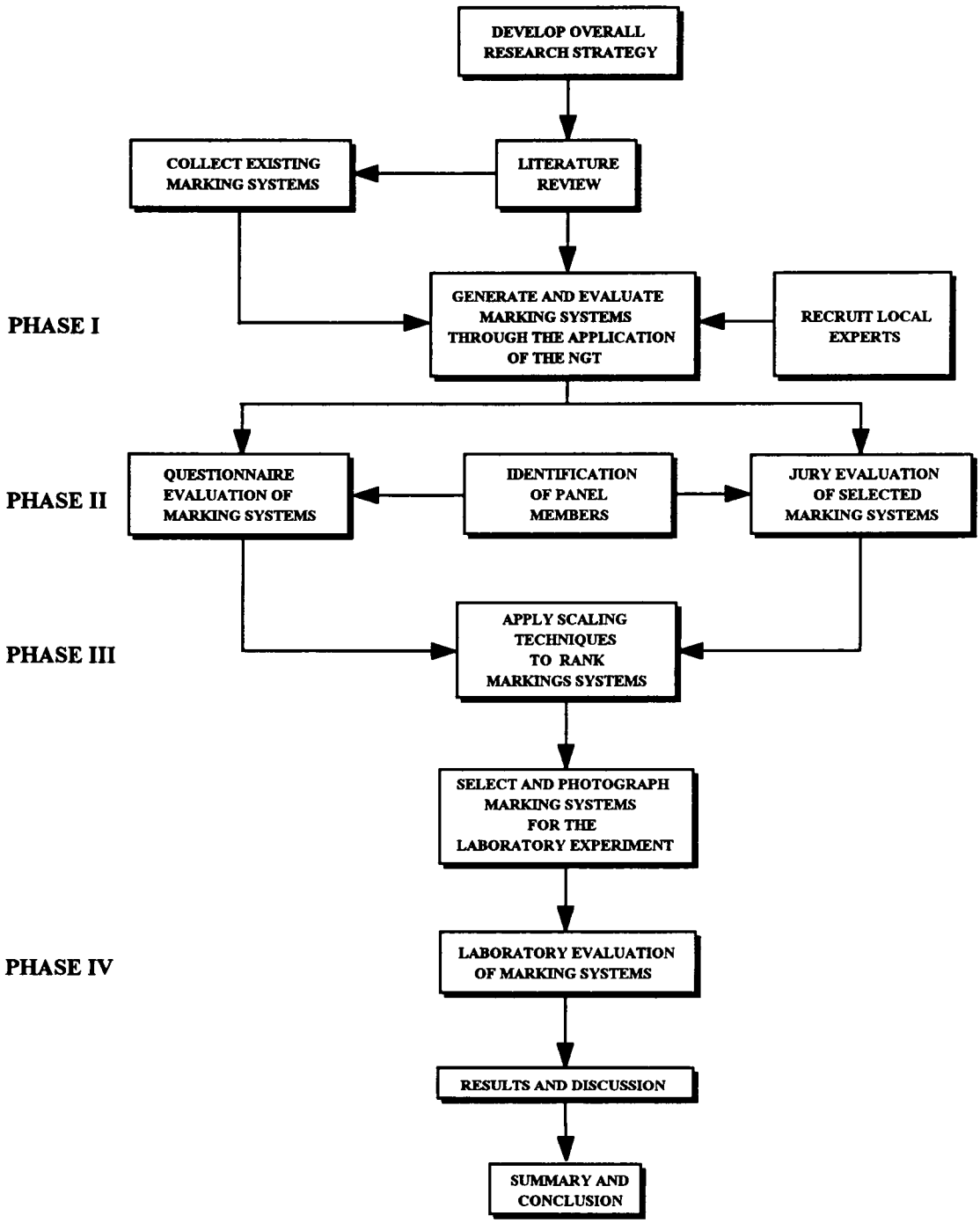


Figure I - 1. Overall research strategy.

Thesis Objectives

Due to the magnitude of the overall research objectives, this paper focuses only upon the completion of Phase II and Phase III of the complete project. The primary thesis objective is to design and administer a questionnaire, collect and analyze data, and make final recommendations that will be laboratory tested in Phase IV of the research.

A questionnaire was used in Phase II to obtain expert evaluations of the eleven experimental retroreflective conspicuity marking systems generated by Phase I as they appeared on scaled mockup of railcars. Results collected from the application of a jury technique provided validation of these marking system designs. Three statistical analysis techniques: 1) Simple ranking, 2) Thurstone's law of paired comparisons, and 3) Likert scaling were used in Phase III to evaluate which marking systems the expert panel "perceived" to be the most effective in increasing the visibility of coal hoppers.

Question to be Investigated

The two questions investigated in this paper were:

1. What are experts' preferences for coal hopper retroreflective conspicuity designs?
2. Which attributes and dimensions of the eleven retroreflective conspicuity markings made one marking system preferable to another in a Likert scaling task?

General Research Methodology

The general research methodology followed was based upon survey techniques. A study process based upon the following steps was designed:

1. Definition of the study objective;

2. Problem formulation and questionnaire design;
3. Questionnaire administration;
4. Data interpretation.

This study will evaluate conspicuity marking systems that were applied to scale model hopper cars, as suggested by the research sponsors. The eleven experimental retroreflective conspicuity marking systems that were predetermined through literature research and the Nominal Group Technique (NGT) of Phase I will serve as possible alternatives for further evaluation.

The questionnaire developed contained five sections. Upon the returns of these surveys, the questionnaire was broken down into three distinct sections for final analysis and evaluations. Each section evaluated the eleven designs by using Simple ranking, Thurstone's paired comparison, and Likert scaling.

A mailed questionnaire enables the use of "geographically dispersed" experts which in turn assures that more diverse responses may be collected. Participants are experts, individuals who are viewed by their peers as having experience and/or knowledge in conspicuity markings, or professionals in the transportation industry. Potential candidates are contacted by phone and asked to participate. Once the selection process is resolved, the questionnaire can be mailed to the panel of "experts."

This grouping of test techniques will provide a set of markings that will be further evaluated in a laboratory and field experiment.

Scope and Delimitations of the Study

Limited funds and time constraints will allow only one iteration of the (mail survey). Early in the research, a Delphi technique was proposed to evaluate conspicuity

markings developed by the NGT. Despite a small sample, the project staff felt that useful information could be obtained from the returned questionnaires.

Another limitation of the study is that expert judgments of effectiveness of railcar conspicuity markings are only opinions and don't represent driver performance in an operational setting. One should also remember that viewing pictures of markings on railcars may yield results quite different than the responses from drivers approaching railcars with markings illuminated by vehicle head lamps.

CHAPTER II

LITERATURE REVIEW

A literature review identified many techniques that could be used to generate information and opinion to evaluate a set of the retroreflective conspicuity marking designs. Based on the advantages and disadvantages of each process, a modified Delphi Technique was selected for this phase of the research. The methodology is "generally fast, inexpensive, easy to understand, and versatile in the sense that it can be applied wherever expert opinion is believed to exist" (Sackman, 1975).

Opinions and Decision Making Processes

Individual vs. Group Opinions

Personal judgment, decision making, and response can be effected whether the individual is alone or part of a group. Although individuals are more effective than groups in arriving at informed opinions, "introversion and isolation can lead to unfortunate aberrations of opinion and outlook" (Sackman, 1975). However, when group discussion clarifies issues and makes honest communication possible, group decisions prove better (Sackman, 1975). In short, the general conclusion is that groups using an effective process, on average, out perform average individuals working alone.

The actual behavior of individuals within the group (group process) determine the final "group product." Maier (1967) concludes that the comparative effectiveness of individuals versus groups varies widely. He stresses the important role played by experienced group leaders acting as neutral facilitators in achieving successful group

results. Social psychologists have long been aware of powerful tendencies for individuals to conform to group opinion in structured situations (Stogdill 1959, and Berelson and Steiner 1964). According to Sherif (1964), initial random judgments soon converge closely around the group norm after a few rounds of group opinion.

Personal Judgment

According to Delbecq, Van de Ven, and Gustafson (1975), two unique phases of creative or judgmental problem solving can be identified: 1) a fact finding phase and 2) an evaluation phase. The fact-finding phase involves problem search and idea generation. The evaluation phase is concerned with the analysis and selection of the best alternative solution. Research appears to support the idea that these phases are two distinct decision-making activities requiring different roles and processes (Bales and Strodtbeck, 1969; and Simon and Newell, 1958). Maier and Hoffman (1964) suggest that, to avoid "group ambiguity amidst differences in decision-making phases", one type of group process should be used for idea generation and the other used to reach a solution. The program administrator determines which group decision-making process should be used in each phase of problem solving.

Group Processes

Delbecq, Van de Ven, and Gustafson (1975) specified several advantage and disadvantage characteristics of group performance:

1. Overall - The overall structure and methodology of decision-making processes.
2. Role orientation of groups members - The tendency for groups to shift attention between social and task-oriented roles.
3. Search behavior - The style used, and amount of effort directed by a group to generate task-relevant information and to identify problems.
4. Normative behavior - The level of conformity among members of the group

and degree to which members feel free to express ideas in group discussions.

5. Equality of participation - The degree to which members of the group can contribute to generation, evaluation, and selection choice of the group's output.
6. Group composition - The personalities and social skills of individuals and the number of individuals involved.
7. Conflict resolution - The method or procedure used by groups to resolve conflicts and disagreements.
8. Closure - The extent to which the group arrives at a clear end and the degree of gained accomplishment group members feel.
9. Resource utilization - The effort, time, and cost involved in each process.

Delphi Technique

Delphi is a means for aggregating the judgments of an isolated number of individuals to improve decision making quality. Because it does not require face-to-face contact, it is particularly useful for the systematic solicitation and collation of written responses and judgments of experts on a particular topic. A set of carefully designed, sequential questionnaires provide the data. In the first questionnaire, experts are asked to respond to a broad question. Each subsequent questionnaire contains summarized information and feedback of opinions derived from responses obtained in earlier series. Experts have anonymity and the anonymity of their responses. The process ends when either participant consensus or a point of diminishing returns is reached (Dalbecq, 1967; Sackman, 1975; Rescher, 1969; Quade, 1970; Delbecq, Van de Ven, and Gustafson, 1975).

Origin of Delphi

The Delphi Technique was developed during studies by Dalkey and his associates at the Rand Corporation, on scientific and technological forecasting. It was originally used as a process for technological forecasting. Since this time, Delphi has

grown into a forecasting tool of human attitudes and values (Reisman et al. 1969), a general purpose tool for human communication and consensus, and a method for group problem solving (Delbecq, Van de Ven, and Gustafson, 1975; Helmer, 1967; Pyke and North, 1969).

Objective of Delphi

Objectives of the Delphi process identified by Delbecq, Van de Ven, and Gustafson (1975) are as followed:

1. Determine or develop a range of possible program alternatives.
2. Explore or expose underlying assumptions or information leading to different judgments.
3. Seek out information that may generate the maximum consensus of the respondent group.
4. Correlate informed judgments on a topic spanning a wide range of disciplines.
5. Educate the respondent group as to the diverse and interrelated aspects of the topic.

Requirements

Usually, one or more of the following properties of the application lead to the need for employing the Delphi technique:

1. The problem does not lend itself to precise analytical techniques but can benefit from subjective judgments on a collective basis.
2. The individuals needed to contribute to the examination of a broad or complex problem.
3. More individuals are needed than can effectively interact in a face-to-face exchange
4. Time and cost, make frequent group meetings infeasible.
5. The efficiency of face-to-face meetings can be increased by a supplemental group communication process.
6. Disagreements among individuals are so severe or politically unpalatable that the communication process must be refereed or anonymity assured.
7. The heterogeneity of the participants must be preserved to assure validity of the results, that is, avoidance of domination by quantity or by strength of

personality ("jury room effect").

Before the Delphi process can proceed, Sackman (1975) emphasized ten key questions that must be identified and clarified:

1. Is the Delphi concept of the expert and its claim to represent valid expert opinion scientifically tenable, or is it overstated?
2. Is Delphi claims of the superiority of group over individual opinion, and of the superiority of remote and private opinion over face-to-face encounter, meaningful and valid generalizations?
3. Is Delphi consensus authentic or specious consensus?
4. Does Delphi anonymity reinforces scientific accountability or unaccountability in method and findings?
5. Does Delphi systematically encourages or discourages the adversary process and exploratory thinking?
6. Are Delphi questions, particularly forecasting question, precise and meaningful?
7. Are Delphi responses precise and unambiguous?
8. Are Delphi results meaningful and unambiguous?
9. Is Delphi primarily concerned with collections of snap-judgment opinions of polled individuals from unknown samples, or is it concerned with coherent predictions, analyses, or forecasts of operationally defined and systematically studied behavior or events?
10. Does Delphi represents critical tradition, or is it uncritically isolated from the mainstream of scientific questionnaire development and behavioral experimentation? And does Delphi set a desirable or an undesirable precedent for interdisciplinary science in the professional planning and policy studies community?

There are three critical conditions necessary to complete a successful Delphi:

1. Adequate time. The time required to carry out is about 45 days (Delbecq, Van de Ven, and Gustafson, 1975).
2. Participant skill in written communication. The participant is required to have reading and writing skills to convey adequate information in writing form.
3. High participant motivation is necessary since other people are not present to stimulate and maintain motivation. Research team may want to convey the importance of the Delphi's objectives and the importance of their participation to motivate participants. In addition, the procedure of selecting potential participants through nomination can also increase motivation since there is a degree of flattery associated with being nominated to be an "expert" respondent.

Delphi Characteristics and Terminology

To conduct the Delphi process, Turoff (1970) suggests at least three separate groups of individuals, each performing different roles:

1. Decision maker(s)- the individual or individuals expecting some sort of product from the exercise that is used for their purpose.
2. Staff group - the group responsible includes: designs/formulating, types, send the initial questionnaire, collects the responses, summarizes the returns, and redesigns the follow-up questionnaires if necessary.
3. Respondent group - the group whose judgments are being sought and who are asked to respond to the questionnaires or agree to answer the questionnaire. The word "respondent" has been referenced as a "panel" in the Delphi context (Sackman, 1975). However, it should be noted that the term "panelist" is not the appropriate term to use in the Delphi context. Panelists usually communicate directly and exchange opinions with each other, primarily in a face-to-face setting. With Delphi, we have respondents, not panelists, because communication is strictly by confidential questionnaire. Moreover, all responses are filtered through the intermediary of the Delphi director or his representative before reaching anyone else. There is no interactive discourse in Delphi procedures. Respondents represented a non-communicating group, linked primarily by remote statistical feedback.

In addition, there are other Delphi characteristics that must be identified and clarified to simplify the practice of sampling expert opinion through a mailed questionnaire.

Experts vs. Nonexperts

Sackman (1975) states it is almost impossible to find current psychometric or social science literature on "experts." Experts are defined as people who possess relevant information or have professional training and experience in the subject area of interest which decision makers want to define. The Delphi technique involves the use of experts to generate and contribute opinions. However, an informed group of individuals in the object area of inquiry can provide individual and group Delphi opinions essentially

indistinguishable from those of the experts. Whether the opinions of an informed group versus "experts" differ must depend on the training of the experts and the domain of interest.

Accuracy, validity and Reliability of Delphi

Dalkey, 1969 stressed three quintessential attributes that contribute to authentic consensus and valid results: anonymity of panelists, statistical response, and iterative polling with feedback. For this research, one iteration was done in the Delphi process. However, the modification was only necessary since the first iteration was basically conducted in the NGT to identify items ("fact-finding" phase), and the second iteration (using respondents other than those queried in phase I) was used with Delphi to obtain wider participation in responding and voting.

With anonymous sampling of "experts", Delphi practitioner asserts that Delphi outputs are only as good as the expert inputs, admonishing us with the GIGO principle (garbage in/garbage out). Delphi practitioners object to this conclusion, pointing out that Delphi has been proven "valid" and accurate" in a few relatively recent studies involving almanac-type items (Dalkey 1969) and for relatively short-term prediction (Martino 1972).

Modified Delphi Technique

Delphi is a quick and easy way to obtain maximum expert opinion in different locations through a mailed questionnaire (Sackman, 1975). A modified Delphi technique was used to obtain expert opinion. The technique is a Delphi in that expert opinion is solicited concerning railcar conspicuity marking. The technique was modified in that multiple iterations were not performed in the interest of time and costs. Essentially, a

questionnaire was sent to a group of experts to obtain their opinions about railcar conspicuity designs developed by the NGT in Phase I of the research.

Single Survey vs. Repeated Surveys

The number of "rounds" or iterative submissions of a questionnaire necessary to obtain the sufficient information can vary depending on the availability of time and the budget. Based on the advantages of each process, the single survey proved to hold its own merit. Some advantages of the single survey over a continuous operation are as follows: 1) An up-to-date information is obtained within a specified time to facilitate and speed decisions without concerns with "seasonal, secular, and catastrophic variations;" 2) It is easier and cheaper to administer with the geographically widespread samples; 3) The analysis of the collected data and presentation of the results can be provided more rapidly. Surveys are usually divided into single large survey or several repeated smaller surveys. The advantages of smaller surveys are to obtain better statistical inference that in turns improve quality and accuracy of the data and "yield additional information about the variations that occur between the periods, and also estimate seasonal and secular trends" (Kish, 1965).

Therefore, the single survey proved to be a sufficient approach for the process of this research since the nature of the problem being investigated was constrained by a limited research budget. The single survey can obtain maximum consensus on the preferable and nonpreferable retroreflective conspicuity marking designs from sampling expert opinion in a shorter period of time and with less funds and labor required.

Validity of Authentic Consensus

Sutherland (cited in Linestone and Turoff, 1975) defines consensus in terms of the rate at which it is achieved. The rate at which a consensus is achieved is measured by the rate at which the raw variance in responses declines over subsequent questionnaires. Thus, in utilizing the mailed questionnaire to solicit the respondent's degree of preference on the alternatives, the collective agreement reached will be concluded as a consensus among the group.

CHAPTER III

QUESTIONNAIRE

Introduction

The purpose of research design is to carry out measurements and collect data. To meet that goal in this project, a questionnaire was used. This questionnaire was designed to rank experts' preferences for retroreflective conspicuity marking designs. To obtain complete, accurate and relevant information that suits the study's aims and the nature of its respondents, Hoinville, Jowell and Associate (1977) suggested that a broad distinction between two types of questionnaire be identified. The two types of questionnaires are the descriptive and the analytic. Once the criterion for selection is made, the next objective is to develop a questionnaire that is: 1) easy for respondents to understand and respond to accurately and clearly; and 2) easy for the researcher to administer and develop statistical analysis on the returned data. Its design must minimize potential errors from respondents and administrator. Additionally, since the respondent's participation is voluntary, the flow, structure and length of the questionnaire should encourage the respondent's cooperation, maintain the respondent's interest and elicit candid responses.

Descriptive vs. Analytic Questionnaires.

The purpose of the designed questionnaire is to obtain information that would help analyze the relationships between all the conspicuity markings as well as to provide the basis for deciding which markings are considered better by experts. In order to structure a well-designed questionnaire, one must decide which type should be used to collect data with maximal reliability and validity. The first type of questionnaire, the

descriptive, is used when a simple count is desired. When an exhaustive count is impossible, this type questionnaire counts a representative sample, then makes inferences about the population as a whole. An important point to realize is that such surveys primarily indicate the portion of a population having a certain characteristic or the frequency of occurrence of certain events; these surveys are not designed to "explain" anything or to show relationships between one variable and another. The descriptive survey's function is essentially fact-finding and actuarial. The achieved results are often used to make predictions for future action.

The analytic, relational survey, is set up specifically to explore relationships between particular variables. This type of survey is sometimes referred to as "the poor man's experiment," since its design is quite similar to that of laboratory experiments (Oppenheim, 1966). Like experiments in the laboratory, it is usually set up to explore specific hypotheses. In comparison with the descriptive questionnaire, the analytic questionnaire is less oriented toward representativeness and more toward finding associations and explanations.

The criterion for the selection was simple. The descriptive type of questionnaire was selected since the purpose of this research was to evaluate railcar conspicuity by sampling expert opinions. Thus, a descriptive questionnaire was sent to experts to determine most and least favored conspicuity designs.

Design of the Questionnaire

The questionnaire was structured to facilitate determination of favorability of hopper car conspicuity markings and to subsequently eliminate those receiving poor scores. These findings will further reduce the number of markings involved in laboratory testing in later phases of the project.

The questionnaire contained five sections. The first section was designed such that 11 experimental conspicuity markings (shown in Appendix A) were paired with one another. There are 55 or [(n)(n-1)/2] paired combinations that must be compared. (The Thurtone's paired comparison is described in Appendix B.) The respondents were instructed to circle the marking number below the photograph of the marking judged to be more effective in enhancing the visibility of hopper cars. The second section was designed such that all 11 conspicuity marking systems were presented together. The objective of this section was to obtain a relative ranking of these marking systems from best to worst. The respondents were instructed to assign rankings from the best marking "1" to the worst marking "11".

The third section of the questionnaire determined which attributes and dimensions of each of the conspicuity marking influenced the respondents' selection in previous sections. The objective of this section of the questionnaire was to identify which attributes and dimensions made one system preferable to another by using the Likert scaling techniques. These attributes are detectability (is something there?), recognizability (what is there?), uniqueness (it is like no other) and confusibility (different from all other). The dimensions that define these attributes are color(s), high contrast with the background, the pattern of the marking, and the placement of the marking on the hopper car. Once again the respondents are instructed to rate the ten statements, one for each attribute and dimension per conspicuity marking by circling the phrase indicating how strongly they rate these attributes and dimensions. (The Likert scaling technique is described in Appendix B.)

The fourth section of the questionnaire is designed to allow respondents to share any ideas and suggestions on conspicuity marking systems. And finally, the fifth section asks the respondents to provide biographical information for the purpose of developing a

profile of respondents participating in the survey. (The questionnaire is in Appendix D.)

Pilot Test of the Questionnaire

Initially, the questionnaire was evaluated independently by team members and modified based on their recommendations. Then five educators from The University of Tennessee Transportation Department graciously volunteered to pretest the questionnaire. They were specifically instructed to work through them independently. In the process of reading and following the instruction, the volunteers were asked to make notes on several things:

- Completion time,
- Whether the words are simple, and direct,
- Whether the questions and instructions are concise and clear,
- If each question is short and simple and written in unambiguous, understandable language, and
- If the format of the questionnaire is made easy to follow.

The purpose of having the pilot test was to evaluate not only the questionnaire items but also the adequacy of the sampling instructions and the length of time taken to answer the questionnaire. The results of a pretest can be used to clarify the wording of the items, sharpen the focus of the items, structure certain responses, and eliminate unnecessary and/or redundant items in the questionnaire. However, the results of the pretest indicated that modifications to the questionnaire would be unnecessary. Thus, at this point the questionnaire was ready to be mailed to experts.

Selection of Respondents

The initial participants were selected from a list of names of people who attended the 1992 Symposium at The University of Tennessee Transportation Department. Potential participants were contacted by telephone to ask them for their participation and

Potential participants were contacted by telephone to ask them for their participation and to discuss the purpose and importance of the study and their obligations. Participants were then asked to suggest other experts who should be asked to participate in the research. Another way used to increase the respondent's motivation was through the process of nomination since there is degree of flattery associated with being nominated as an "expert" respondent.

Of 150 potential participants contacted, 79 "transportation experts" (listed in Appendix C) agreed to participate in the Delphi survey. Participants were either experts, or individuals viewed by their colleagues as having experience and knowledge in either railroad grade crossing safety, traffic engineering, human factors engineering, or human performance.

CHAPTER IV

RESULTS AND DISCUSSION

The questionnaire was mailed to all 79 experts who agreed to participate in the study. A total of 43 completed questionnaires were returned for a response rate of 54.4%. A review of the nonrespondent group identified no commonalities that would invalidate this analysis.

All but 11.6% of the respondents were male. Over 75% of the respondents were age 40 and over. A minority of these respondents (18.6%) had self-reported color vision defects. Sixty-five percent of the respondents hold positions in Highway-rail safety. Over 75% of the respondents had 15 years or more experience in the transportation field. Figure IV-1 shows the demographics of the respondents.

Evaluations were accomplished by using three scaling techniques. They were Thurstone's paired comparison, simple ranking, and Likert scaling. By using these statistical techniques, it was possible to rank the 11 conspicuity marking designs.

The first question to be answered in this project was what are the experts' subjective preferences for coal hopper retroreflective conspicuity designs? This was accomplished by conducting a Thurstone's paired comparison test. (The Thurstone's paired comparison technique is described in Appendix B.) The results of this test were tabulated and a probability dominance matrix was developed. The dominance matrix is shown in Table IV-1.

