R. DORER

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# ADVANCE PROCEEDINGS

of the

# SECOND

# CLASSIFICATION YARD TECHNOLOGY

# WORKSHOP

co-sponsored by

## FEDERAL RAILROAD ADMINISTRATION
and
## AMERICAN RAILWAY ENGINEERING ASSOCIATION

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U.S. Department of Transportation
**Federal Railroad Administration**

AREA
AMERICAN RAILWAY ENGINEERING ASSOCIATION

# SECOND CLASSIFICATION YARD TECHNOLOGY WORKSHOP

## ORGANIZATION:

| | |
|---|---|
| Co-Chairmen: | **Myles Mitchell,** Director - Office of Freight and Passenger Systems, Federal Railroad Administration<br><br>**Paul Van Cleve,** Director - Office of Engineering, Chessie System<br>Chairman, Yards and Terminals Committee, American Railway Engineering Association (AREA) |
| Program Co-Chairmen: | **William Cracker,** Research Manager-Office of Research and Development, Federal Railroad Administration<br><br>**B.H. Price,** Senior Development Engineer - Bessemer and Lake Erie Railroad |
| Management Services: | **Ellen S. Witt,** Conference Management |

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***PRESENTATION ONLY**

## WELCOMING REMARKS

Myles B. Mitchell
Federal Railroad Administration

The Office of Research and Development of the Federal Railroad Administration is pleased to cosponser this workshop with the Yards and Terminals Committee of the American Railway Engineering Association. The purpose of the workshop is to present recent developments in yard related research along with discussing problem areas deserving further research. Also, railroad representatives will present reports on recently completed yard projects especially focusing on design areas of improvement and innovation. We are all anxious to exchange views and learn from this workshop experience.

We have found the workshop as a useful forum to exchange information with the industry. Our first Classification Yard Technology Workshop (October 1979) sponsored by the FRA Office of Research and Development, provided a means of disseminating information on research, however, at the same time we enjoyed extensive industry participation and feedback. Significant inputs to enhance the meaning and direction of our yard technology program were realized through presentations of User Perspectives by railroad representatives along with responses to written questionnaires and the very meaningful discussion periods. This second workshop, with the active sponsorship and participation of the AREA will certainly follow suit, especially with the AREA organized technical panels.

Some of you might have asked why we picked St. Louis for the workshop. Well, we tried to pick a location which has a high concentration of railroad people and easy accessibility for travel. Obviously, besides Chicago, where our 1979 Workshop was held, St. Louis has these attractions. In consultation with our cosponsor, AREA Yards & Terminals Committee, we decided on St. Louis. Judging by the success of the first workshop and the likely success of this one, the industry might want to sponsor another one, perhaps in another region of country where the workshop may have exposure to additional people not afforded the opportunity to attend the first two workshops.

Regarding the substance of the workshop, we cannot be too serious as to the importance of yard technology. We believe yard technology deserves our utmost attention. Many studies indicate that the yard is one of the main culprits to railroad problems associated with: service reliability, car utilization, and loss & damage. Recent statistics (taken in 1979) indicate a car spends 7 of its 9 days underload of the average car-cycle time in yards and terminals. This idle time in yards and terminals contributes nothing to more productive transportation. The average car-cycle time from the year 1951 at 18.4 days to the year 1979 at 26 days shows the trend is not getting any better, even though there has been an increase in unit trains and run-through trains.

With this discouraging performance attributed in a large measure to yards, the cost of yards has remained a significant portion of the railroad industry budget. Yard operating and maintenance cost is at approximately $3.2 billion per year. The projected capital investment for new/major upgrade yards in the next 25 years may be as much as $3 billion (based on estimated 200 yard projects at average $15 million per project). With these kinds of resources at stake in a capital-starved industry, we certainly must ponder as to whether the current level of productivity for yards is the best we can do.

Of course you might say our options might be to avoid yards or improve them. With the well-known car detention times of yards, an operational scenario for a "yardless journey" for a train makes good sense. However, we are all aware that yards will be part of freight railroading for some time to come. Therefore, any future investment in yards should be based on applying the best technology. Even though improved technology will not cure all the ills of yards, it can provide improvement in an area which deserves attention. In our yard technology program, we have attempted to develop the most advanced technology, within the grasp of railroads for almost immediate application. We have attempted to improve the technology without imposing undue risk on individual railroads who are willing to innovate.

Because the railroad industry is a capital-starved industry, railroads find it most difficult justifying a yard project, let alone introducing new design or systems. Something new will introduce additional risk. FRA involvement in yard technology is meant to act as a catalyst to increase level of change for improvements in yards. Through the participative projects, FRA might share some of this risk for the potential betterment of the entire industry. Also, there are so few times an individual railroad needs to build a yard. This research program will provide them access to this knowledge that otherwise would be difficult to obtain.