These tabulated probabilities were then converted to z scores which are shown in Table IV-2. The obtained average z scores for each marking are shown in the second to last column of Table IV-2. Moreover, because average z scores (scale value) are used to

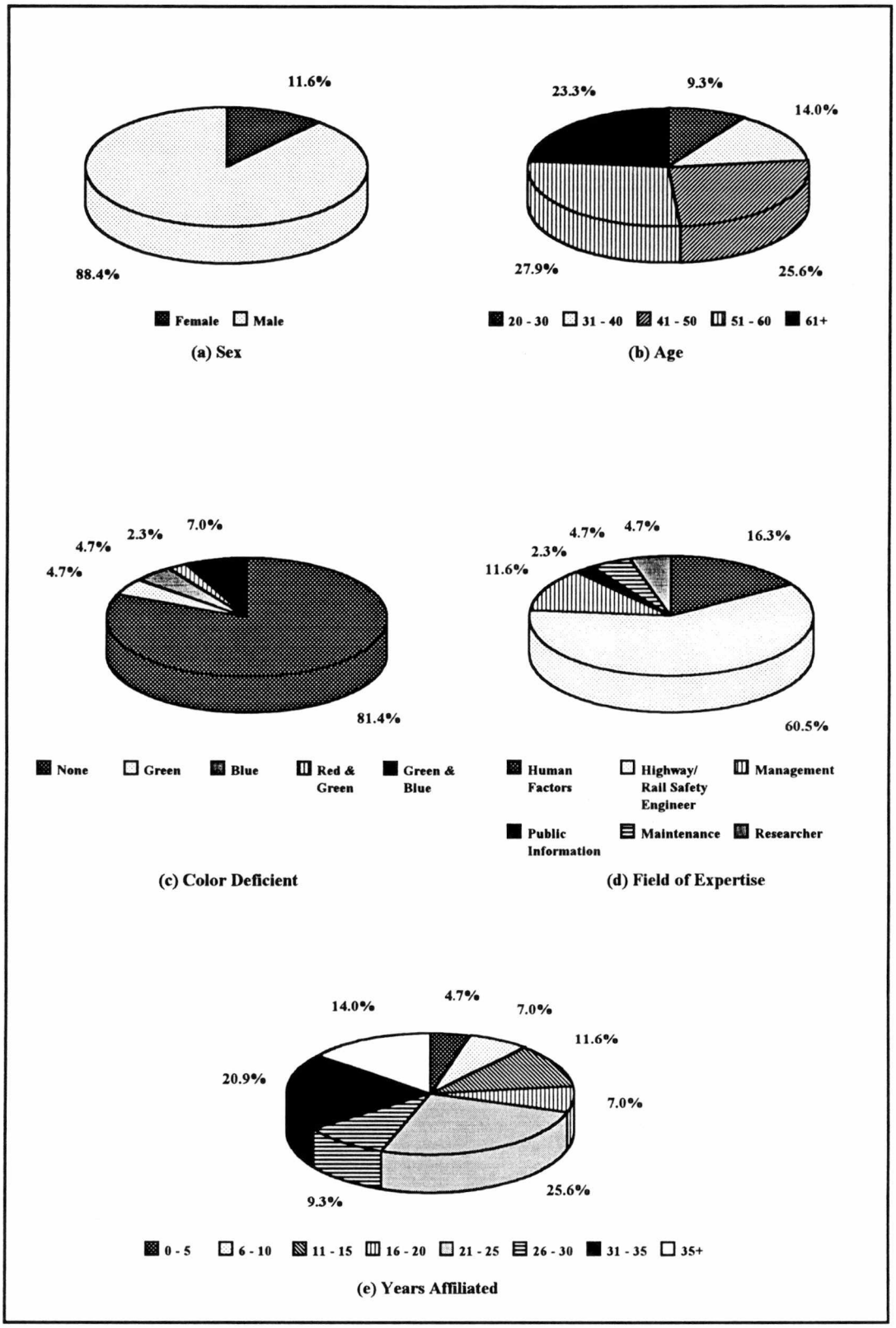


Figure IV - 1. Demographics of respondents.

Table IV-1. Dominance matrix of preferences (probability that row marking dominated column marking.)

Mrk	1	2	3	4	5	6	7	8	9	10	11
1	0.50	0.65	0.43	0.80	0.58	0.41	0.82	0.19	0.77	0.61	0.93
2.	.035	0.50	0.27	0.74	0.36	0.33	0.79	0.07	0.66	0.34	0.93
3	0.57	0.73	0.50	0.93	0.68	0.61	0.91	0.23	0.91	0.70	0.95
4	0.20	0.26	0.07	0.50	0.23	0.11	0.73	0.09	0.52	0.16	0.80
5	0.42	0.64	0.32	0.77	0.50	0.32	0.79	0.20	0.79	0.50	0.91
6	0.59	0.67	0.38	0.89	0.68	0.50	0.84	0.18	0.84	0.64	0.95
7	0.18	0.21	0.09	0.26	0.21	0.16	0.50	0.07	0.48	0.16	0.71
8	0.81	0.93	0.77	0.91	0.80	0.81	0.93	0.50	0.91	0.91	0.98
9	0.23	0.34	0.09	0.48	0.21	0.16	0.52	0.09	0.50	0.23	0.75
10	0.39	0.66	0.30	0.84	0.50	0.36	0.84	0.09	0.77	0.50	0.88
11	0.07	0.07	0.05	0.20	0.09	0.05	0.29	0.02	0.25	0.11	0.50

Table IV-2. Dominance matrix of z score (values based on probabilities in Table IV-1.)

Marking	1	2	3	4	5	6	7	8	9	10	11	Total	Average	Adjusted Z Score*
1	0.00	0.39	-0.17	0.83	0.21	-0.23	0.91	-0.89	0.75	0.29	1.49	3.56	0.32	1.5
2	-0.39	0.00	-0.60	0.66	-0.35	-0.45	0.81	-1.49	0.41	-0.41	1.49	-0.33	-0.03	1.15
3	0.17	0.60	0.00	1.49	0.47	0.29	1.34	-0.75	1.34	0.52	1.68	7.15	0.65	1.83
4	-0.83	-0.66	-1.49	0.00	-0.75	-1.21	0.62	-1.34	0.06	-1.00	0.83	-5.76	-0.52	0.65
5	-0.21	0.35	-0.47	0.75	0.00	-0.47	0.81	-0.83	0.81	0.00	1.34	2.07	0.19	1.37
6	0.23	0.45	-0.29	1.21	0.47	0.00	0.98	-0.89	1.00	0.35	1.69	5.20	0.47	1.65
7	-0.91	-0.81	-1.34	-0.62	-0.81	-0.98	0.00	-1.48	-0.06	-1.00	0.57	-7.43	-0.68	0.5
8	0.89	1.49	0.75	1.34	0.83	0.89	1.48	0.00	1.34	1.34	2.00	12.33	1.12	2.3
9	-0.75	-0.41	-1.34	-0.06	-0.81	-1.00	0.06	-1.34	0.00	-0.75	0.67	-5.71	-0.52	0.66
10	-0.29	0.41	-0.52	1.00	0.00	-0.35	1.00	-1.34	0.75	0.00	1.21	1.87	0.17	1.35
11	-1.49	-1.49	-1.68	-0.83	-1.34	-1.69	-0.57	-2.00	-0.67	-1.21	0.00	-12.96	-1.18	0

* Add the average row z - value to +1.18 to set the least preferred marking value equal to "0."

place group preferences on an interval scale, the most negative value of (-1.18) in the average z column is added to that column to obtain the adjusted z scores which are shown as the last column of Table IV-2. Adding (-1.18) to each z value in the next to last column establishes a zero point on an interval scale (see Figure IV-2). This zero point represents the railcar marking least preferred by the experts.

The higher the z-score suggested that the larger percent of the respondents chose one marking more favorable in comparison with the other markings. The paired comparison data is given in Table IV-3 and graphical representation of this data is given in Figure IV-3. The conclusion of this test indicated that the most favored marking is #8 and the least is #11.

The second statistical technique used was simple ranking. In this technique, participants are asked to rank the 11 conspicuity marking designs relative to one another. The markings were ranked "1" best, to "11" worst. The individual rankings from each participant were then totaled for each marking. The smallest total was judged the best by the group as a whole. Incrementally higher totals suggested the next best and so on. The highest total suggested the worst marking as judged by the group. This procedure produced a group average ranking of best to worst.

Consistency of results between the Thurstone's paired comparison and the simple ranking provides validation of the results. However, comparison with the Thurstone's paired comparison data requires that another step be taken with the simple ranking data. Thurstone's method produces z-scores that exhibit an inverse relationship between magnitude and judged effectiveness (the higher the Z-score, the better the marking). Thus, the simple ranking data was inverted to match this convention. A number 1 rank was inverted to an 11, a 2 to a 10, 3 to 9, . . . and 11 to 1. This was performed by subtracting 12 from each rank and taking the absolute value of the answer.

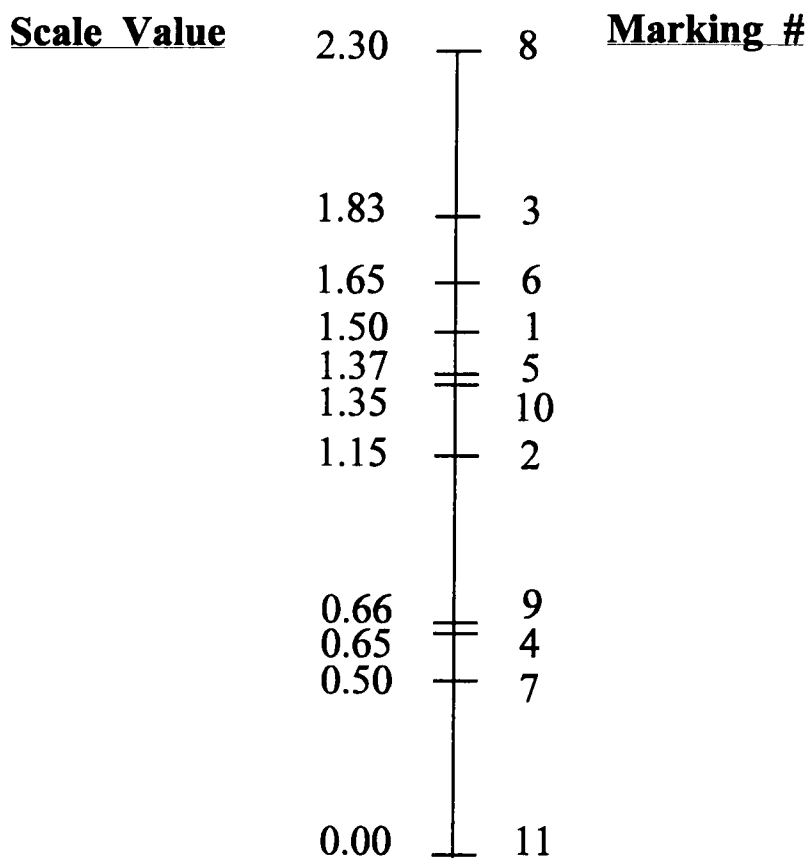


Figure IV-2. Scale values (mean z values) for the preference of markings.

Table IV - 3. Ranking of markings by the paired comparison technique.

Ranking	Marking #	Design	Color(s)	z - score
1	8	Picket Fence	Yellow	2.30
2	3	Outline	Yellow	1.83
3	6	Highway Center Line	Yellow	1.65
4	1	Crossing Gate	Red/White	1.50
5	5	Diamonds and Bars	Red/White & Orange	1.37
6	10	Truck Frame	Red/White	1.35
7	2	Saw Tooth	Red/White	1.15
8	9	Volpe/Field Test	Red/White	0.66
9	4	Chevrons	Red/White	0.65
10	7	Crossbuck	Red	0.50
11	11	Standard	Non-Retroreflective White Marking	0.00

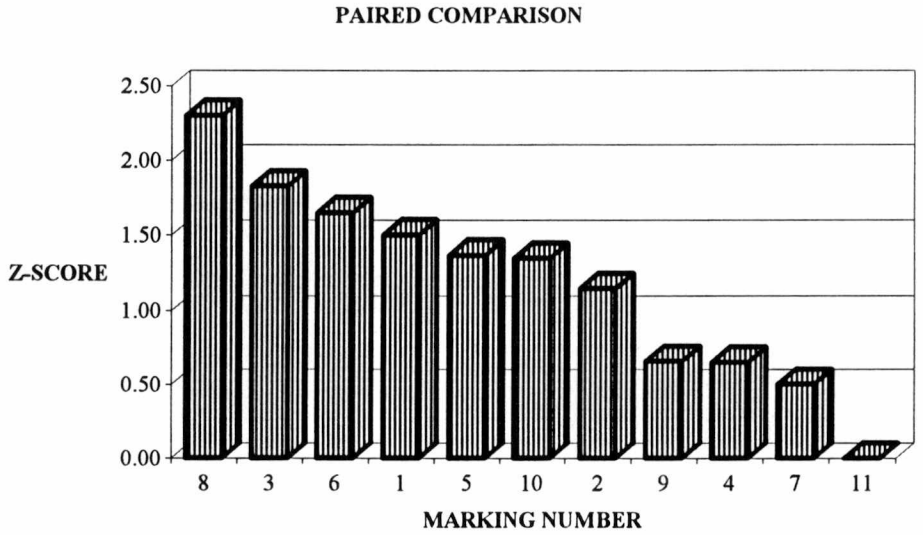


Figure IV - 3. Bar chart of the eleven markings from the paired comparison technique.

Thus, for ranking #1, 1 - 12 = |-11| or ranking #11; ranking # 2, 2 - 12 = |-10| or ranking #10; and so on. The individual inverted rankings from each participant were then totaled for each marking. Now, The largest total was judged the best by the group as a whole. Incrementally smaller totals suggested the next best and so on. The lowest total suggested the worst marking as judged by the group. This procedure produced an inverted group average ranking of best to worst that did nothing to affect the original rankings. Table IV-4 shows the data collected from the ranking and the original and inverted ranks. A graphical representation of this data is given in Figure IV-4.

Table IV-5 and Figure IV-5 compare the rankings of the simple ranking and paired comparison data. With the exception of ranks #8 and #9 (markings #9 and #4), both methods provided the same rankings. The transposed ranking by different methods might be explained by a population that has a similar preference for markings #9 and #4. Visually, #9 and #4 both contain red and white markings applied to opposite ends of the railcar. Number 4 marking is red-gap-white-gap-red, left and right facing chevrons applied to the full height of the left and right sides of the car. Number 9 markings include vertical red and white strips applied to the full height of the corners of the railcar.

A similar preference was displayed for the markings #5 and #10. In this case, however, the final comparative ranking was the same. Markings #5 and #10 both include red and white strips running horizontally just above the side sill. Marking #5 is red over white strips applied full length of the railcar just above the side sill with fluorescent orange diamonds superimposed on the red over white strips ever eight feet beginning at the horizontal center line of the car. Markings #10 is alternating red and white strips applied to the full length of the railcar with corner marking applied just below the top cord on the last two full side panel ends of the railcar body.

Although a larger sample might have shown more differentiation (the sample

Table IV - 4. Simple ranking of the inverted scores.

Ranking	Marking #	Design(Pattern)	Color(s)	Original Score	Inverted Score
1	8	Picket Fence	Yellow	108	420
2	3	Outline	Yellow	163	365
3	6	Highway Center Line	Yellow	173	355
4	1	Crossing Gate	Red/White	226	302
5	5	Diamonds and Bars	Red/White & Orange	235	293
6	10	Truck Frame	Red/White	238	290
7	2	Saw Tooth	Red/White	272	256
8	4	Chevrons	Red/White	336	192
9	9	Volpe/Field Test	Red/White	348	180
10	7	Crossbuck	Red	365	163
11	11	Standard	Non-Retroreflective White Marking	440	88

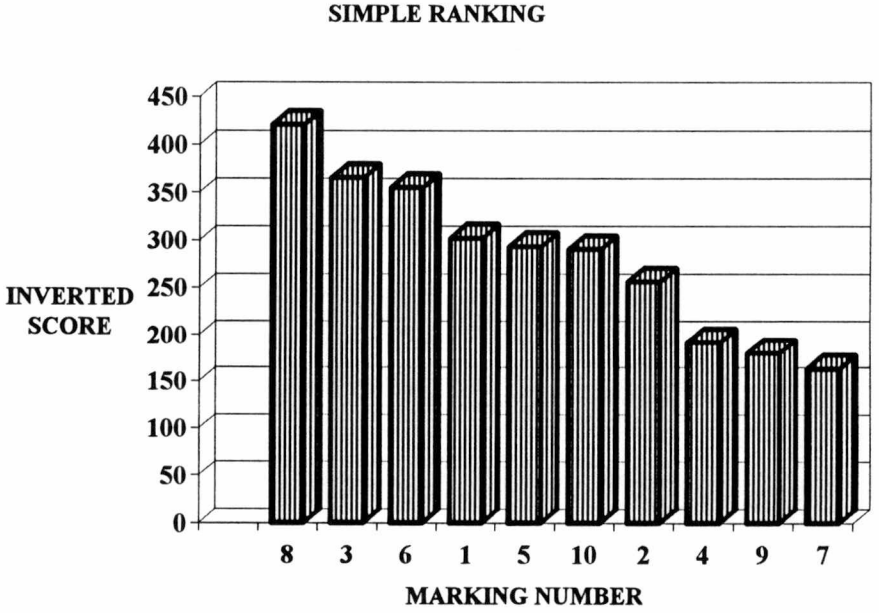


Figure IV - 4. Bar chart rankings of the eleven markings from the simple ranking technique.

Table IV - 5. Comparison of simple rankings and paired comparison rankings.

Marking	Color(s)	Simple Ranking	Paired Comparison Ranking
1: Crossing Gate	Red/White	4	4
2: Saw Tooth	Red/White	7	7
3: Outline	Yellow	2	2
4: Chevrons	Red/White	8	9
5: Diamonds and Bars	Red/White & Orange	5	5
6: Highway Center Line	Yellow	3	3
7: Crossbuck	Red	10	10
8: Picket Fence	Yellow	1	1
9: Volpe/Field Test	Red/White	9	8
10: Truck Frame	Red/White	6	6
11: Standard	Non-Retroreflective White Marking	11	11

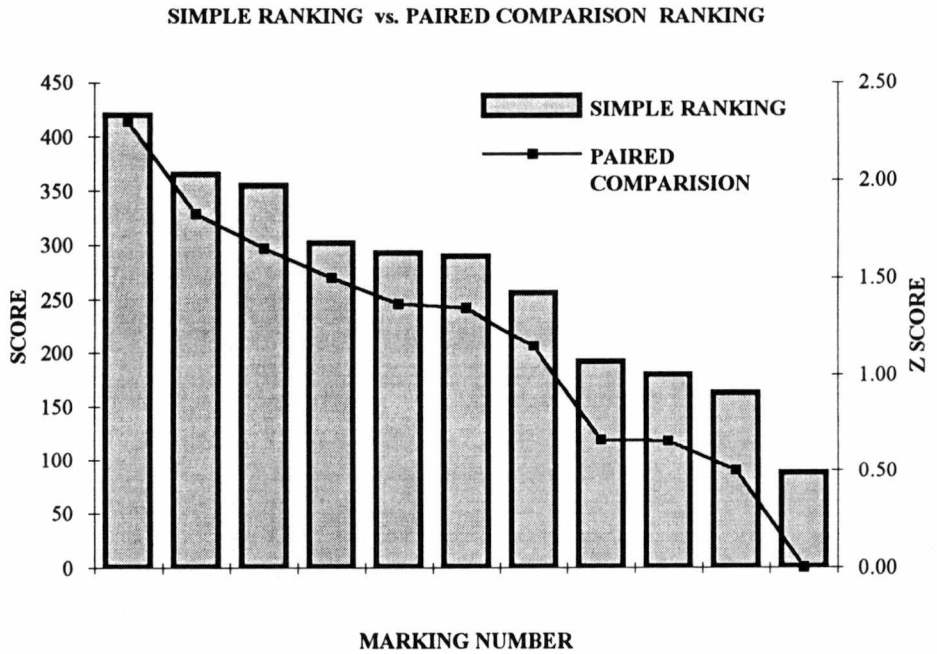


Figure IV - 5. Comparison of simple and paired comparison results.

size was 44), the goal in this phase was to determine the extremes. That is, the researchers were interested in determining which markings the expert group felt were the best and the least effective.

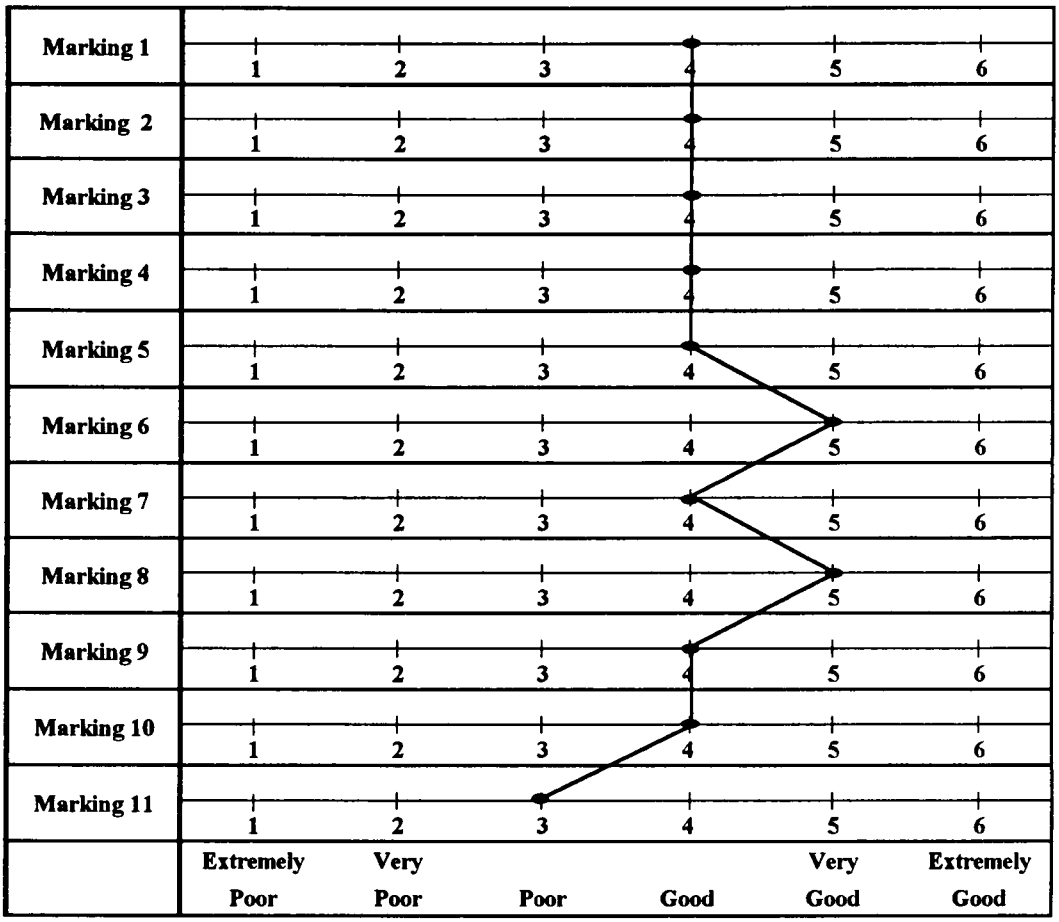
The second and final question to be answer was which attributes and dimensions of the eleven retroreflective conspicuity markings made one marking system preferable to another? Individual semantic differential profile plots are shown in Figures IV-6 through IV-15. Each plot was developed from data in Section III (Rating of Attributes and Dimensions of Conspicuity Markings) of the questionnaire sent to a group of railroad, transportation, human factors, and highway/rail safety engineers. Each railcar marking was rated on a Likert scale for ten statements. For example, statement (1) was as follows:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult

Statement (10) was as follows:

The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For ease of data analysis, each score was assigned a value which ranged from 1, "difficult" to 6, "easy". The results from this analysis are presented in Table IV-6 to show the median and range of the ten statements for all eleven markings. The sum of the medians for each marking were then ranked. Higher values indicated higher preference. The range sum was used to clarify median ties. For example; the median sum for markings #4 and marking #5 was 40. The ranges were 33 and 31 respectively. Thus, because marking #5 had less variability (a smaller range), it was judged to be the higher in rank.



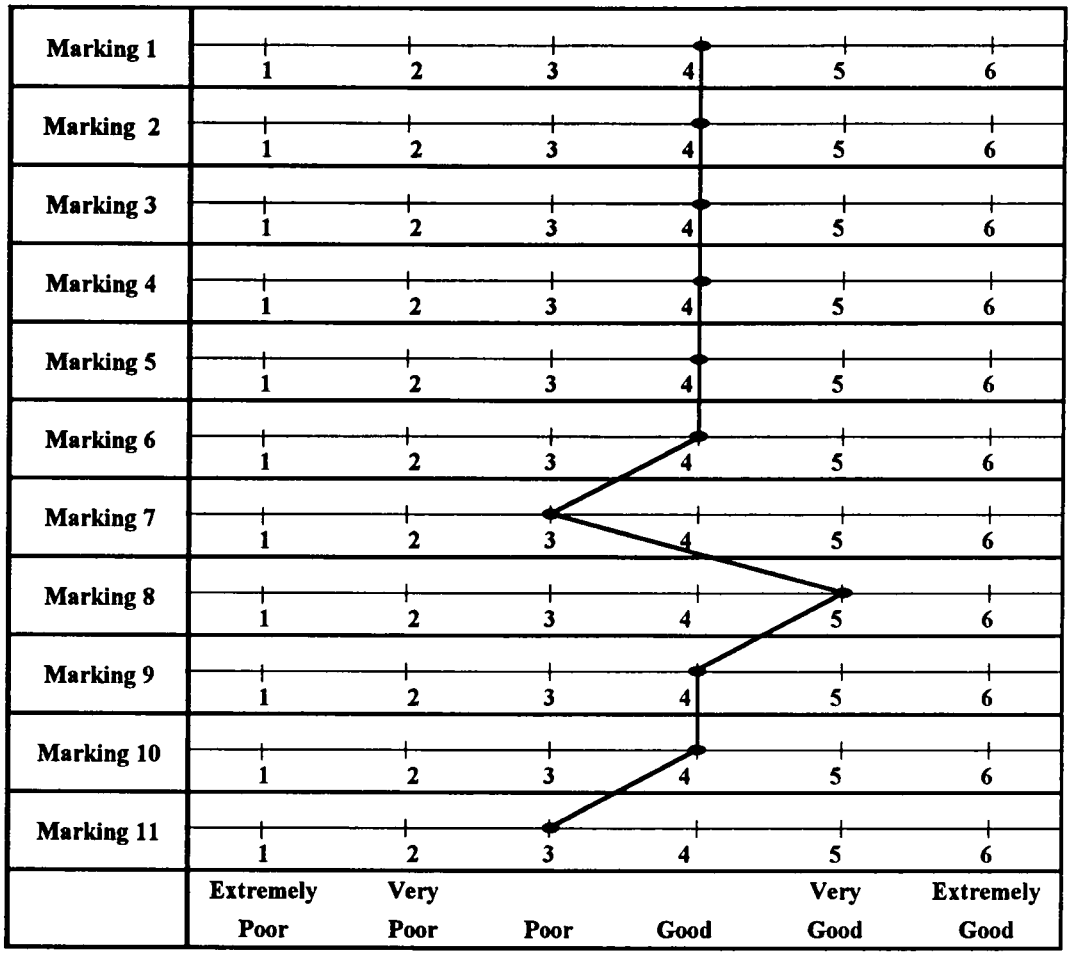
(1 = Extremely Poor; 2 = Very Poor; 3 = Poor; 4 = Good; 5 = Very Good; 6 = Extremely Good.)

Figure IV - 6. Median Likert rating of eleven markings for statement #1.

Statement #1 is "The marking will make detecting the freight car..."

MARKING (S) *	MEDIAN LIKERT RATING
1. Crossing Gate	4.00
2. Saw Tooth	4.00
3. Outline	4.00
4. Chevrons	4.00
5. Diamonds and Bars	4.00
6. Highway Center Lines	5.00
7. Cross Buck	4.00
8. Picket Fence	5.00
9. Volpe/Field Test	4.00
10. Truck	4.00
11. Standard	3.00

* See Appendix A for complete description.

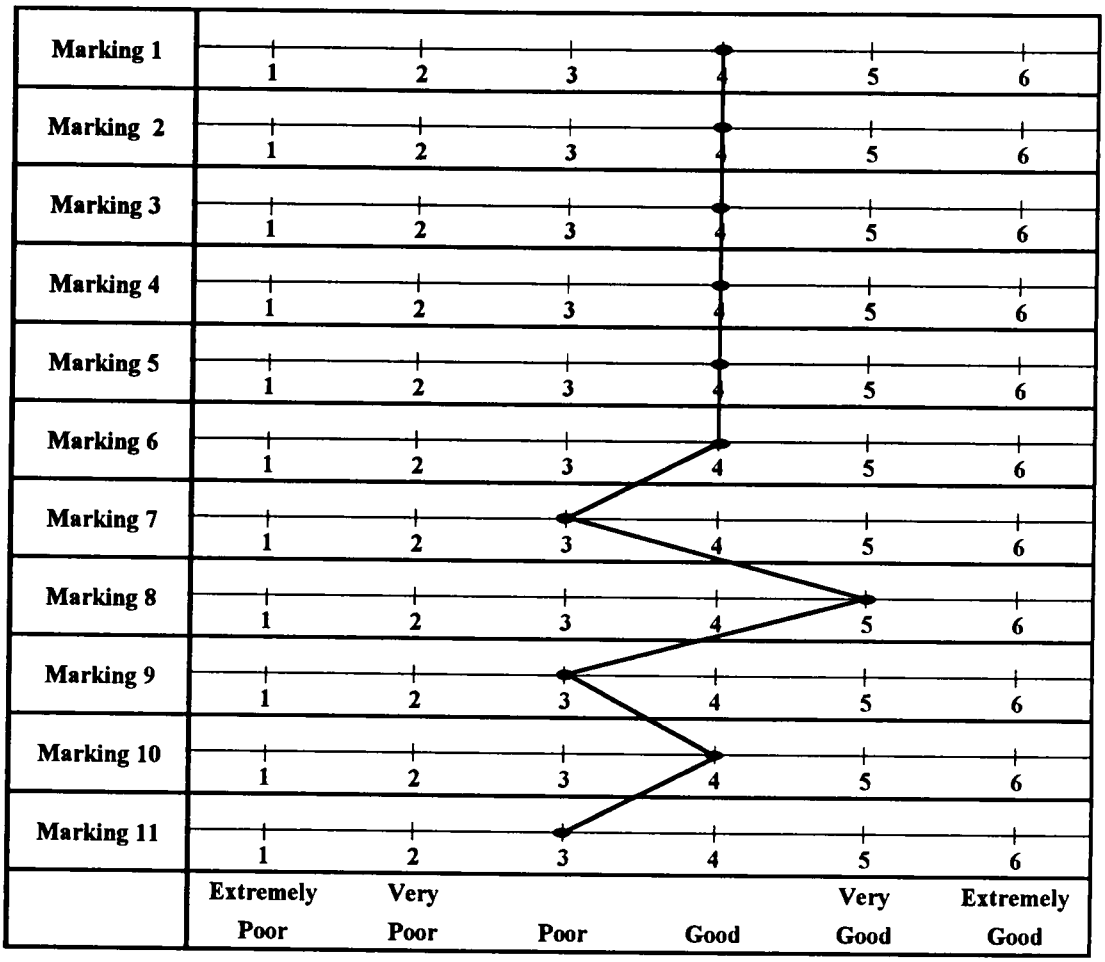


(1 = Extremely Poor; 2 = Very Poor; 3 = Poor; 4 = Good; 5 = Very Good; 6 = Extremely Good.)

Figure IV - 7. Median Likert rating of eleven markings for statement #2. Statement #2 is "The marking will make recognizing the freight car..."

MARKING (S) *	MEDIAN LIKERT RATING
1. Crossing Gate	4.00
2. Saw Tooth	4.00
3. Outline	4.00
4. Chevrons	4.00
5. Diamonds and Bars	4.00
6. Highway Center Lines	4.00
7. Cross Buck	3.00
8. Picket Fence	5.00
9. Volpe/Field Test	4.00
10. Truck	4.00
11. Standard	3.00

* See Appendix A for complete description.

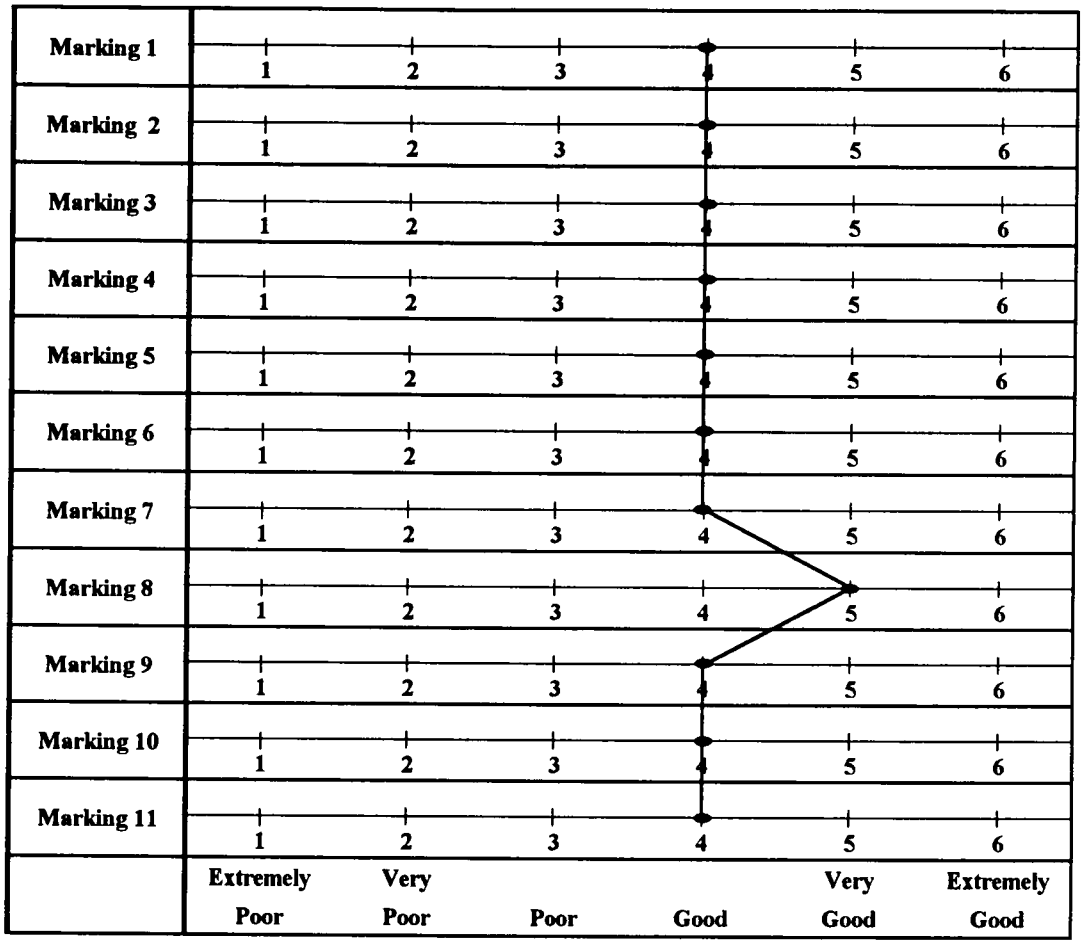


(1 = Extremely Poor; 2 = Very Poor; 3 = Poor; 4 = Good; 5 = Very Good; 6 = Extremely Good.)

Figure IV - 8. Median Likert rating of eleven markings for statement #3. Statement #3 is "The understanding of the marking is..."

MARKING (S) *	MEDIAN LIKERT RATING
1. Crossing Gate	4.00
2. Saw Tooth	4.00
3. Outline	4.00
4. Chevrons	4.00
5. Diamonds and Bars	4.00
6. Highway Center Lines	4.00
7. Cross Buck	3.00
8. Picket Fence	5.00
9. Volpe/Field Test	3.00
10. Truck	4.00
11. Standard	3.00

* See Appendix A for complete description.

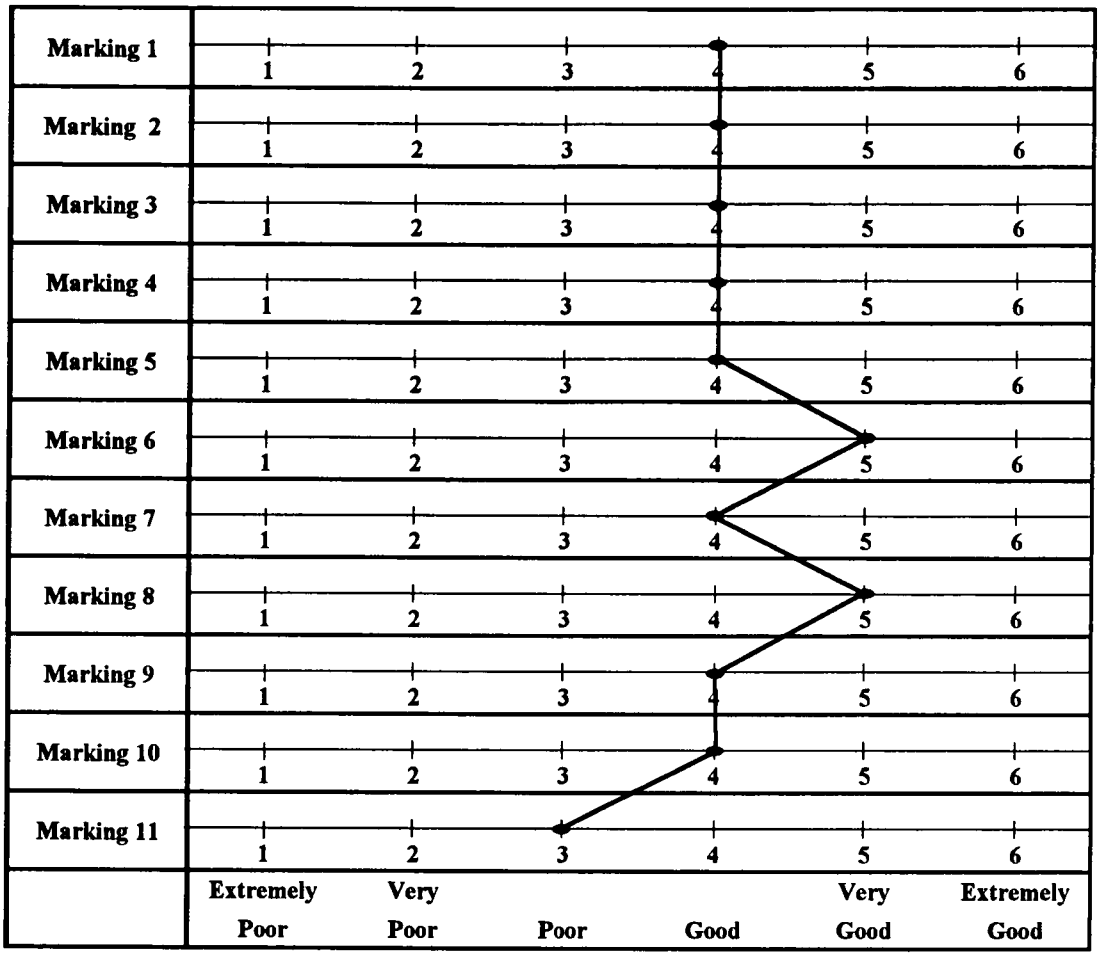


(1 = Extremely Poor; 2 = Very Poor; 3 = Poor; 4 = Good; 5 = Very Good; 6 = Extremely Good.)

Figure IV - 9. Median Likert rating of eleven markings for statement #4. Statement #4 is "Confusing the marking with another marking is..."

MARKING (S) *	AVERAGE LIKERT RATING
1. Crossing Gate	4.00
2. Saw Tooth	4.00
3. Outline	4.00
4. Chevrons	4.00
5. Diamonds and Bars	4.00
6. Highway Center Lines	4.00
7. Cross Buck	4.00
8. Picket Fence	5.00
9. Volpe/Field Test	4.00
10. Truck	4.00
11. Standard	4.00

* See Appendix A for complete description.

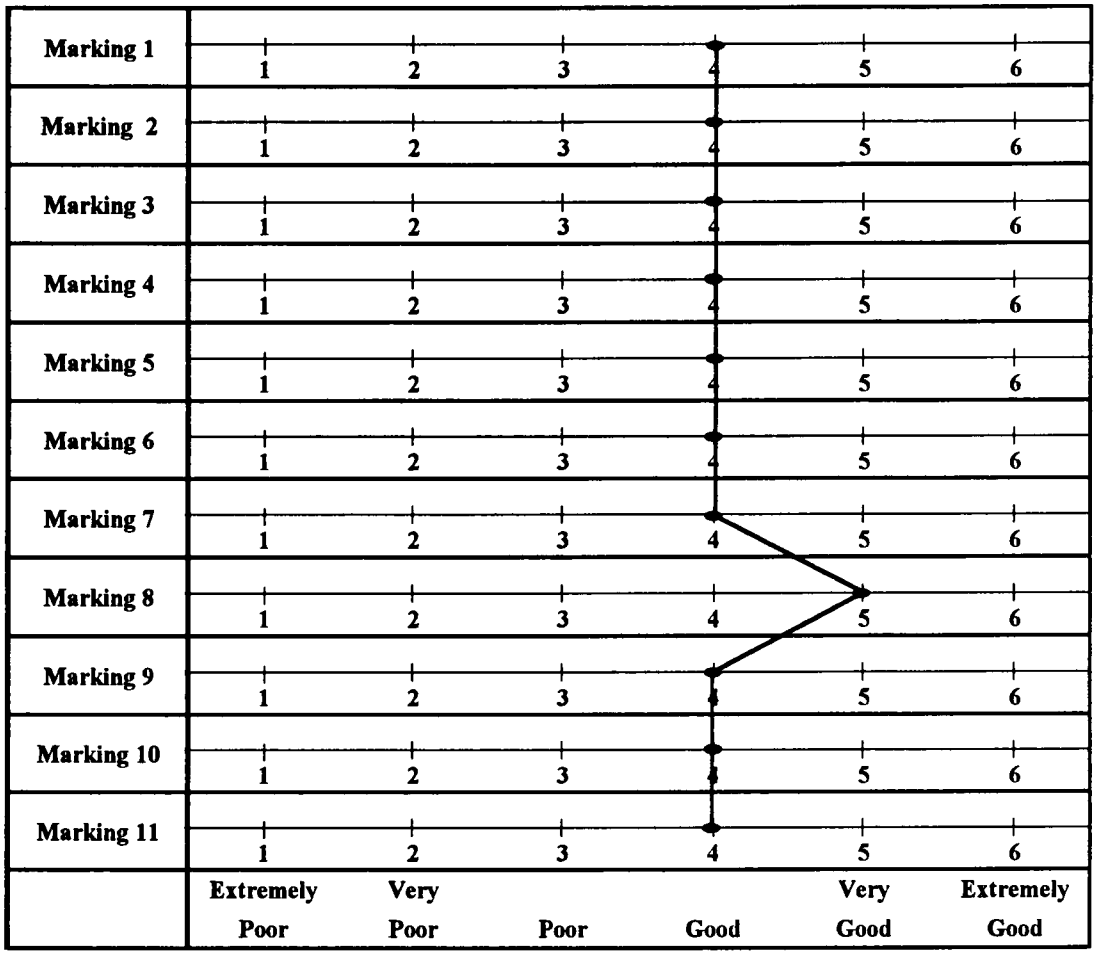


(1 = Extremely Poor; 2 = Very Poor; 3 = Poor; 4 = Good; 5 = Very Good; 6 = Extremely Good.)

Figure IV - 10. Median Likert rating of eleven markings for statement #5. Statement #5 is "The conspicuity of the marking is..."

MARKING (S) *	AVERAGE LIKERT RATING
1. Crossing Gate	4.00
2. Saw Tooth	4.00
3. Outline	4.00
4. Chevrons	4.00
5. Diamonds and Bars	4.00
6. Highway Center Lines	5.00
7. Cross Buck	4.00
8. Picket Fence	5.00
9. Volpe/Field Test	4.00
10. Truck	4.00
11. Standard	3.00

* See Appendix A for complete description.

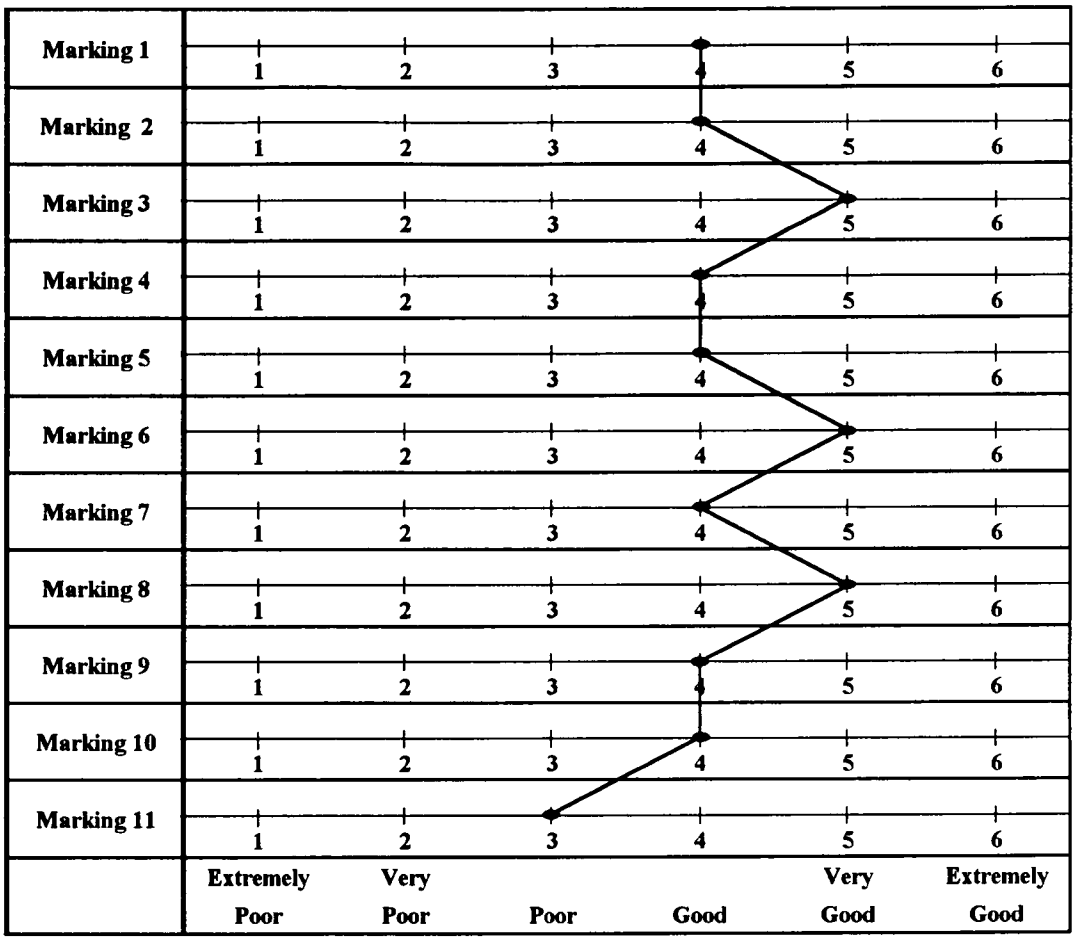


(1 = Extremely Poor; 2 = Very Poor; 3 = Poor; 4 = Good; 5 = Very Good; 6 = Extremely Good.)

Figure IV - 11. Median Likert rating of eleven markings for statement #6. Statement #6 is "The uniqueness of the marking is..."

MARKING (S) *	AVERAGE LIKERT RATING
1. Crossing Gate	4.00
2. Saw Tooth	4.00
3. Outline	4.00
4. Chevrons	4.00
5. Diamonds and Bars	4.00
6. Highway Center Lines	4.00
7. Cross Buck	4.00
8. Picket Fence	5.00
9. Volpe/Field Test	4.00
10. Truck	4.00
11. Standard	4.00

* See Appendix A for complete description.



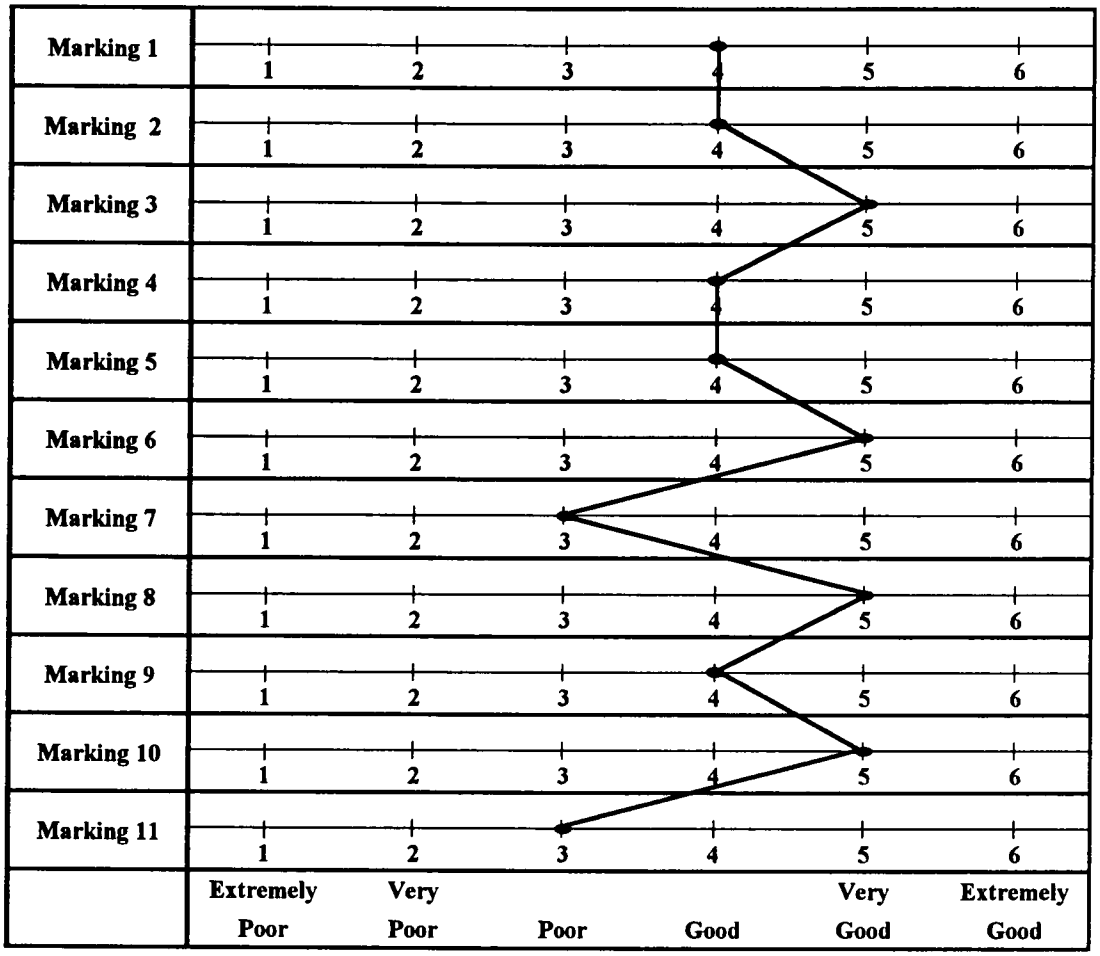
(1 = Extremely Poor; 2 = Very Poor; 3 = Poor; 4 = Good; 5 = Very Good; 6 = Extremely Good.)

Figure IV - 12. Median Likert rating of eleven markings for statement #7.

Statement #7 is "Contrast of the marking with the freight car background is..."

MARKING (S) *	AVERAGE LIKERT RATING
1. Crossing Gate	4.00
2. Saw Tooth	4.00
3. Outline	5.00
4. Chevrons	4.00
5. Diamonds and Bars	4.00
6. Highway Center Lines	5.00
7. Cross Buck	4.00
8. Picket Fence	5.00
9. Volpe/Field Test	4.00
10. Truck	4.00
11. Standard	3.00

* See Appendix A for complete description.



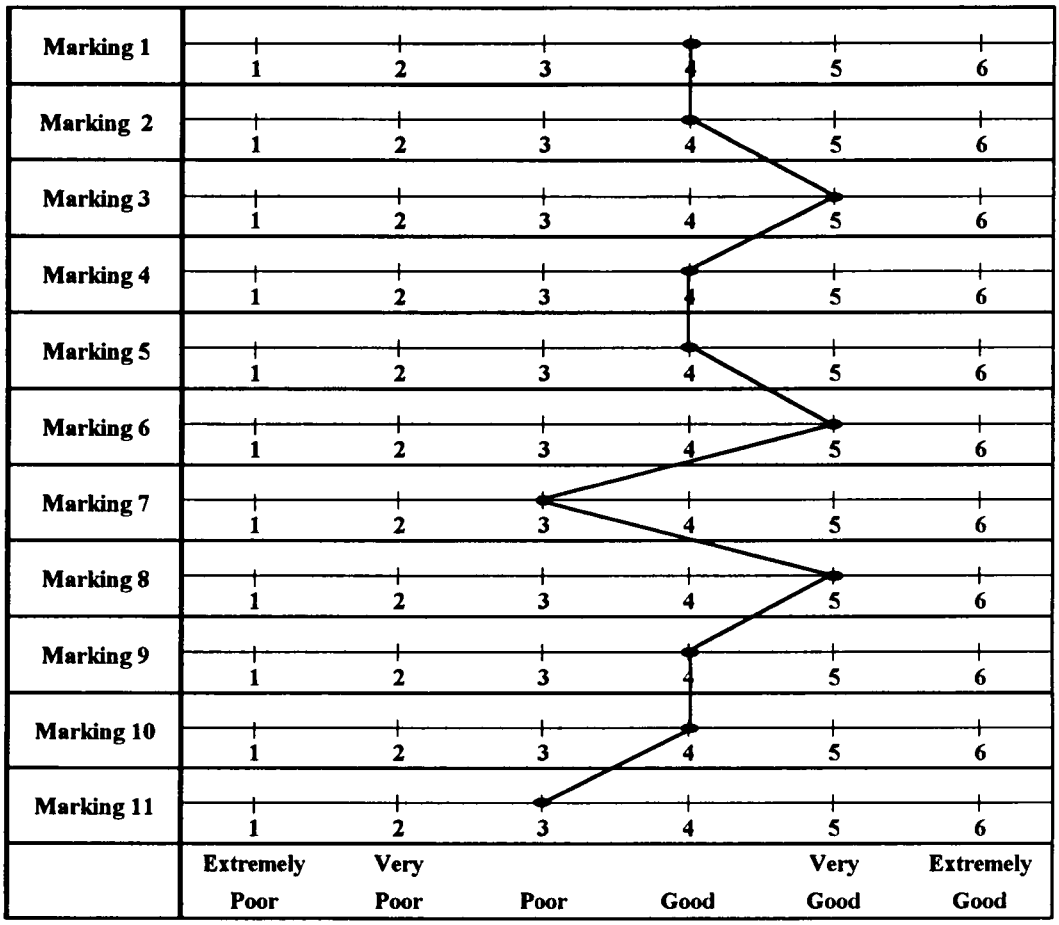
(1 = Extremely Poor; 2 = Very Poor; 3 = Poor; 4 = Good; 5 = Very Good; 6 = Extremely Good.)

Figure IV - 13. Median Likert rating of eleven markings for statement #8.

Statement #8 is "Placement of the marking on the freight car makes detectability..."

MARKING (S) *	AVERAGE LIKERT RATING
1. Crossing Gate	4.00
2. Saw Tooth	4.00
3. Outline	5.00
4. Chevrons	4.00
5. Diamonds and Bars	4.00
6. Highway Center Lines	5.00
7. Cross Buck	3.00
8. Picket Fence	5.00
9. Volpe/Field Test	4.00
10. Truck	5.00
11. Standard	3.00

* See Appendix A for complete description.



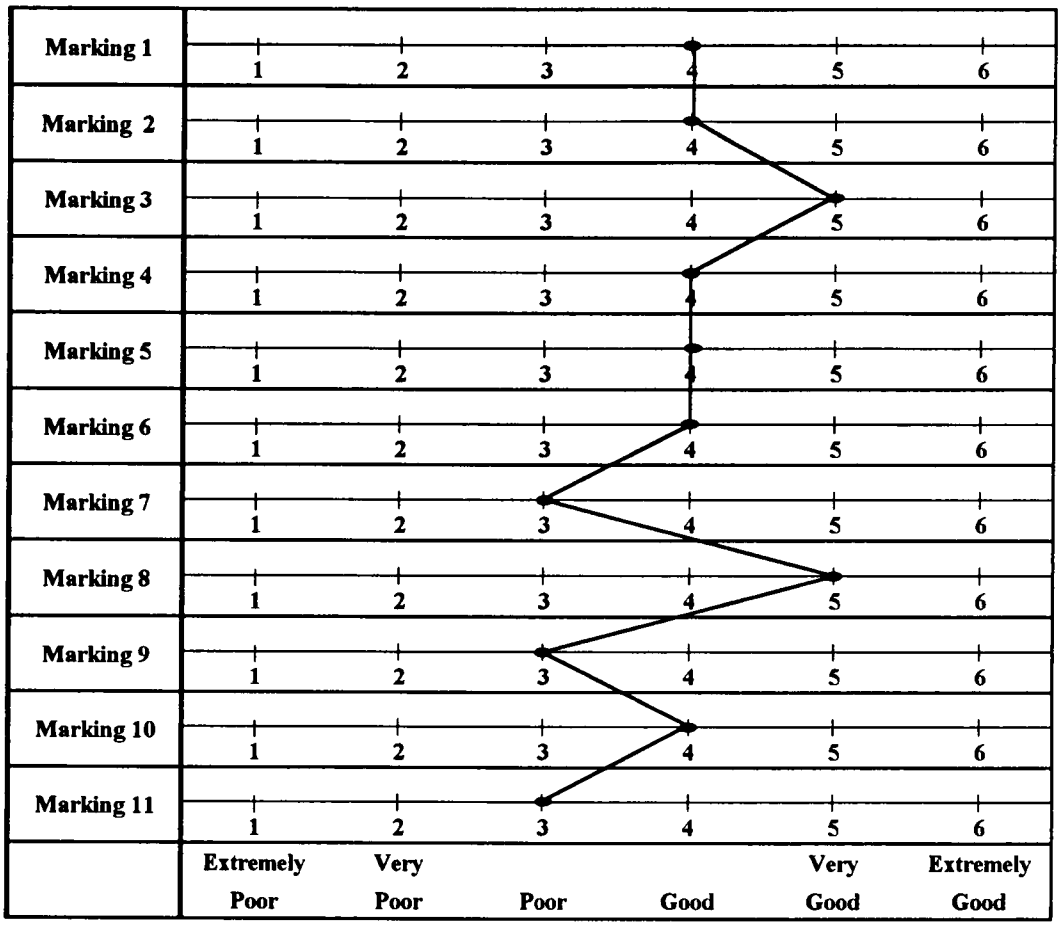
(1 = Extremely Poor; 2 = Very Poor; 3 = Poor; 4 = Good; 5 = Very Good; 6 = Extremely Good.)

Figure V - 14. Median Likert rating of eleven markings for statement #9.

Statement #9 is "The marking color(s) make the detectability of the freight car..."

MARKING (S) *	AVERAGE LIKERT RATING
1. Crossing Gate	4.00
2. Saw Tooth	4.00
3. Outline	5.00
4. Chevrons	4.00
5. Diamonds and Bars	4.00
6. Highway Center Lines	5.00
7. Cross Buck	3.00
8. Picket Fence	5.00
9. Volpe/Field Test	4.00
10. Truck	4.00
11. Standard	3.00

* See Appendix A for complete description.



(1 = Extremely Poor; 2 = Very Poor; 3 = Poor; 4 = Good; 5 = Very Good; 6 = Extremely Good.)

Figure IV - 15. Median Likert rating of eleven markings for statement #10. Statement #10 is "The marking pattern makes detectability of the freight car..."

MARKING (S) *	AVERAGE LIKERT RATING
1. Crossing Gate	4.00
2. Saw Tooth	4.00
3. Outline	5.00
4. Chevrons	4.00
5. Diamonds and Bars	4.00
6. Highway Center Lines	4.00
7. Cross Buck	3.00
8. Picket Fence	5.00
9. Volpe/Field Test	3.00
10. Truck	4.00
11. Standard	3.00

* See Appendix A for complete description.

Table IV - 6. Medians and ranges of the ten statements for eleven markings.

Marking	Color(s)	Statement 1		Statement 2		Statement 3		Statement 4		Statement 5		Statement 6		Statement 7		Statement 8		Statement 9		Statement 10		Total Median	Total Range	Rank of Marking
		Median	Range	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range			
1: Crossing Gate	Red/White	4	4	4	3	4	4	4	5	4	5	4	5	4	3	4	5	4	4	4	4	40	42	7
2: Saw Tooth	Red/White	4	5	4	5	4	4	4	4	4	3	4	5	4	4	4	4	4	4	4	4	40	42	7
3: Outline	Yellow	4	4	4	4	4	4	4	3	4	3	4	3	5	3	5	3	5	5	5	3	49	35	2
4: Chevrons	Red/White	4	3	4	3	4	4	4	4	4	3	4	4	4	2	4	3	4	4	4	3	40	33	6
5: Diamonds and Bars	Red/White & Orange	4	2	4	2	4	5	4	3	4	3	4	3	4	3	4	3	4	4	4	3	40	31	5
6: Highway Center Line	Yellow	5	3	4	2	4	3	4	4	5	3	4	5	5	3	5	5	5	4	4	5	45	37	3
7: Crossbuck	Red	4	4	3	4	3	4	4	4	4	4	4	5	4	4	3	4	3	3	3	4	35	40	9
8: Picket Fence	Yellow	5	3	5	3	5	3	5	3	5	3	5	3	5	3	5	3	5	5	5	3	50	32	1
9: Volpe/Field Test	Red/White	4	5	4	4	3	4	4	4	4	4	4	5	4	4	4	5	4	3	3	4	38	42	8
10: Truck Frame	Red/White	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	4	4	4	4	4	41	40	4
11: Standard	Non-Retroreflective White Marking	3	5	3	5	3	5	4	5	3	4	4	5	3	5	3	5	3	3	3	4	32	46	10

Desciption of the Ten Statements

S1 : The marking will make detecting the freight car...
S2 : The marking will make recognizing the freight car...
S3 : The understanding of the marking is...
S4 : Confusing the marking with another marking is...
S5 : The conspicuity of the marking is...
S6 : The uniqueness of the marking is...
S7 : Contrast of the marking with the freight car background is...
S8 : Placement of the marking on the freight car makes detectability...
S9 : The marking color(s) make the detectability of the freight car...
S10: The marking pattern marks detectability of the freight car...

in rank.

Technically, the means and standard deviations are only appropriate for interval scales. The median and/or mode is the appropriate measure of central tendency for the ordinal scale. The range or interquartile score is the appropriate measure of variability. Although some people do calculate means and variances, technically it is incorrect.

Table IV-7 shows a summary of the best and worst three markings as judged by the medians of statements 1 through 10. As might be expected, the high and low rankings follow closely to those achieved with simple ranking and paired comparisons. All three top choices (markings #8, #3, and #6) contained mono color (yellow) markings of either vertical or horizontal lines. The bottom choice (marking #11) was the standard non-retroreflective marking. The other two bottom choices (markings # 7 and #9) included a simple mono color (red) marking and a red/white marking respectively.

As only one test series was conducted, all three components (simple ranking, Thurstone's paired comparison, and Likert scaling) were compared in the final validation step. Each method produced the same basic high and low rankings. Specifically, the top three (marking #8, #3, and #6) and the last two (marking #7 and #11) were the same in each test. Although the middle five positions shifted somewhat for each test, marking #9 placed 8th in two of the three methods. The convergence of results for the marking evaluation methods is shown in Table IV-8. This convergence of results represents a consistency in the data and provides "face validity" to the research strategy.

Table IV - 7. Summary of best three and worst three markings.

Statement(s)	Best M8	2nd Best M3	3rd Best M6	...	9th Worst M9	10th Worst M7	11th Worst M11
S1 : The marking will make detecting the freight car...	5	4	5		4	4	3
S2 : The marking will make recognizing the freight car...	5	4	4		4	3	3
S3 : The understanding of the marking is...	5	4	4		3	3	3
S4 : Confusing the marking with another marking is...	5	4	4		4	4	4
S5 : The conspicuity of the marking is...	5	4	5		4	4	3
S6 : The uniqueness of the marking is...	5	4	4		4	4	4
S7 : Contrast of the marking with the freight car background is...	5	5	5		4	4	3
S8 : Placement of the marking on the freight car makes detectability...	5	5	5		4	3	3
S9 : The marking color(s) make the detectability of the freight car...	5	5	5		4	3	3
S10: The marking pattern marks detectability of the freight car...	5	5	4		3	3	3

Median Likert rating of statements for markings.

1 = Extremely Poor
2 = Very Poor
3 = Poor
4 = Good
5 = Very Good
6 = Extremely Good

Table IV - 8. Comparison of questionnaire method results.

Marking	Color(s)	Simple Rank	Paired Comparison Rank	Median Likert Rank*
1: Crossing Gate	Red/White	4	4	7 / 8
2: Saw Tooth	Red/White	7	7	7 / 8
3: Outline	Yellow	2	2	2
4: Chevrons	Red/White	8	9	6
5: Diamonds and Bars	Red/White & Orange	5	5	5
6: Highway Center Line	Yellow	3	3	3
7: Crossbuck	Red	10	10	10
8: Picket Fence	Yellow	1	1	1
9: Volpe/Field Test	Red/White	9	8	9
10: Truck Frame	Red/White	6	6	4
11: Standard	Non-Retroreflective White Marking	11	11	11

* Indicates a tie in ranks.

To remain consistency in ranked comparison, ties were assigned both number ranks.

CHAPTER V

SUMMARY AND CONCLUSIONS

The application of retroreflective markings to railcars is a novel idea. Based on research that has shown retroreflective markings applied to large trucks improve conspicuity, this study investigated similar railroad car conspicuity enhancements (Richards and Hungerford, 1993).

This project had two primary objectives. The first objective was to design and administer a questionnaire as part of a modified Delphi technique, to obtain expert evaluations of eleven experimental retroreflective conspicuity marking systems generated from the Phase I of the research. The second objective was to use the collected data and apply three different statistical techniques to evaluate what the expert respondents "perceive" to be the most effective marking system to increase the visibility of coal hoppers. Three different measurement methods were used to evaluate the railcar markings to assess the consistency of results and validity of methods.

The study found, that of the eleven markings tested, there is a definite consensus on which markings are the most and least effective passive retroreflective hopper car markings. The results of this study will reduce the number of marking designs to be laboratory tested in a later phase.

The questionnaire was administered to 79 transportation experts. The statistical results from the questionnaire show that the most effective hopper car markings were #8, #3, and #6 respectively. The three top choices all contained vertical and/or horizontal mono color (yellow) markings against the black coal cars. The most effective, #8 is comprised of vertical 2.5ft. fluorescent yellow strips applied in a "picket fence pattern"

along the side of the railcar. Marking # 3 uses yellow strips to outline the railcar body. In marking #6, fluorescent yellow strips (2.5ft.) are symmetrically applied every 5ft. horizontally just above the side sill. The least effective marking was #11 followed by #7. The least effective marking was #11, a standard non-retroreflective marking. The next least effective was #7, a simple red crossbuck applied to the full height of the left and right ends of the railcar. Marking #9 consists of vertical red and white stripes applied to the full length of the car body just above the side sill with a white corner markings applied to the top cord at the ends of the car body.

The perceived effectiveness of the markings may have been due to the contrast of the yellow marking color against the black base color of the coal hopper. In addition, the experts may have had professional experience with yellow caution or warning signs and signals that skewed the results toward yellow markings.

To further validate the data, the ranked marking designs obtained from the questionnaire were compared with the results obtained from the application of a jury technique conducted by another researcher as part of the overall project. Similar scaling techniques were used in the jury technique to evaluate the conspicuity markings. In this process, the jury was presented with scaled mockups of railcars and asked to evaluate its perceived effectiveness. While experts were respondents to the questionnaire, the jury consisted of individuals who were both experts in transportation and ordinary drivers.

The results from the questionnaire and the jury are given in Table V-9. For the jury, the most preferred markings were #8, #2, and #3 respectively. Two of the top choices, #8 and #3 contain mono color (yellow) markings. Again, #8 is comprised of vertical 2.5ft. fluorescent yellow strips applied in a "picket fence pattern" along the side of the railcar. Marking # 3 uses yellow strips to outline the railcar body. The other top choice, #2, consists of two groups of alternating red and white strips applied in saw tooth

Table V - 9. Comparison of questionnaire and jury results.

	QUESTIONNAIRE			JURY	
	Simple Method	Paired Comparison Method	Likert Method	Simple Method	Paired Comparison Method
RANK			MARKING DESIGNS		
1	Picket Fence	Picket Fence	Picket Fence	Picket Fence	Picket Fence
2	Outline	Outline	Outline	Saw Tooth	Saw Tooth
3	Highway Center Line	Highway Center Line	Highway Center Line	Outline	Outline
4	Crossing Gate	Crossing Gate	Truck Frame	Truck Frame	Truck Frame
5	Diamonds and Bars	Diamonds and Bars	Diamonds and Bars	Crossbuck	Crossing Gate
6	Truck Frame	Truck Frame	Chevrons	Chevrons	Volpe/Field Test
7	Saw Tooth	Saw Tooth	Crossing Gate/Saw Tooth*	Volpe/Field Test	Chevrons
8	Chevrons	Volpe/Field Test	Crossing Gate/Saw Tooth*	Crossing Gate	Crossbuck
9	Volpe/Field Test	Chevrons	Volpe/Field Test	Diamonds and Bars	Highway Center Line
10	Crossbuck	Crossbuck	Crossbuck	Highway Center Line	Diamonds and Bars
11	Standard	Standard	Standard	Standard	Standard

* Indicates a tie in ranks.

Marking Designs

1. Crossing Gate
2. Say Tooth
3. Outline
4. Chevrons
5. Diamonds and Bars
6. Highway Center Lines
7. CrossBuck
8. Picket Fence
9. Volpe/Field Test
10. Standard

pattern, one just below the top cord and the other just above the side sill, running the full length of the railcar. The least perceived effective marking was #11, the standard non-retroreflective marking, followed by marking #5 and # 6. Marking # 5 consists of red over white strips applied the full length of the railcar just above the side sill with fluorescent orange diamonds superimposed on the red over white strips ever eight feet beginning at the horizontal center line of the car. Marking #6 has fluorescent yellow strips (2.5ft.) symmetrically applied every 5ft. horizontally just above the side sill.

A comparison of the Questionnaire and Jury data indicates the same high and low preference for markings #8 and #11 respectively. Ranks 2 through 10 however, were less comparable. A number of possible reasons exist for the deviations. First, there is the difference in presentation of the markings. While the questionnaire presented small photos of static railcars in a daytime setting, the jury technique presented the railcars in a nighttime setting and simulated the appearance of headlamps shining on the retroreflective markings. Second, the tests were conducted in different settings with small sample groups. The questionnaire was administered through the mail, while the jury was conducted in a lab.

Although there was deviation in the results, this evaluation method was able to validate the group consensus of the most and least preferred markings. In drawing conclusions, respondents to both the questionnaire and the jury basically liked and disliked the same markings. Yellow markings on black backgrounds were on average, more favored than red/white, or red markings on black backgrounds. However, any marking was preferred over the standard non-retroreflective marking.

Thus in conclusion, the results of this study recommend that, for black coal hopper railcars, markings #2, #3, #5, #6, #7, #8, #9, and #11 be used for further evaluation in Phase IV of the overall project. This group represents the most and least

preferred markings from both the questionnaire and the jury. Although marking #11 is the standard non-retroreflective marking, it needs to be included as the standard reference point from which other markings can be judged. This recommendation was based on one iteration of a questionnaire. Further evaluations could reduce this recommended marking group.

CHAPTER VI

RECOMMENDATIONS FOR FURTHER RESEARCH

A number of recommendations for further research were developed during this research phase.

1. This research was conducted for black coal hoppers. Further study may be necessary if additional coal hopper colors are to be considered. Additionally, further study may be necessary if additional railcar types are to be considered.

2. Additional time, a larger sample size, and multiple questionnaires may have produced more convergence of questionnaire and jury responses. While the jury was able to discuss and question the researchers directly, the questionnaire respondents were isolated and had to make their own judgements. Additional sample group testing could provide more convergence and confidence in marking preferences.

3. The designs developed in this research need to be further evaluated. In addition, other candidate warning systems such as "strobe lights on cars" and in-vehicle driver alerting devices that are activated by the presence of a train need to be investigated.

4. Laboratory research should be conducted to evaluate subjective human responses to railcar markings such as detection and recognition times as static railcars are approached. Also errors of recognition need to be collected and analyzed to evaluate subjects confusion between cars.

6. The effects of dirt and degradation to the retroreflective markings should be evaluated.

5. This research was conducted with static photos of railcars. Additional [dynamic] laboratory research should be conducted using moving railcars at different speeds with test subjects in simulated moving automobiles. Field tests could then be used to further evaluate and validate the designs.

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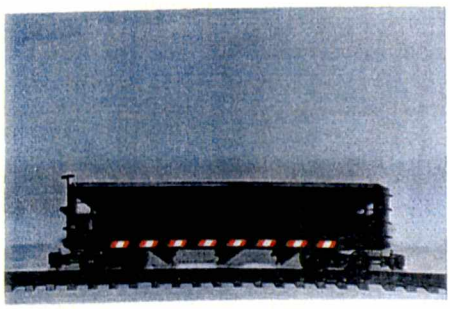
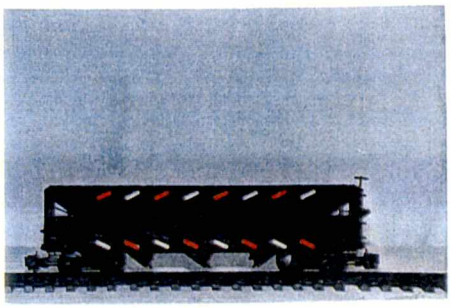
APPENDICES

APPENDIX A

ELEVEN EXPERIMENTAL CONSPICUITY MARKING DESIGNS FOR RESEARCH



RANKING OF MARKING #1 _____



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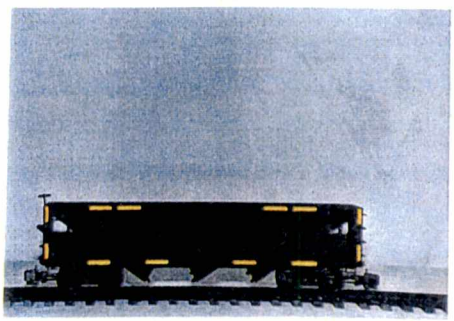

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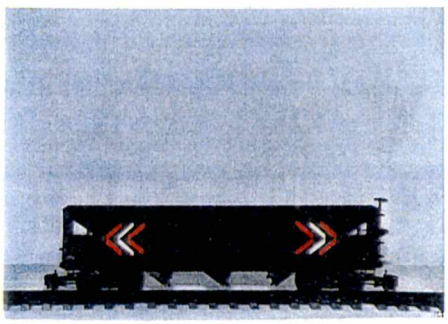

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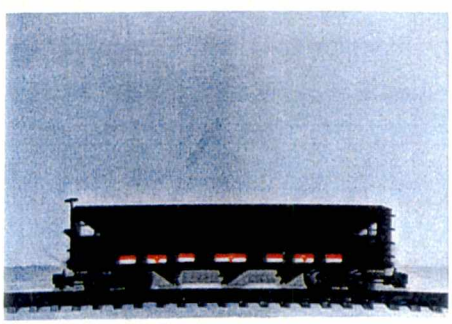

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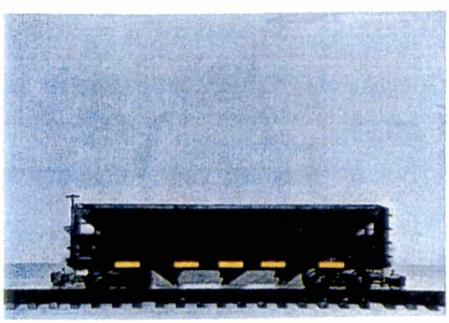

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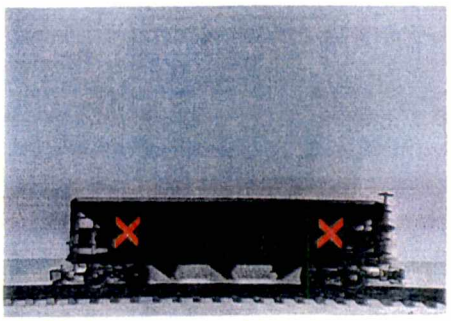

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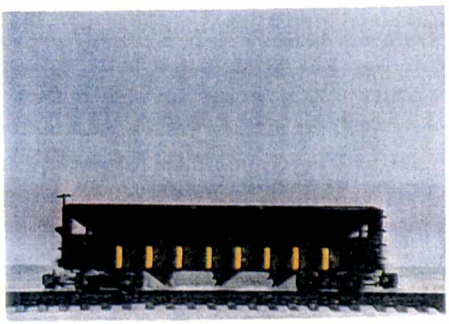

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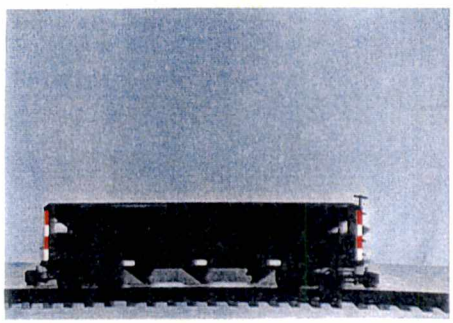

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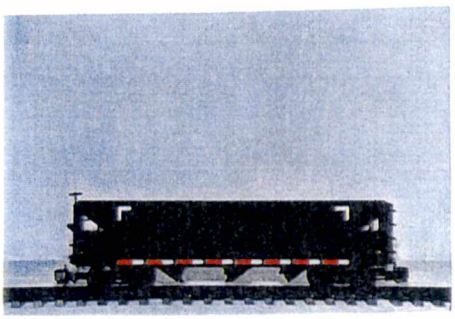

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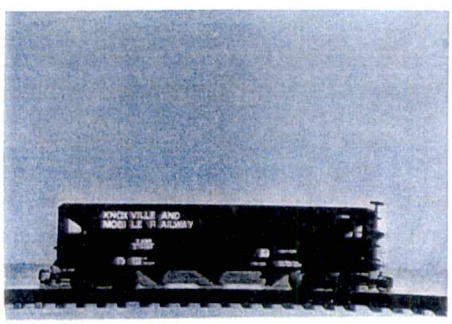


RANKING OF MARKING #11 _____

APPENDIX B

THURSTONE'S METHOD OF PAIRED COMPARISON AND LIKERT SCALING TECHNIQUE

Thurstone's Method of Paired Comparison

Thurstone's technique is a psychophysical technique. Psychophysics is the study of the relationships between observed stimuli and responses and the reasons for those relation. In other words, it allows one to measure how a person judge properties of stimuli.

In the method of paired comparison, a person is to compare all stimuli in a set j with all stimuli in a set k two at a time and then select which of each pair was the more preferred. This is a ranking of two stimuli on a ordinal scale. This process is a form of "paired comparison judgement" which people are better at then at absolute judgement because of the mental limitation people have. However, when the number of the stimuli being compared is large, the transitivity of judgements become more difficult to measure. Therefore, the Thurstonian scaling is used to overcome this lack of transitivity by deriving scale values for the stimuli.

The basic idea of a Thurstone scale is that each stimulus j is compared with every other stimulus k to determine which of the two is the more preferable one. There are [(n) (n-1)/2] paired comparisons of N items that must be compared. Thurstone made an assumption that each time a stimulus is presented, it is represented by a point along a psychological scale that is determined by an underlying discriminal process which causes a person to react to the stimulus. However, a given stimulus may not always excite the same discriminal process because of inherent variability in the person. As a result, there are a number of different discriminal processes associated with that given stimulus. Therefore, each time a pair of stimuli are presented to a person, two points are produced along the psychological scale. And as the stimulus is presented to the person for a large number of times, the frequency distribution on the psychological scales of discriminal processes associated with that stimulus is normally distributed.

Figure A-1 shows the distributions of the responses given for the two stimuli. The discriminal dispersions of any given pair of stimuli also forma normal distribution on the psychological scale. The distribution of the differences between stimulus j and stimulus k is shown in Figure A-2. This distribution has a mean of $\mu_k - \mu_j$ and the standard deviation of the differences between two normal distributions is $\sigma_{kj} = [\ \sigma^2_j + \sigma^2_k - 2r_{kj}\sigma_j\sigma_k\ ]^{1/2}$ where r_{kj} is the correlation coefficient between the discriminal processes. It is also assumed that $r_{kj} = 0$, $\sigma_j = \sigma_k$ and $\sigma_{kj} = 1$ since σ_k, σ_j and r_{kj} are usually unknown. Therefore, these assumptions reduce Thurstone's law to $\mu_k - \mu_j = z_{kj}$ where z_kj is a standard normal variable with distribution N (0,1).

In summary, the scale values are established by calculating the standard deviations of the means of the discriminal dispersion and placing them on an interval scale. Each pair of N stimuli is presented to the subjects to indicate the dominate stimulus of the pair. This group data is used to create a dominance matrix that showed the probabilities stimulus j is preferred over stimulus k, with each cell in the matrix corresponding to a pair of stimuli. These probabilities are used to determine an average z value (scale value = mean z value). This z value can then be used to rank the preference on an interval scale. A high z score indicates that an attribute that was highly preferred, and the low z score indicates an attribute that was not preferred.

Likert Scaling Technique

Likert technique is often used in survey questionnaires to measure the degree in which the respondents agree or disagree with each statement. This technique provides an absolute scaling of statements. However, by providing an "anchor point" of the types "very easy" and "easy", the respondent can make comparative judgments instead of

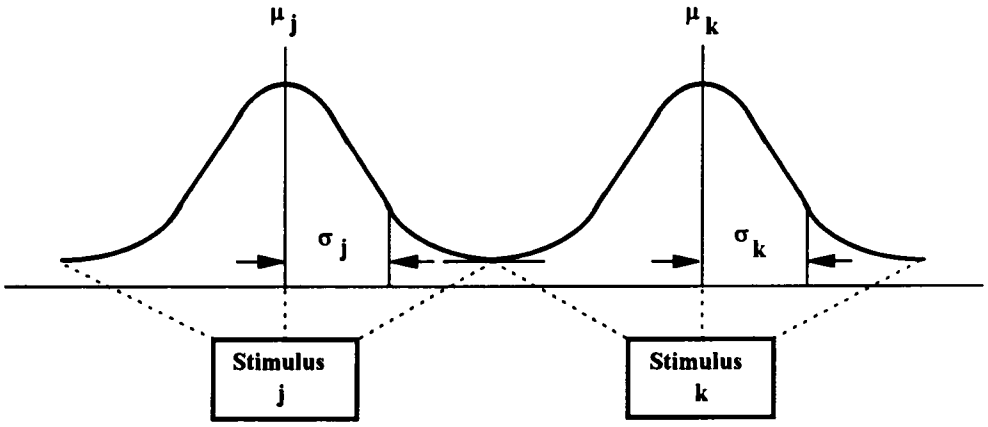


Figure A -1. Discriminal process distributions for stimuli j and k.

Source: Hungerford, 1981.

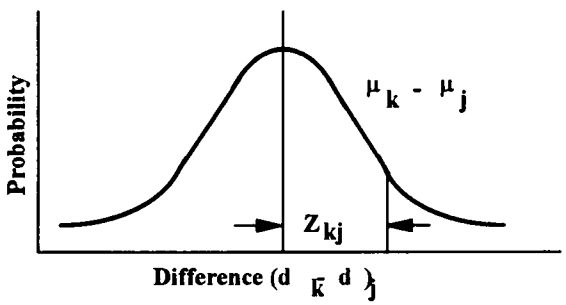


Figure A - 2. Distribution of pair differences.

Source: Hungerford, 1981.

absolute judgments since the respondent can compare all statements with the anchor points.

Each respondent will be asked to select one of the six choices for each statement. They range from "extremely good" to "very good", "good", "poor", "very poor", and "extremely poor." These six choices are given the score of 6, 5, 4, 3, and 1 to help calculate and record the responses of each respondent easier. It would be decided that the high scale score be a favorable response, then favorable statements must be scored 6 for "extremely good," down to 1 for "extremely poor." Having scored each statement from 6 to 1, the next step was to sum up all valid responses on the ten statements for each eleven markings to obtain a total score. The total score for each statement was then divided by the number of respondents who answered this particular statement to obtain the average score. The high average score indicates that the statement was the most favorable, and the low average score indicates the least favorable.

APPENDIX C

PARTICIPANTS IN MAILED SURVEY

Mr. Mal Baird
Director, Public Trans & Aero
Tennessee DOT 505 Deaderick Suite 400
Nashville, TN 37243-0325

Mr. Jack Barbee
General Chairman of the United
Transportation Union
P.O. Box 9599
Knoxville, TN 37940

Mr. Tom Benson
Regional Vice President
State Relations, CSX Transportation
109 Westpark Drive, Suite 310
Brentwood, TN 37027

Ms. Susan Bickford
Public Affairs
Norfolk Southern Corporation
611 Commerce Street, Suite 2904
Nashville, TN 37203

Mr. Richard Bowen
Railroad Planner
AOT/Rail, Air & Public Transportation
133 State Street
Montpelier, VT 05633

Ms. Karen Brunelle
Transportation Safety Engineer
Federal Highway Administration
249 Cumberland Bend Drive
Nashville, TN 37228

Mr. J. M. Brunkenhoefer
National Legislative Director of the United
Transportation Union
400 North Capitol Street, NW, Suite 856
Washington, DC 20001

Mr. Ray Callahan
Rail/Highway Grade Crossing
Supervisor
Rail and Water Division of Idaho
DOT
AMES, IA 50010

Mr. James E. Carrico, Sr.
Assistant State Legislative Director

Mr. Charles B. Castner
Consultant

Mr. John Dodson
Consultant
Roadrail Services
3204 Santa Fe Drive
Austin, TX 78741

Mr. Fran Giacoma
Senior Civil Engineer
Conrail
P.O. Box 14142
Philadelphia, PA 19101-1412

Mr. William H. Gossard
Transportation Safety Specialist
NTSB(RE-10) 490 L'Enfant Plaza East, SW
Washington, DC 20594

Mr. Keith Hinshaw
Research Evaluation Engineer
Ohio DOT
25 South Front Street, Room 604
Columbus, OH 43215

Mr. Bert D. Kellerhall
Railroad Inspector
Tennessee Public Service Commission
2730 Mendota Code
Memphis, TN 38133

Ms. Susan J. Kirkland
Railroad Inspector Supervisor
Ohio DOT-Rail Division
50 W. Broad Street
Columbus, OH 43215

Mr. James P. Finn
Vice President
Brotherhood of Railroad Signalmen
601 West Golf Road-Box U
Mount Prospect, IL 60056

Mr. William A. Goodwin
Associate Vice President for
Research
Tennessee Technological University
Derryberry Hall, Room 308
Campus Box 5012
Cookeville, TN 38505

Dr. Lee Han
Professor
The University of Tennessee
Perkins Building
Knoxville, TN 37996

Mr. James W. Johnson
Grade Crossing Safety Planner
Southern Pacific Transportation
624 Scott Avenue
Kansas City, KS 66105

Mr. Joseph E. Ketron
Rail Transportation Engineer
Virginia Department of Rail
Transportation
1401 E. Broad Street
Richmond, VA 23219

Ms. Essie Kloeppel
TSHRC Room T-101
6300 George Town Pike
McLean, VA 22101

Mr. Alex Kocsis
Senior Investigator
Transportation Safety Board
Place Du Centre
200 Promade Du Portage, 4th Floor
Hull, Quebec K1A1K8
CANADA

Mr. Tyler Kress
The University of Tennessee
153 Alumni Memorial Building
Knoxville, TN 37996-1506

Mr. Robert Lauby
Chief of Railroad Division
Railroad Division
490 L'Enfant Plaza East, SW
Washington, DC 20594

Mr. John W. Lewis
Rail-Highway Manager
Rail and Transit Division Montana DOT
P.O. Box 201001
Helena, MT 59620-1001

Mr. Sidney J. Louick
Chief, Safety Programs Branch (HHS-22)
FHWA, Office of Highway Safety
400 Seventh Street, SW
Washington, DC 20590

Mr. Dick A. Mather
Railroad Crossing Signal Specialist
Oregon Public Utility Commission
Rail Safety
550 Capital Street, N
Salem, OR 97310-1380

Mr. Phillip R. Poichuk, P.E.
Senior Crossing Engineer
Railway Safety Directorate
Transport Canada
344 Slater Street, 15th Floor
Ottawa, Ontario K1A0N5 CANADA

Mr. A. W. Polich
Director-Public Projects Sante Fe Railway
4515 Kansas Avenue Kansas City, Kansas 66106

Mr. Craig J. Reiley
Technical Coordinator of Crossing Safety
Oregon Public Utility Service
550 Capital Street
Salem, OR 97310

Mr. Joseph N. Reinhardt
Railroad Planner
Public Utilities Commission-Ohio
180 E. Broad Street, 5th Floor
Columbus, OH 43266-0573

Mr. Hol Richards
Consultant
P.O. Box 10350
College Station, TX 77842

Mr. Frank Roskind
Office of Safety Analysis, RRS-21.1
Federal Railroad Administration,
Room 8301
400 Seventh Street, S. W.
Washington, DC 20590

Dr. Eugene R. Russell
Professor of Civil Engineering
Kansas State University
Seaton Hall
Manhattan, KS 66506-2905

Mr. George Thibault
Project Manager
Minnesota DOT
395 John Ireland Blvd, Mail Stop 470
St. Paul, MN 55155

Mr. Rudy Umbs
Chief of Traffic Standards
Federal Highway Administration, HHS-21
Washington, DC 20590

Mr. Alvin M. Zager
Utilities Engineer
Tennessee DOT
600 James K. Polk Building
Nashville, TN 37243-0337

Mr. Keith Shaffer
Grade Crossing Specialist
Ohio DOT-Rail Division
50 W. Broad Street
Columbus, OH 43216

Mr. Larry E. Tibbits
Railroad Coordination Engineer
Michigan DOT, Engineering Services Division
425 West Ottawa Street
Lansing, MI 48909

Mr. Bob Winans
Highway Engineer
Federal Highway Administration, HNG-12
400 Seventh Street, SW
Washington, DC 20590

APPENDIX D

QUESTIONNAIRE

EXPERIMENTAL CONSPICUITY MARKING SYSTEMS

FOR FREIGHT CARS

QUESTIONNAIRE

Please Return To
Chau Pham
The University of Tennessee
Transportation Center
342 South Stadium Hall
Knoxville TN 37996-0700
(615) 974-5255

SURVEY PARTICIPANTS
PLEASE READ THE FOLLOWING INSTRUCTIONS BEFORE PROCEEDING FURTHER

The purpose of this survey is to obtain an expert evaluation of eleven experimental retroreflective marking systems for freight cars. The function of these marking systems is to increase the visibility of freight trains at night. It is believed that these markings can reduce run-into-train accidents at railroad grade crossings with passive controls. These marking systems have been applied to scale model hopper cars so that they can be evaluated in a laboratory setting. Hopper cars were chosen for this study because they often are operated in unit trains and are one of the most difficult freight cars for drivers to see.

The question this research is attempting to answer is: What combination of geometric shape, color or pattern of colors, size, and distribution of a given marking system will be most effective in increasing the visibility of freight cars for drivers? In order to answer this question, a series of evaluations have been planned. Also, the responses to this evaluation will be used to reduce the number of designs being considered by eliminating those designs that receive poor scores.

This questionnaire contains five sections and should take approximately 30 minutes to complete. Please complete the sections in the order presented. Do not hesitate to contact us if you have any questions or problems. When you have finished, please insert the questionnaire into the provided self-addressed stamped envelope and return it to us via United States Postal Service.

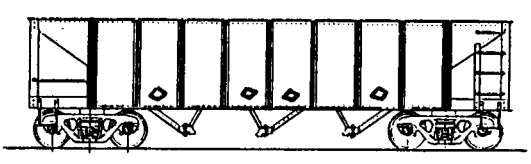
SECTION I

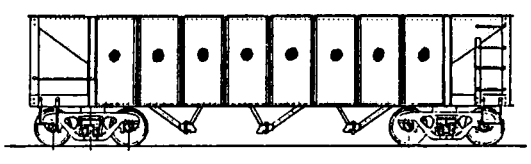
PAIRED COMPARISONS OF EXPERIMENTAL CONSPICUITY MARKING SYSTEMS FOR FREIGHT CAR

INSTRUCTIONS

For each pair of freight car experimental conspicuity markings presented on the following pages, circle the marking number below the photograph of the marking you judge to be the most effective in enhancing the visibility of freight trains. For example, if you think that the car with marking #20 is preferable to the car with marking #15, you would draw a circle around the label "MARKING #20" that is below the preferred car.

PAIR 100

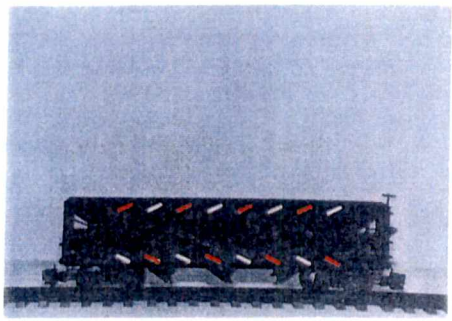




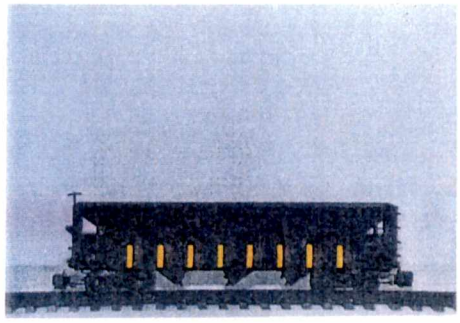
MARKING #15

MARKING #20

PAIR 1

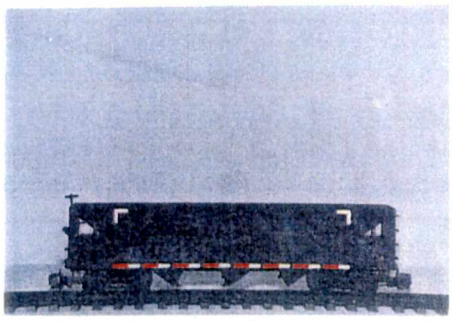


MARKING #2



MARKING #8

PAIR 2



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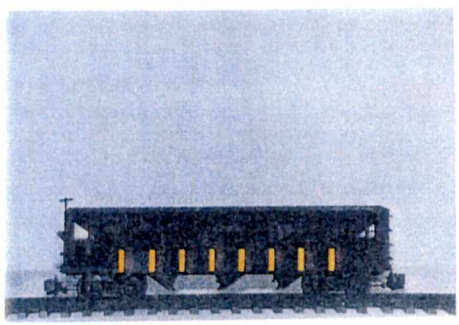

MARKING #8

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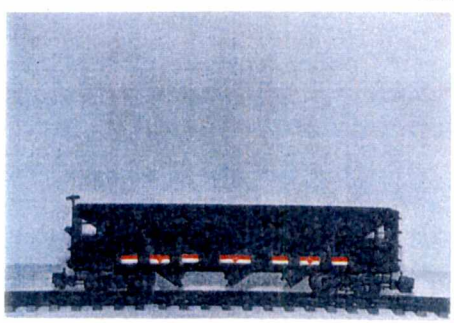

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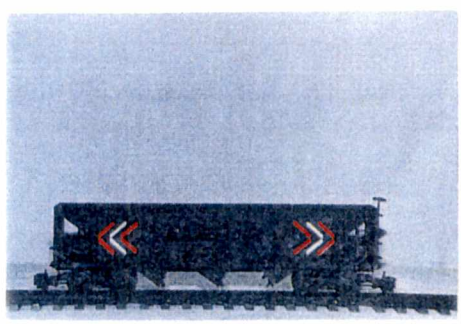

MARKING #4

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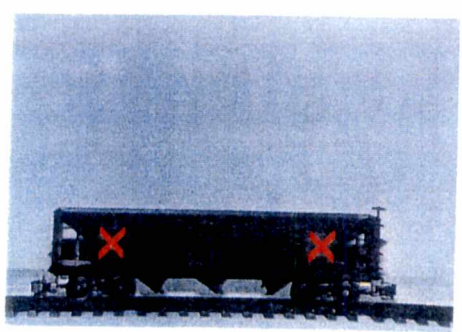

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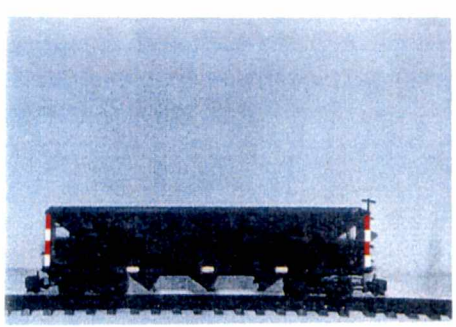

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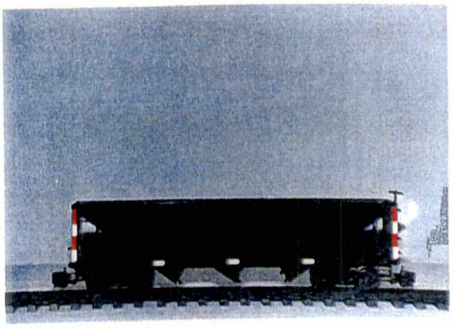

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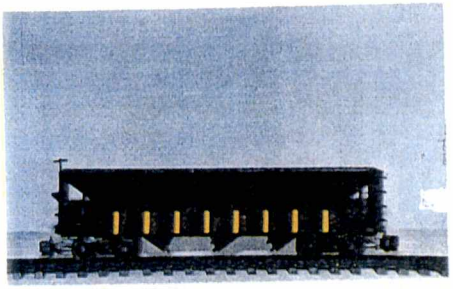

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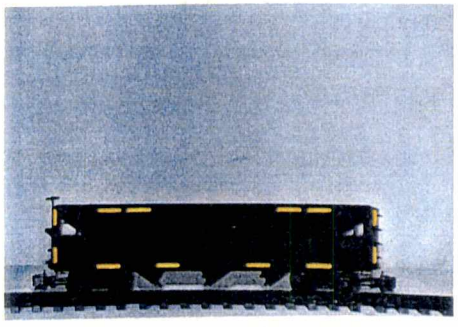

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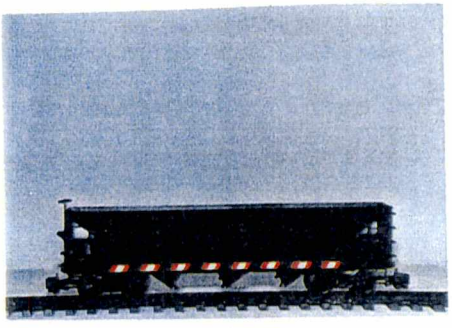

MARKING #1

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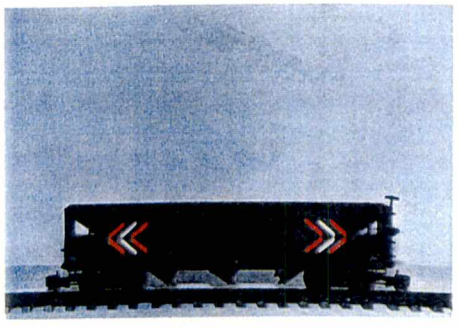

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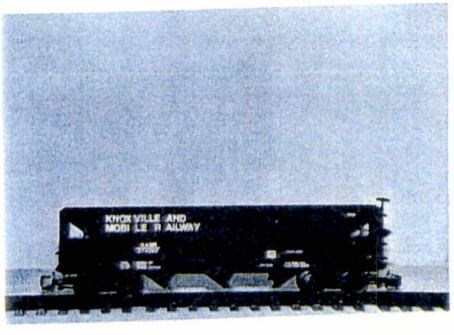

MARKING #11

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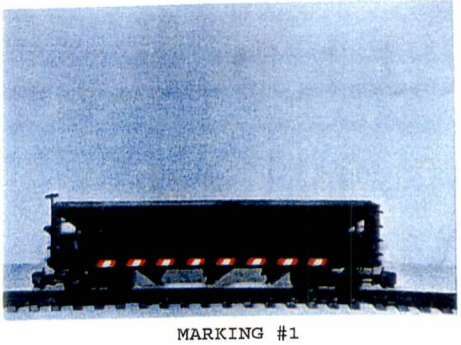

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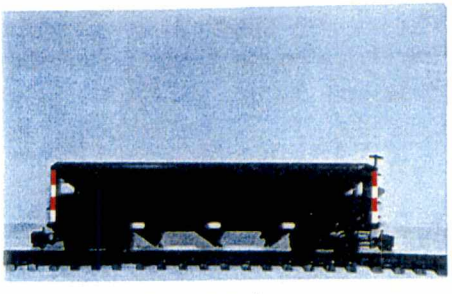

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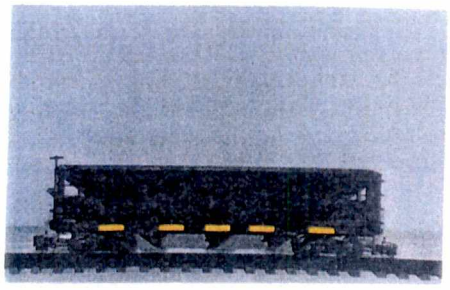

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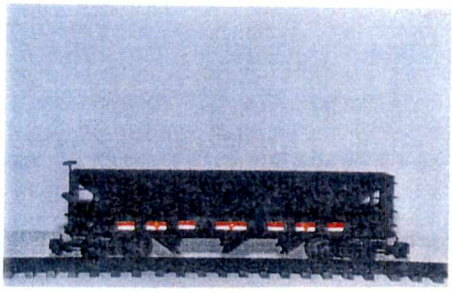

MARKING #5

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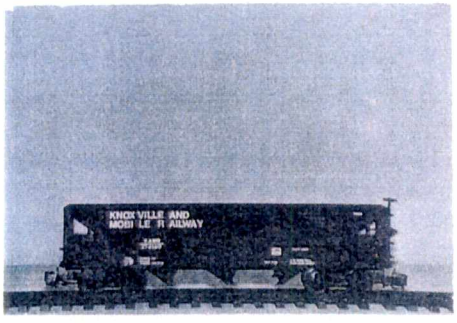

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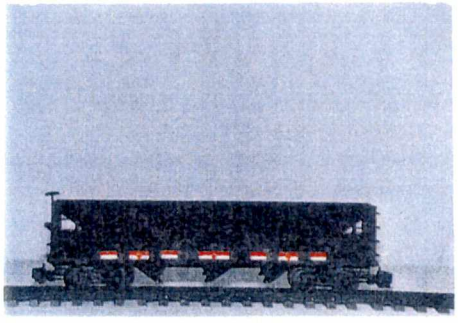

MARKING #5

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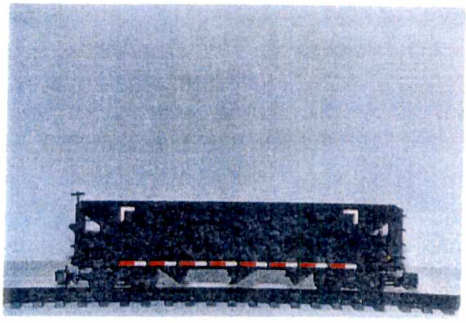

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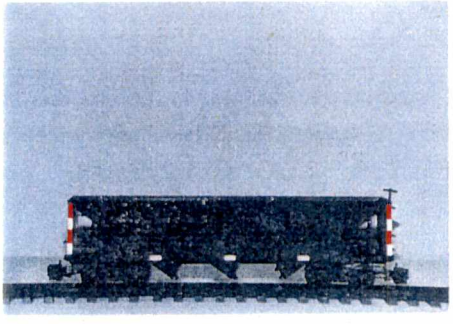

MARKING #9

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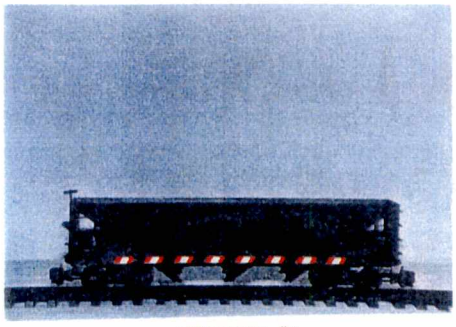

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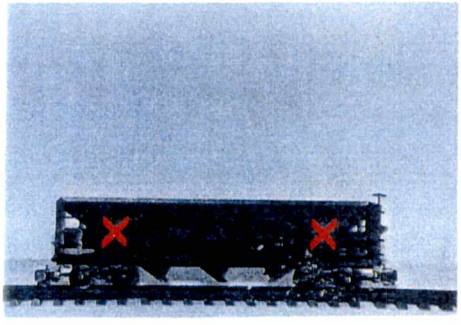

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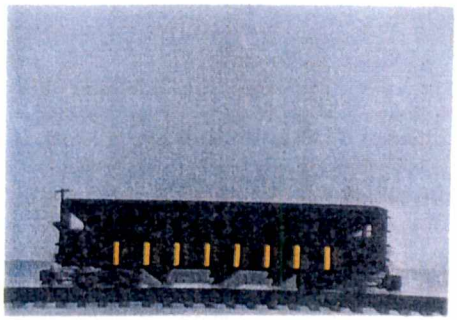

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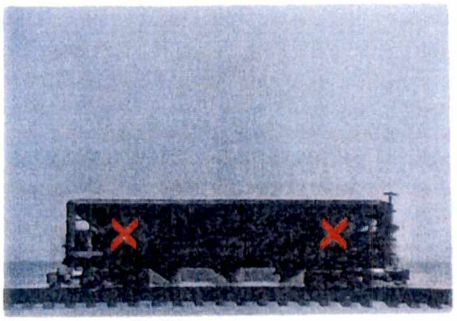

MARKING #7

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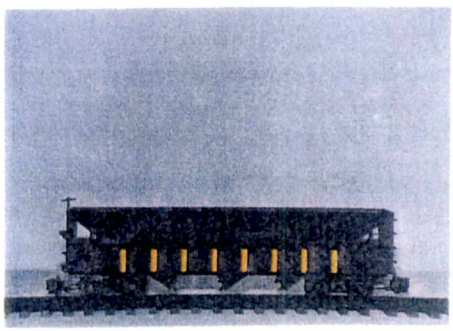

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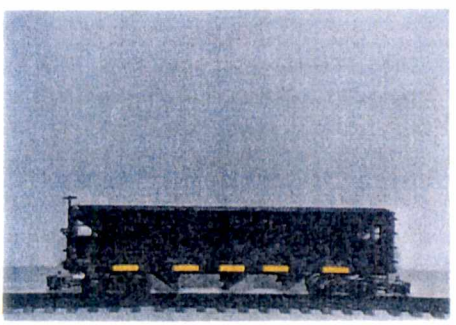

MARKING #6

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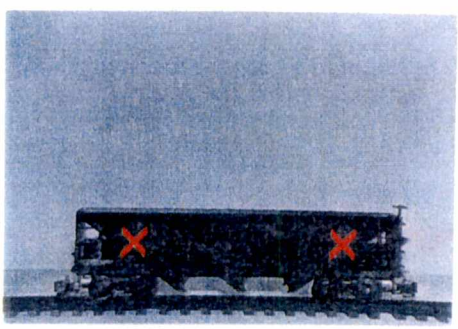
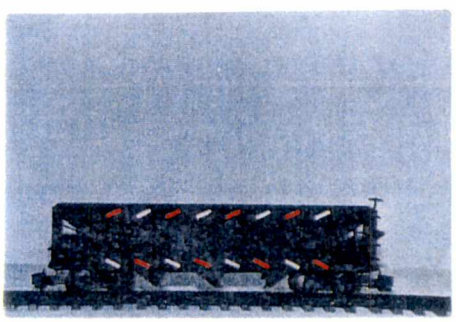
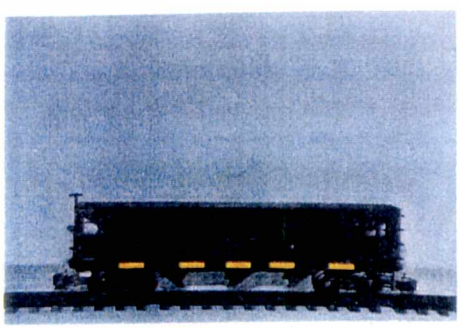


MARKING #7



MARKING #2

PAIR 16



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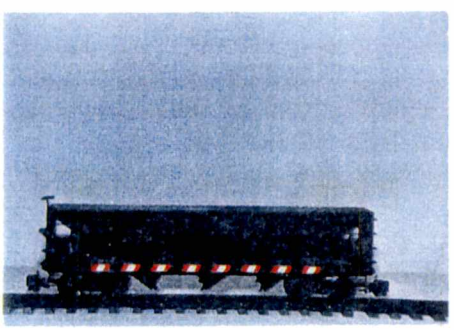
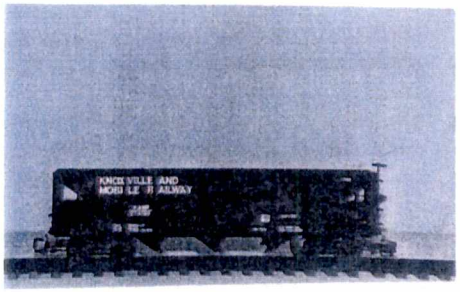
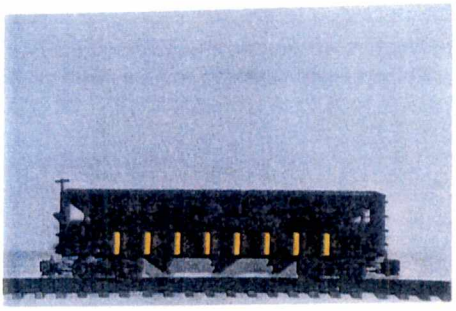


MARKING #1

PAIR 17



MARKING #11



MARKING #8

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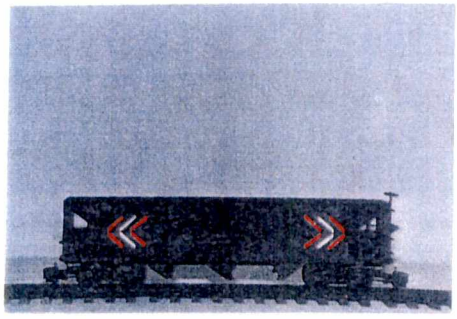
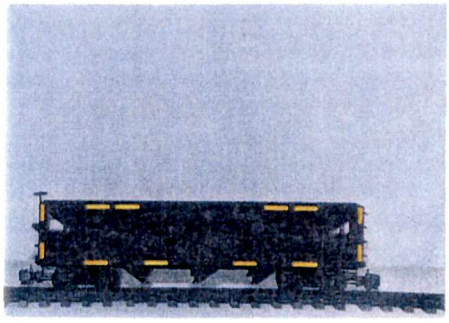
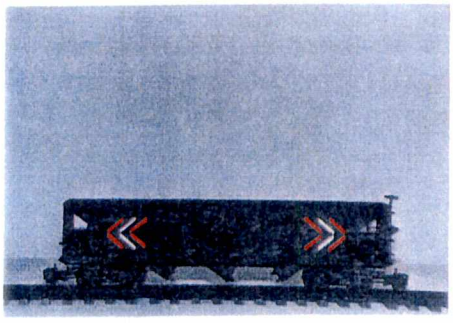


MARKING #4

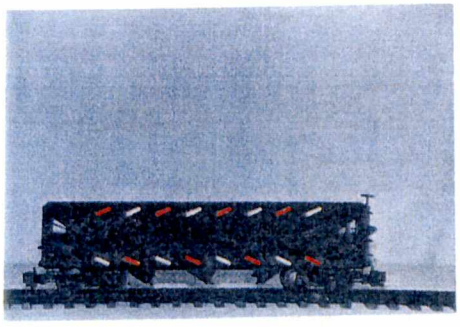


MARKING #3

PAIR 19



MARKING #4



MARKING #2

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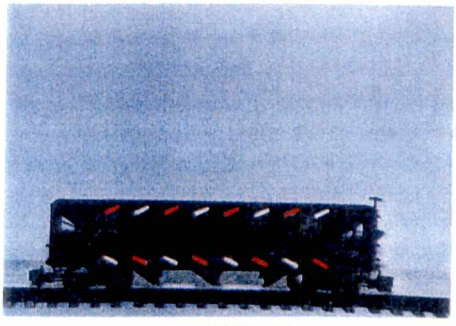
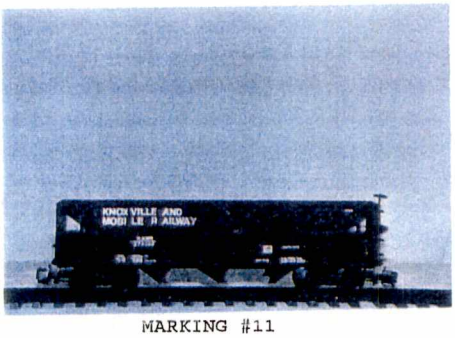


MARKING #2



MARKING #11

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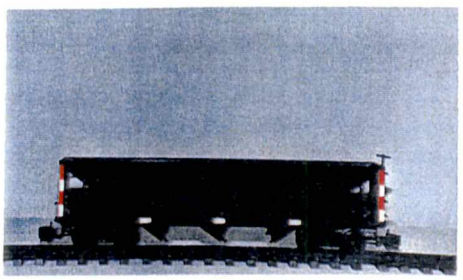
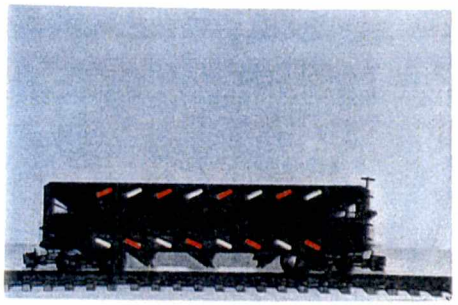
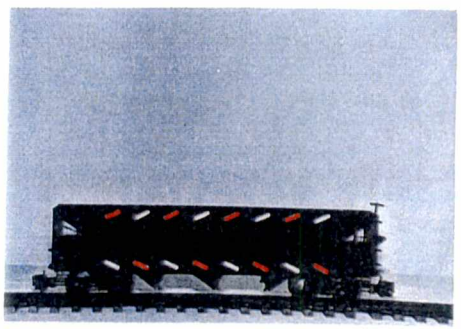


MARKING #9

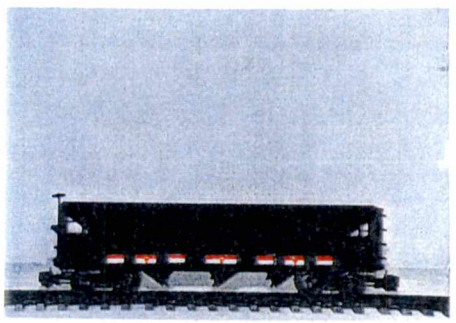


MARKING #2

PAIR 22

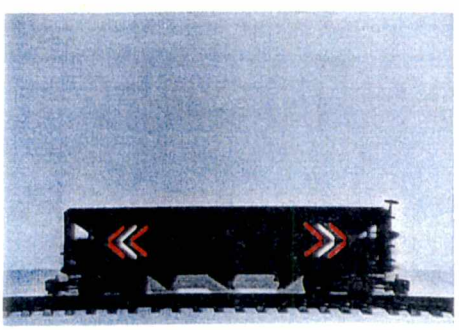


MARKING #2



MARKING #5

PAIR 23



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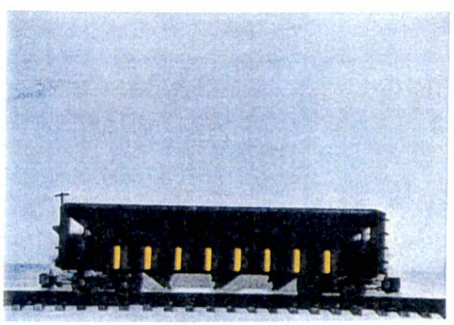
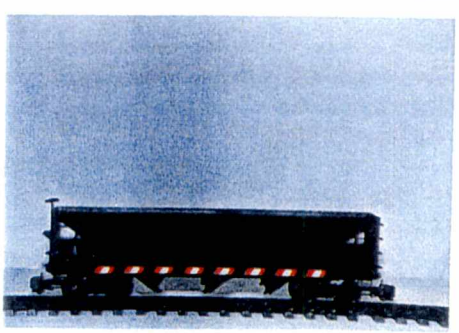
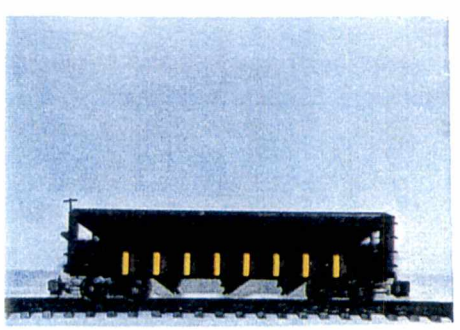


MARKING #8

PAIR 24



MARKING #1



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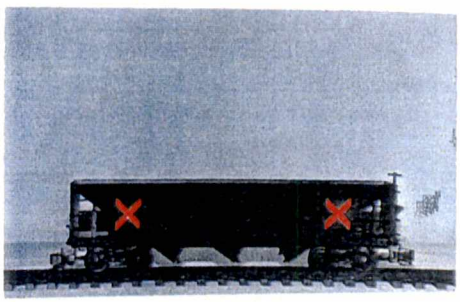
PAIR 25



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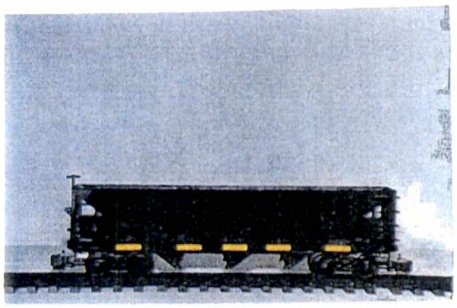
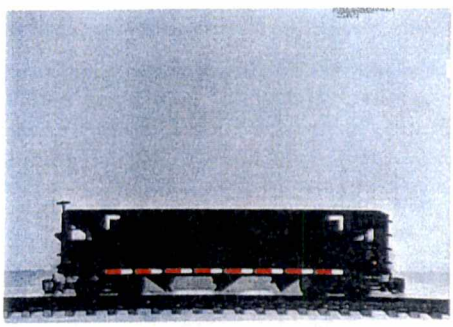


MARKING #6

PAIR 26



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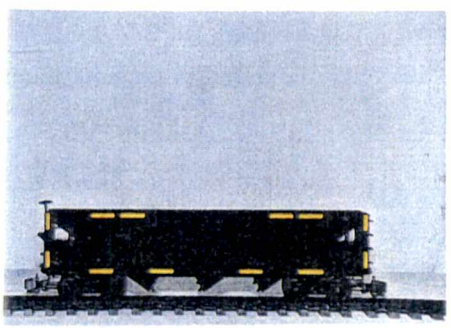
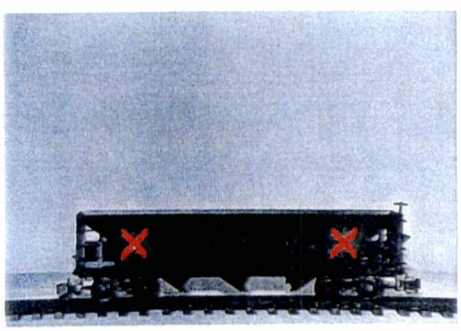
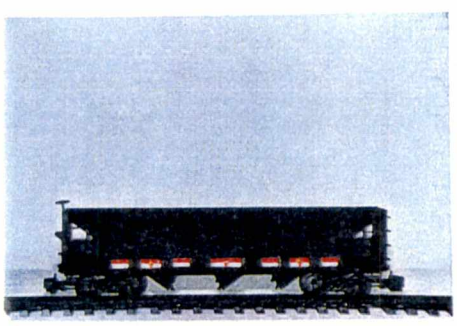


MARKING #3

PAIR 27

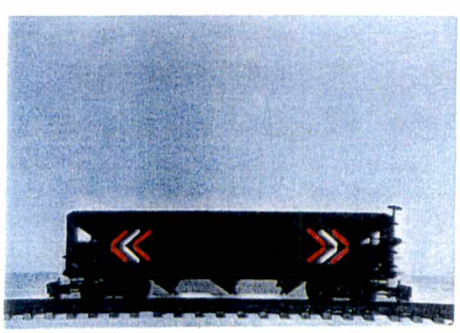


MARKING #7



MARKING #5

PAIR 28



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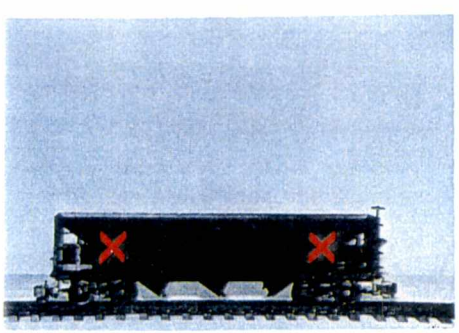

MARKING #7

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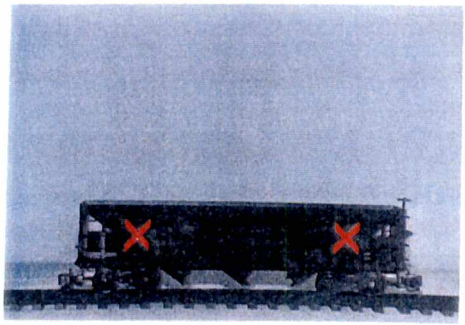

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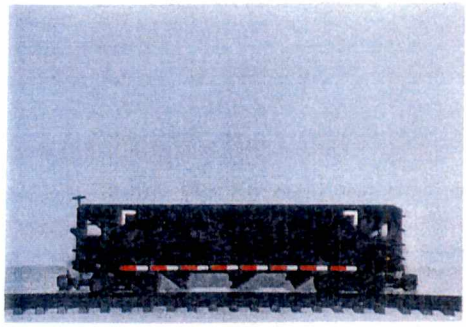

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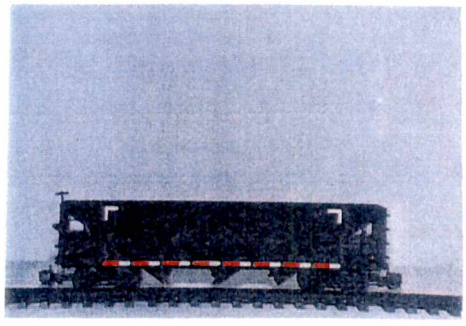
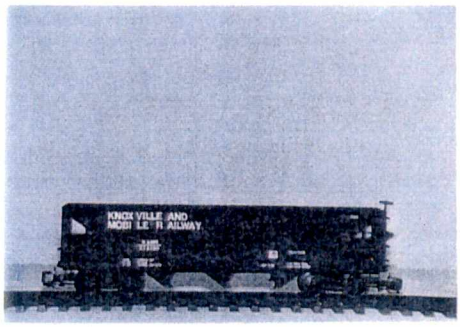
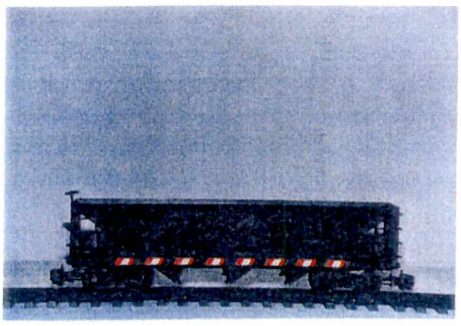


MARKING #10

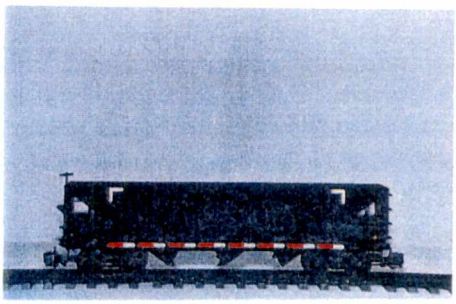


MARKING #11

PAIR 31

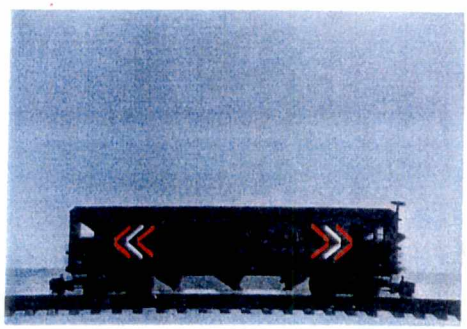


MARKING #1

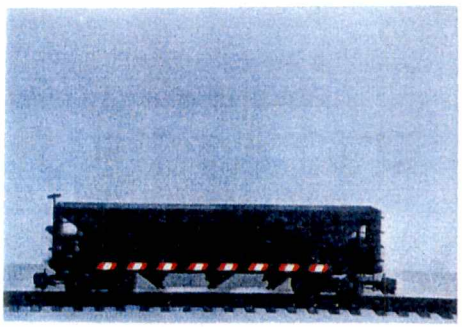


MARKING #10

PAIR 32

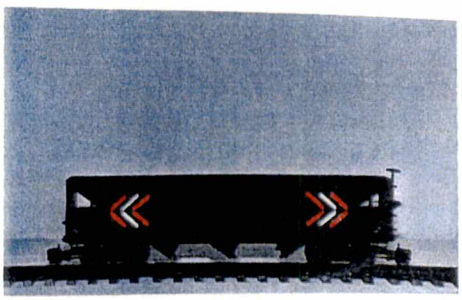


MARKING #4

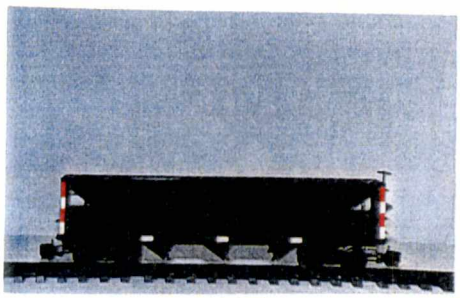


MARKING #1

PAIR 33

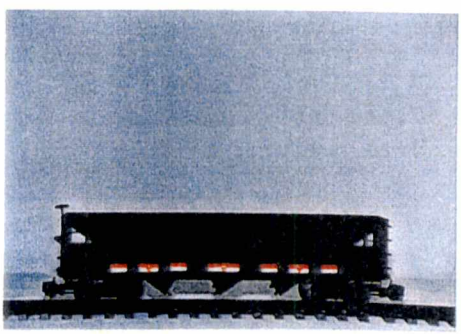


MARKING #4

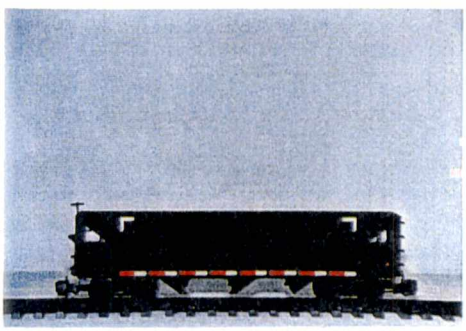


MARKING #9

PAIR 34

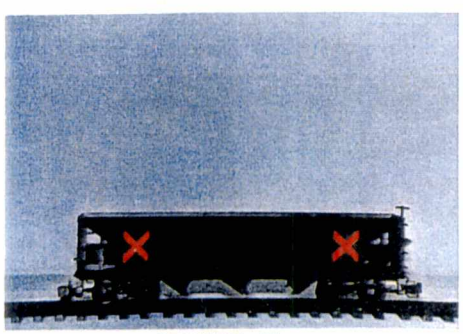


MARKING #5

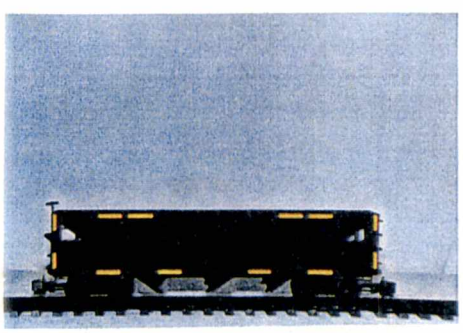


MARKING #10

PAIR 35

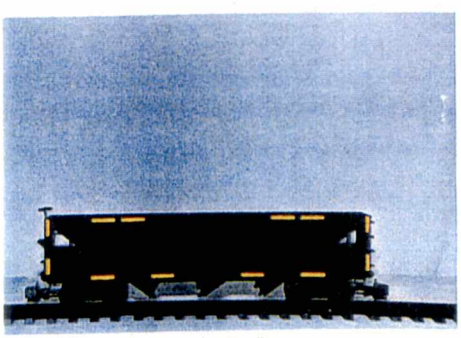


MARKING #7

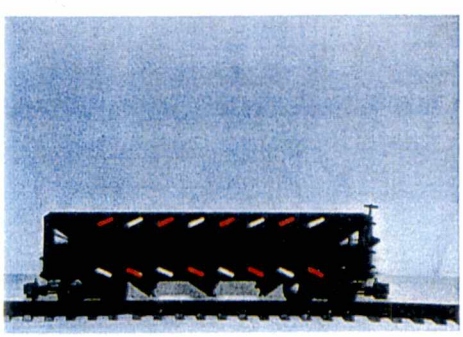


MARKING #3

PAIR 36

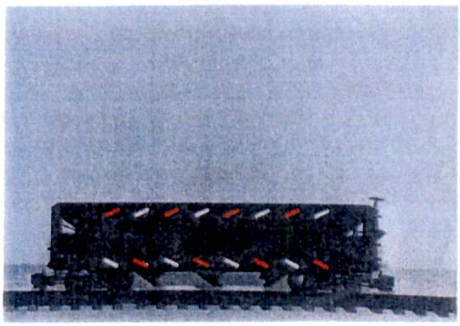


MARKING #3

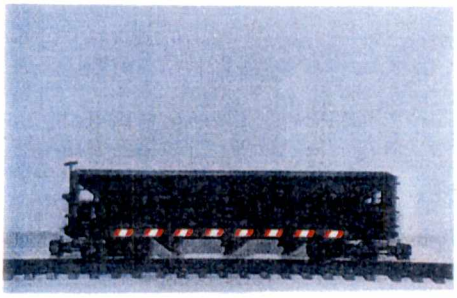


MARKING #2

PAIR 37

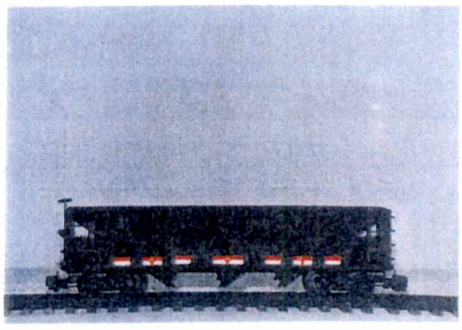


MARKING #2

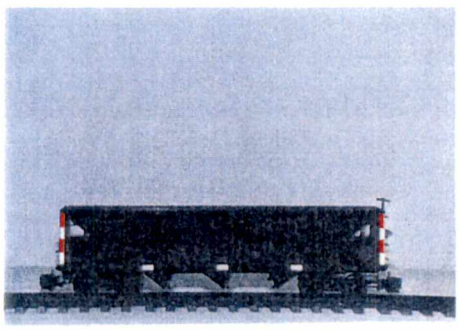


MARKING #1

PAIR 38

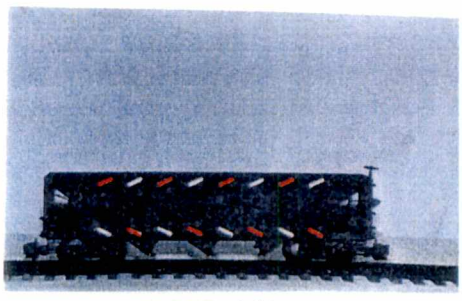


MARKING #5

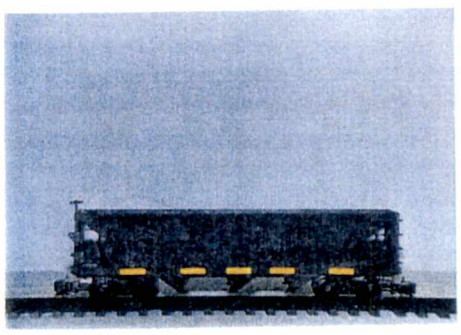


MARKING #9

PAIR 39

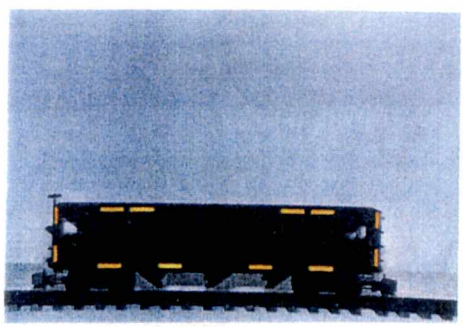


MARKING #2

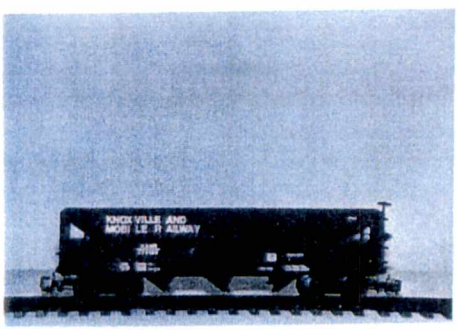


MARKING #6

PAIR 40

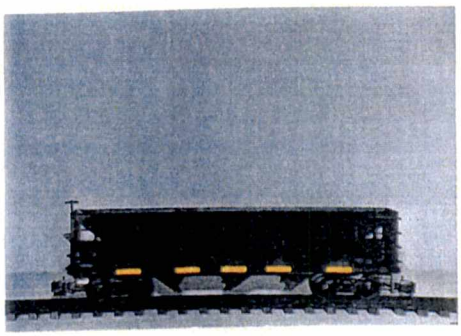


MARKING #3

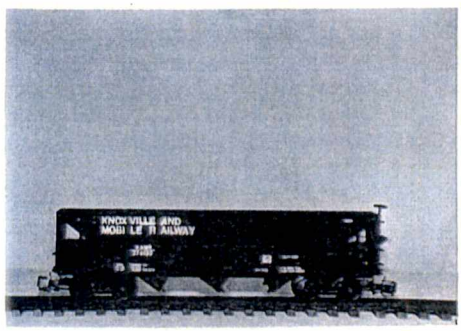


MARKING #11

PAIR 41

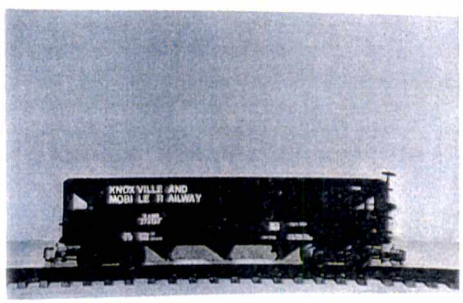


MARKING #6

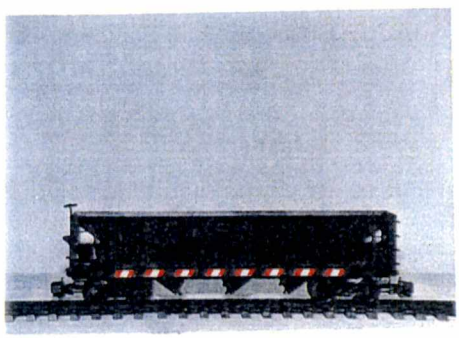


MARKING #11

PAIR 42

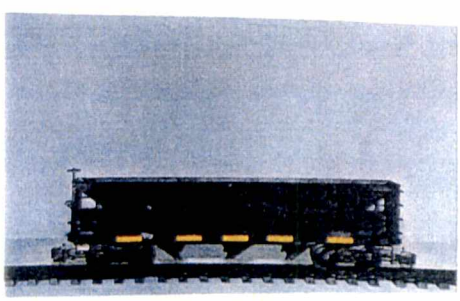


MARKING #11

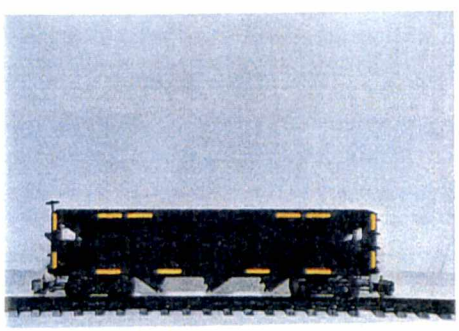


MARKING #1

PAIR 43

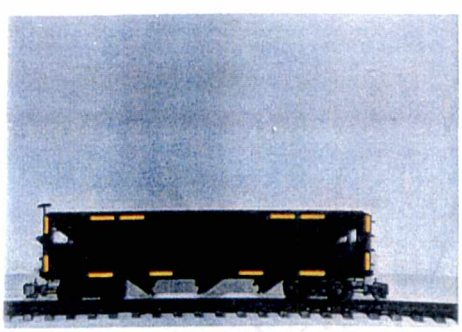


MARKING #6

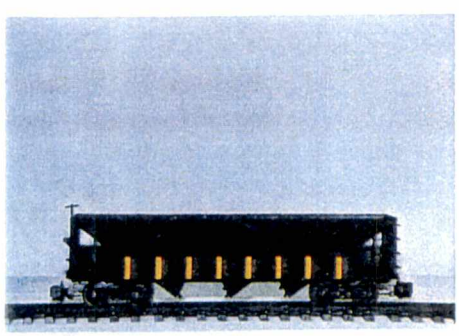


MARKING #3

PAIR 44

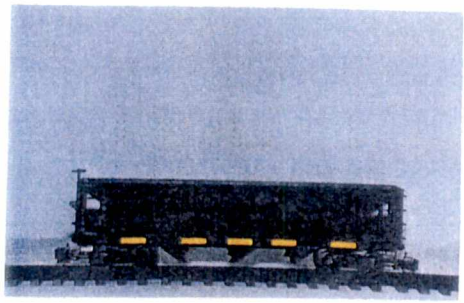


MARKING #3

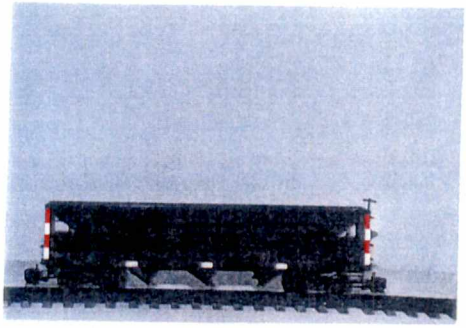


MARKING #8

PAIR 45

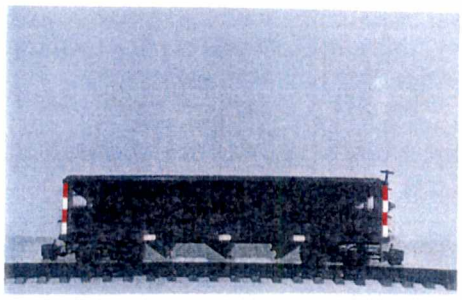


MARKING #6

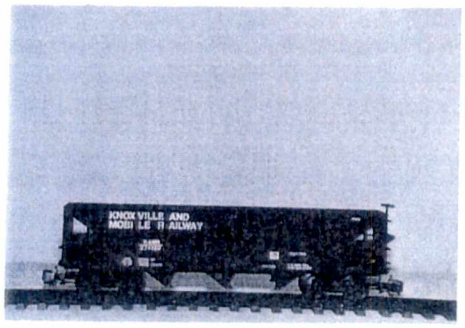


MARKING #9

PAIR 46

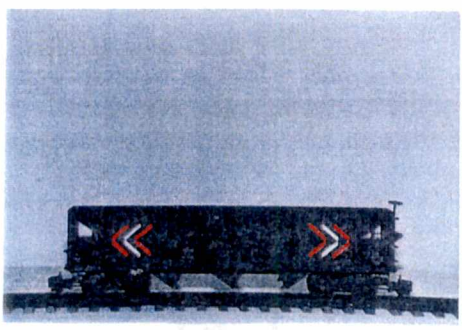


MARKING #9

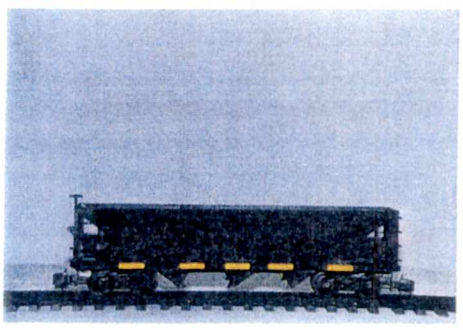


MARKING #11

PAIR 47

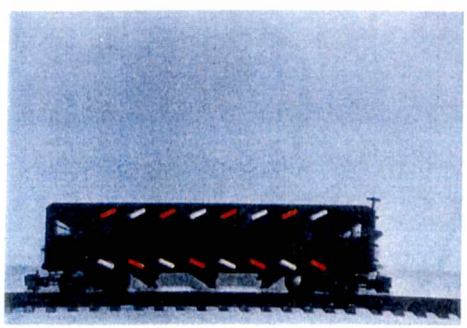


MARKING #4

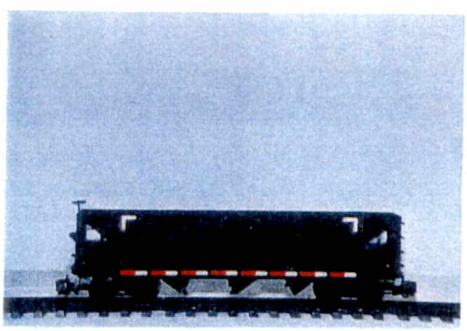


MARKING #6

PAIR 48

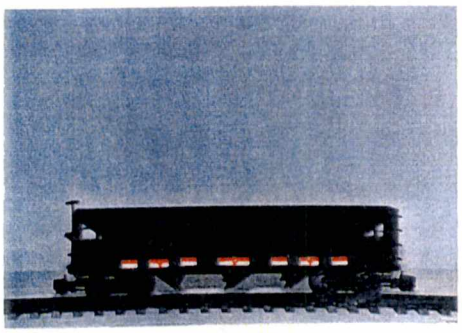


MARKING #2

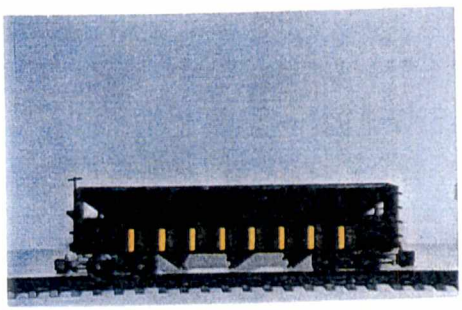


MARKING #10

PAIR 49

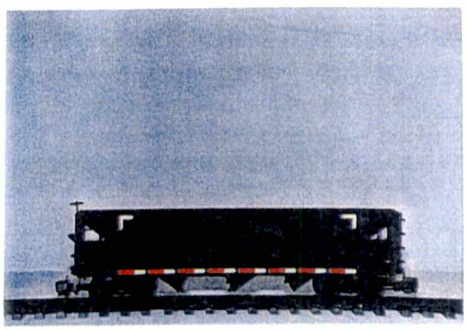


MARKING #5

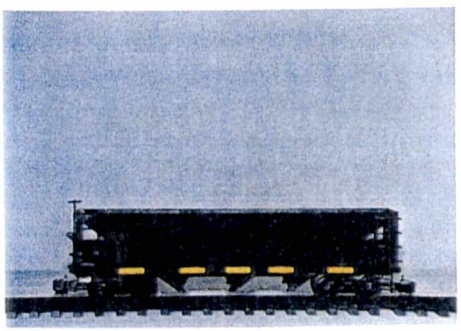


MARKING #8

PAIR 50

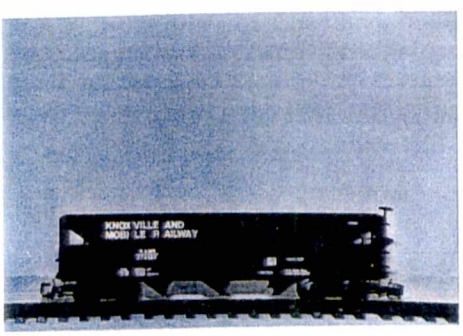


MARKING #10

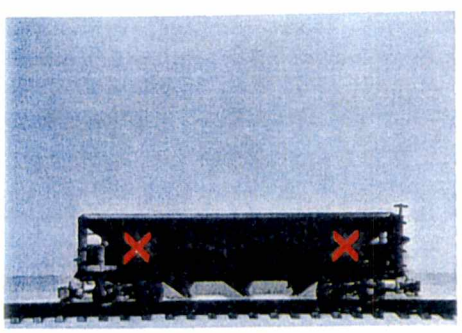


MARKING #6

PAIR 51

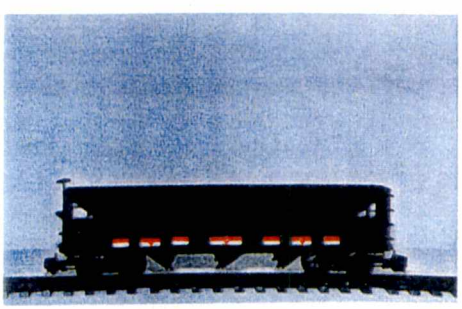


MARKING #11

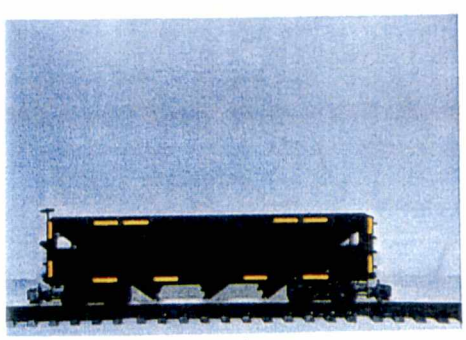


MARKING #7

PAIR 52

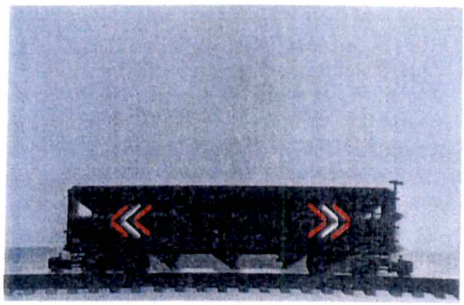


MARKING #5

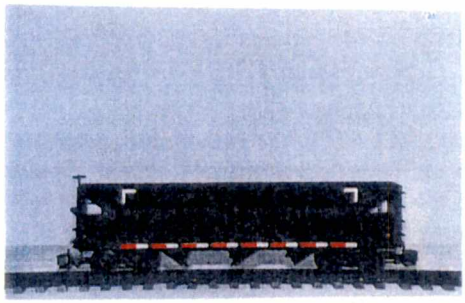


MARKING #3

PAIR 53

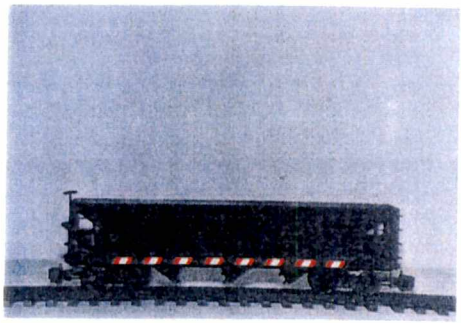


MARKING #4

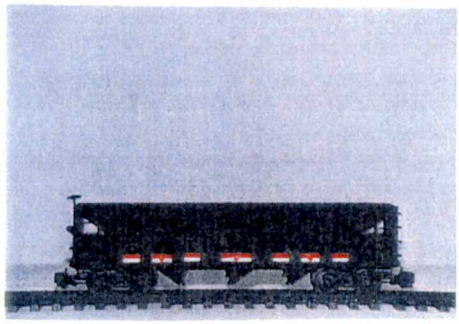


MARKING #10

PAIR 54

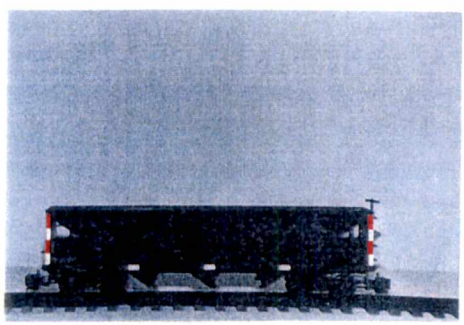


MARKING #1

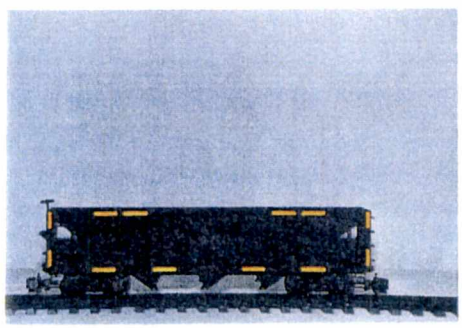


MARKING #5

PAIR 55



MARKING #9



MARKING #3

SECTION II

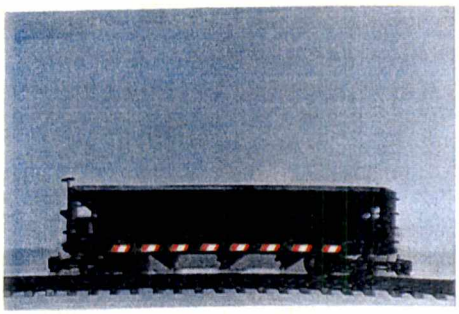
A RELATIVE RANKING OF EXPERIMENTAL CONSPICUITY MARKING SYSTEMS FOR FREIGHT CARS

INSTRUCTIONS

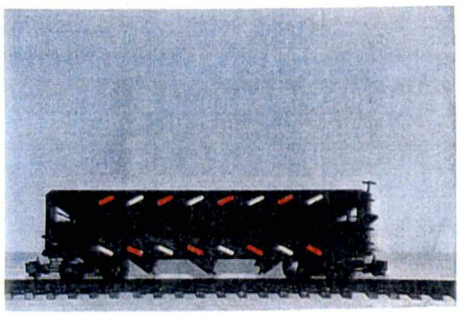
Rank the eleven marking systems shown on the following two facing pages from best to worst as to how you judge their effectiveness in enhancing the visibility of freight cars. People have found it helpful to assign a score of "11" to the marking judged to be the most effective and to assign a score of "1" to the marking judged the least effective. These two scores, "11" for most effective and "1" for least, are recorded in the blanks at the end of the identifying label below each design. For example, I might initially select marking #7 as the most effective (a score of 11) and marking #4 as the least (a score of 1). I would then write the score 11 in the blank below design 7, (e.g., MARKING #7 __11__), and the score 1 in the blank below design 4, (e.g., MARKING #4 __4__).

Then from the remaining set of 9 markings, a score of "10" to the marking judged to be the second most effective and to assign a score of "2" to the marking judged the next least effective. These two scores, "10" for most effective and "2" for least, are recorded in the blanks at the end of these two identifying labels (e.g., Markings #2 and #8 are chosen, and the scores filled in thus: MARKING #2 __1__ and MARKING #8 __2__).

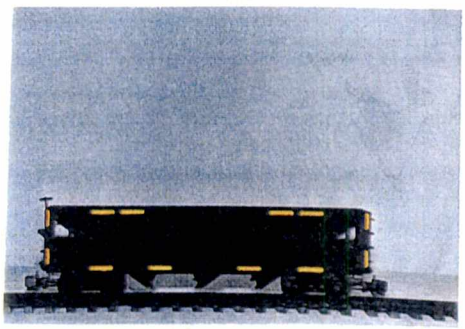
Repeat this procedure until all markings have been scored and recorded.



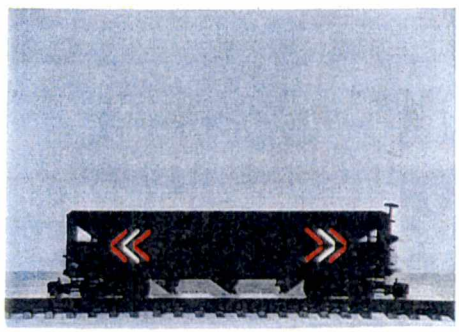
RANKING OF MARKING #1 _____



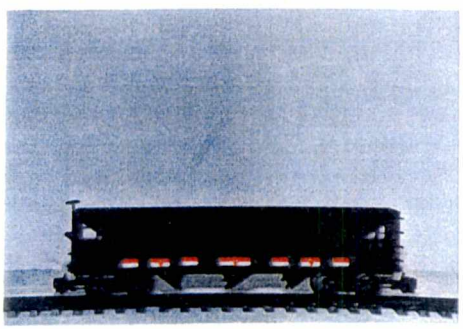
RANKING OF MARKING #2 _____



RANKING OF MARKING #3 _____



RANKING OF MARKING #4 _____



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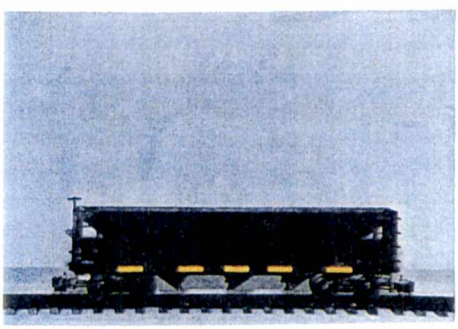

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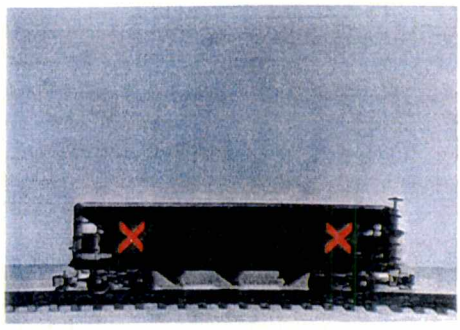

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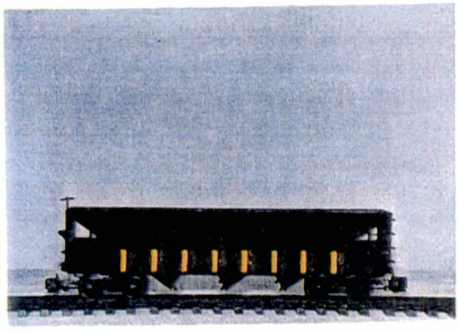

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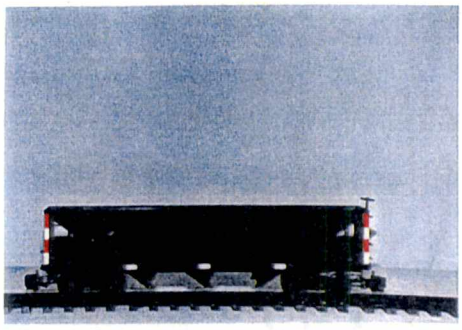

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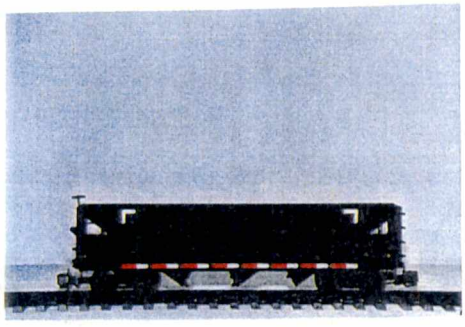

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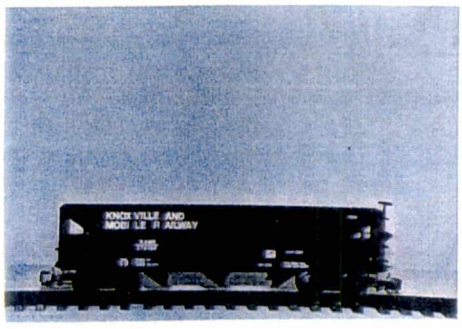


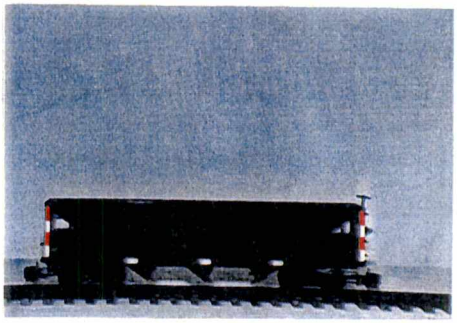
RANKING OF MARKING #11 _____

SECTION III

RATING OF ATTRIBUTES AND DIMENSIONS OF CONSPICUITY MARKINGS

INSTRUCTIONS

Several attributes of conspicuity have been identified as being of interest in this study. These attributes are detectability (is something there?), recognizability (what is there?), uniqueness (it is like no other), confusibility (different from all others). The dimensions that define these attributes are color(s), high contrast with the background, the pattern of the marking, and the placement of the marking on the freight car. The evaluations performed in the previous sections may not be sufficient to identify which attributes and dimensions made one system preferable to another, this section will ask you to rate each attribute and dimension that you consider as to its importance in creating conspicuity marking systems. On the following pages, please indicate how strongly you rate each of these attributes and dimensions by circling one of the numbers on the scale for each of these dimensions.



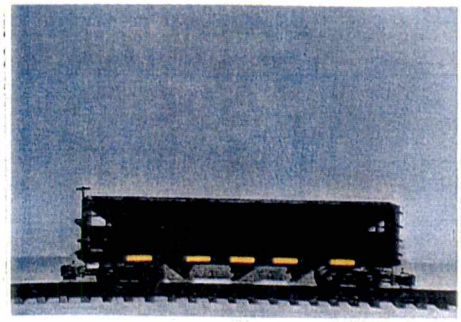
MARKING 9

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking on the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor



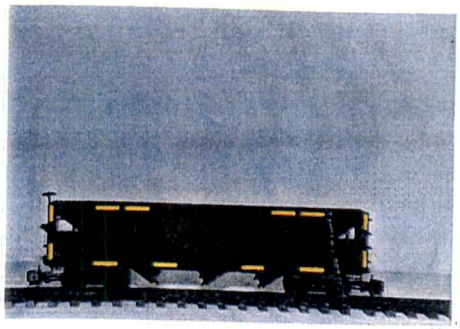
MARKING 6

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking on the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor



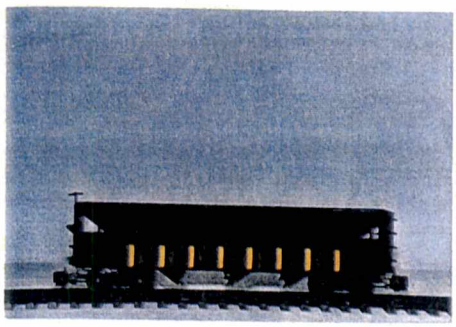
MARKING 3

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking on the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor



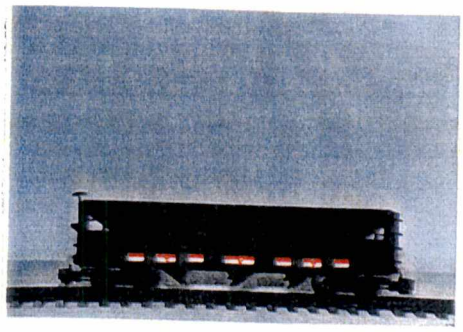
MARKING 8

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking on the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor



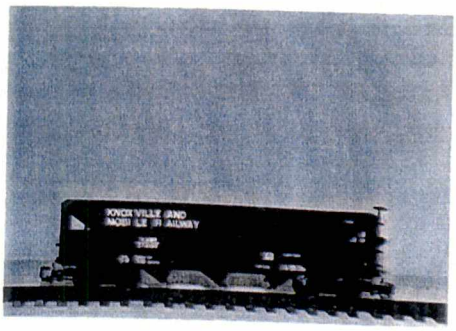
MARKING 5

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking on the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor



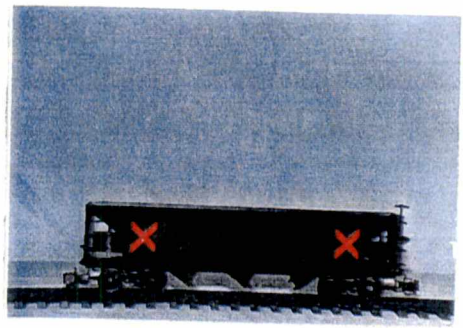
MARKING 11

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking on the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor



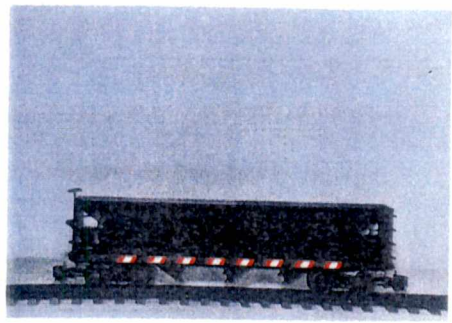
MARKING 7

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking on the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor



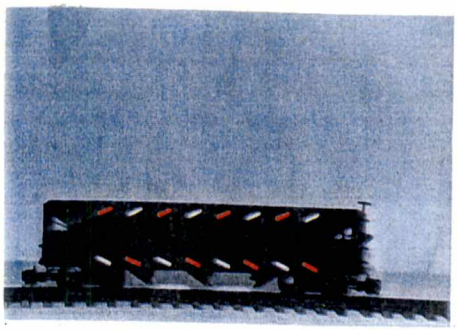
MARKING 1

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking on the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor



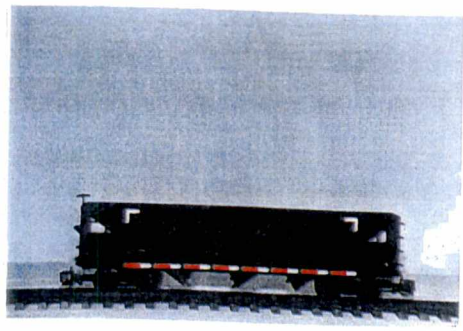
MARKING 2

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking on the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor



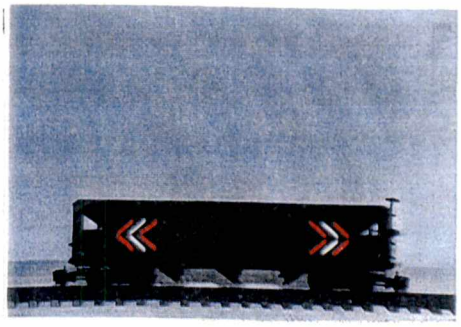
MARKING 10

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking on the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor



MARKING 4

For the following dimensions, circle the phrase that best describes the effectiveness of that dimension for the marking system in question:

The marking will make detecting the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The marking will make recognizing the freight car:	Extremely Easy	Very Easy	Easy	Difficult	Very Difficult	Extremely Difficult
The understanding of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Confusing the marking with another marking is:	Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Extremely Likely
The conspicuity of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The uniqueness of the marking is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

For each item, circle the phrase that best describes the effectiveness each dimension adds to making the marking detectable:

Contrast of the marking with the freight car background is:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
Placement of the marking on the freight car makes detectability:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking color(s) make the detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor
The marking pattern makes detectability of the freight car:	Extremely Good	Very Good	Good	Poor	Very Poor	Extremely Poor

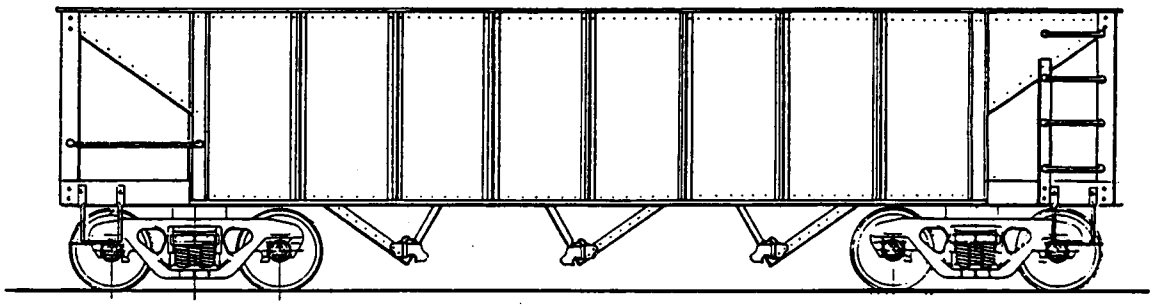
SECTION IV

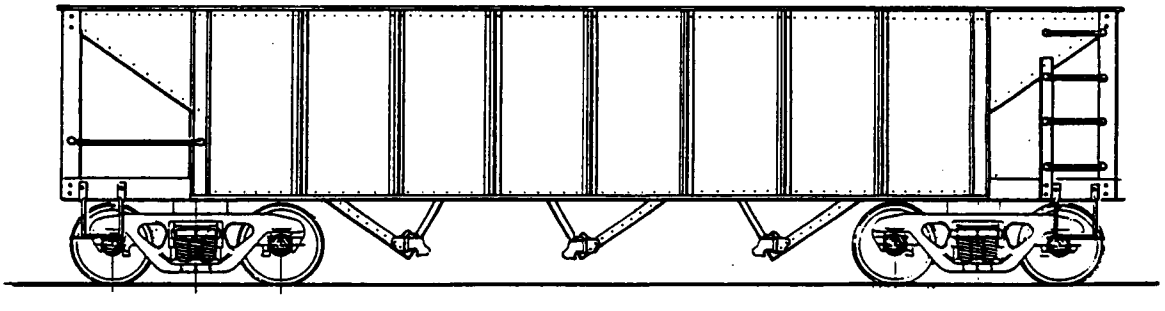
SUGGESTED CONSPICUITY MARKING SYSTEMS FOR FREIGHT CARS

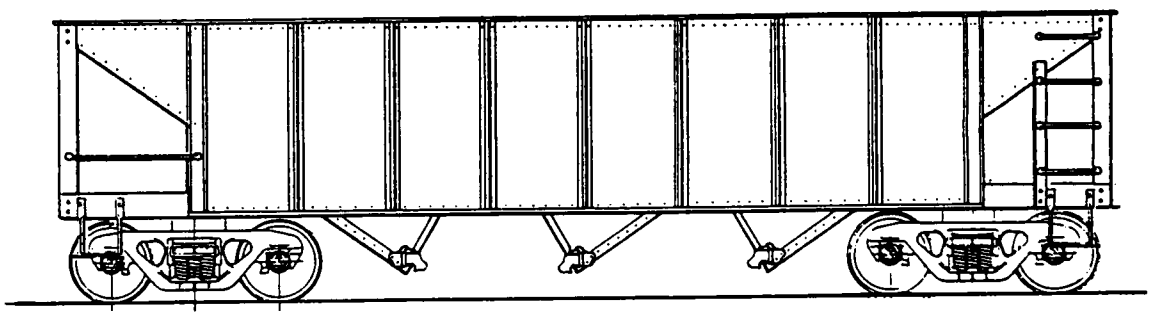
INSTRUCTIONS

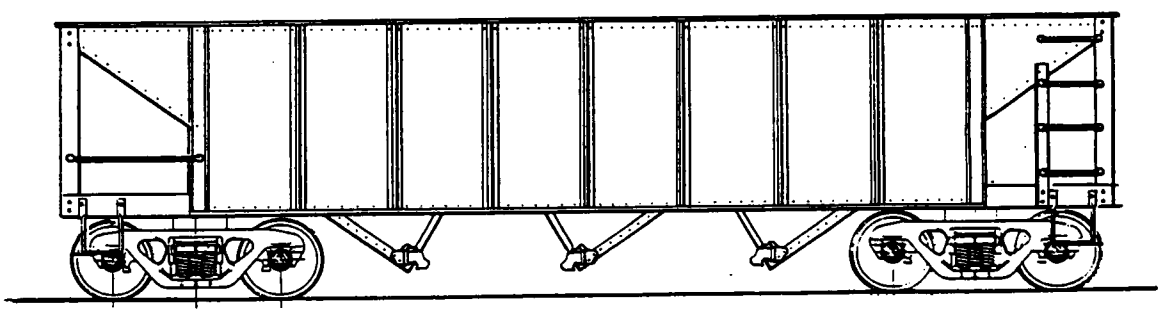
This section contains diagrams of a hopper car on which you may draw your own suggestions for conspicuity marking systems if you desire. We hope you will share with us any ideas you may have.

You may use colored pencils or pens to sketch you ideas or you may use a black or blue pen and indicate what the color or combination of colors are. The size of the marking is also important.









SECTION V

CONFIDENTIAL
BIOGRAPHICAL INFORMATION

INSTRUCTIONS

Please provide the information requested on the following two pages. This information will allow us to develop a profile of the participants in our survey. As indicated above, all information provided in this section will only be used to develop a profile of the participants. All responses and opinions are confidential and your anonymity is guaranteed.

1. GENDER: (Circle one) Male Female

2. AGE: (Circle one)

   20-30 30-40 40-50 50-60 60+

3. What color or colors, if any, do you have trouble seeing? (Circle all that apply)

   NONE RED GREEN YELLOW BLUE

4. How are you affiliated with the transportation industry? (Circle all that apply)

   Federal Government State Government
   Railroad Industry Contractor
   Consultant Signal/Supply Industry
   University Regulatory
   Researcher
   Other [_____]

5. How many years have you been affiliated with the transportation industry? (Circle one)

   0- 5 10-15 20-25 30-35 5-10
   15-20 25-30 35 + ___

6. How would you best describe your "expertise" in transportation, e.g., human factors, highway-rail safety engineer?

   _____

7. Have you had any training or experience in designing or evaluating (Circle all that apply):

   no experience
   signing (such as highway signs)
   rail traffic control devices
   delimiters
   highway traffic control devices

8. Are you aware of any efforts in the railroad industry to apply any type of reflective markings to rail cars? If so:

YES NO

If yes, please answer the following:

Who is doing this? _____

What is being done? _____

_____

Was there a change in accidents rates? _____

VITA

Chau Linh Pham was born in Saigon, Vietnam on June 14, 1969. Ms. Pham and members of her immediate family came to United States in April, 1975, joining her father who was already attending The University of Tennessee at Knoxville. She attended school in Tennessee and Texas, completing her Bachelor of Science Degree in Industrial Engineering at The University of Tennessee in May, 1992. Following graduation, she started work for the Knox County American Disability Act (ADA) office, developing job descriptions in compliance with federal guidelines. In January, 1993, she re-entered The University of Tennessee at Knoxville, working first as a graduate assistant and later as research assistant while she completed her graduate studies. In May, 1995, she received a Master of Science degree in Industrial Engineering.