The nature of our research program is to encourage participation of the industry in the formulation and implementation of research projects. We can better serve the needs of the industry when representative committees and railroads provide guidance as to their need. In particular, we have actively interfaced with the AREA Yards & Terminals Committee (of which this workshop is a good example) and the AAR Special Applications Committee of Communication & Signal Division. Most of the projects that will be presented at this workshop have also had the active participation of many railroads including: Conrail, Boston & Maine (B&M), Richmond, Fredericksburg & Potomac (RF&P), Union Pacific (UP), The Atchison, Topeka & Santa Fe, Burlington Northern (BN), Southern, and Grand Trunk Western (GTW).

The basic impact of the projects will be upon individual railroads involved in yard improvement programs; it is they who are the primary potential users of the results. The railroads who invest in and apply the technology can realize immediate benefits. They do not have to wait or be dependent on industry-wide adoption, such as car standards. Equipment suppliers, particularly those which provide yard systems, are also likely to be affected as they often play a major role in the design process. The Government in recent years has become increasingly involved in rail planning and investment activities, whether Federal or State. This research could assist them in support of planning and decision-making.

Classification Yard Technology research addresses only one FRA research area affecting yards. The FRA Office of Policy and the FRA Office of Federal Assistance have sponsored work which includes:

- Task forces of local labor and management committees to study changes in local operations to improve car utilization.

- Contracting for studies of yard and terminal restructuring to eliminate or relocate yards or specific bottlenecks in transfering cars between railroads.

The Classification Yard Technology Program concentrates on the design improvements of systems and hardware associated with the yard rather than the rail network.

We look forward to a most meaningful workshop. We all have a common stake in improving yards. Hopefully, the technology discussed at this workshop will provide some new avenues for improvement.

# OVERVIEW FOR YARD RESEARCH PROGRAM

William F. Cracker
Federal Railroad Administration

This is our second yard workshop. The first workshop held in Chicago in October 1979 provided the attendees (130) with an acquaintance to our yard research program. We feel that now we can build on the initiative of the first workshop, to further fulfill our yard research objectives . . . to reduce operating costs and increase productivity and safety in the yard. While the first workshop provided many interim reports on our projects (documented in the Yard Workshop Proceedings Report #FRA/ORD 80/17), this workshop will provide final results and reports for a major segment of our current yard research program. Also, we are anxious to receive feedback on technology requiring further research.

Yards are an area of technology we believe is timely. Judging by the responses from our first workshop questionnaire, 71% of you will be undertaking yard projects in the near future or presently have projects underway. Further, a recent FRA study* indicates that 200 classification yards will receive major reworking or will be newly constructed in the next 25 years. Obviously, this technology application goes beyond yard construction projects, but may assist in the planning, operation, and system improvements for yards. If we must have yards, let us have the best technology. With the scarcity of capital in the industry today, and with yards costing up to $50 million each, we cannot afford anything less than the best technology. Perhaps, we can improve yard productivity using the technological leverage to offset the dramatic cost increases of energy and to increase the value of labor.

Yards are an area of technology we believe is applicable. Our projects are predicated on the participation by the industry for guidance and support to assure that the results are realistic and usable. This second workshop with the cosponsorship of the FRA/AREA exemplifies this approach. We have collaborated with industry committees, railroads, and suppliers in performing research. We have followed a Project Management Master Plan (5-year plan) that had been presented to industry for review. Also, the questionnaire responses from the first workshop generally confirmed our earlier prioritization of research needs included in our plans developed by our survey report*. In particular, these responses identified hardware that typically generate the most problems which included retarders, computers, wheel detectors. Retarders were mentioned by many in the responses emphasized the noise consideration. We are addressing all of these areas.

Yards need to be improved. Our research indicates 25 to 40% of the time freight cars spend in the yard is closely associated with deficiencies related to yard layout and design. This is roughly equivalent to a loss of 55 million to 85 million car days per year, an under utilization of approximately 210,000 freight cars. So improvements in the yard can have significant benefits within and beyond the yards. It is no wonder that the recent General Accounting Office report dated November 10, 1980, concluded "There is no shortage of freight cars - railroads must make better use of what they have." Further, this report went on to say that the principal bottleneck to efficient freight car utilization is yards and terminals where freight cars spend about 60% of their time.

We have produced significant results in our yard research program and would like to share them with you. Of course, this workshop agenda includes many presentations on the results of this program. However, at this time we might characterize some of these results and identify the significance of some of the outputs.

> The yard design methodology project developed state-of-the-art guidelines through both computer-assisted and "handbook" techniques. The relevance of these guidelines have been verified through 3 case studies. One case study where sufficient economic data was available

*(SRI Report--Survey & Assessment of Yards)

indicated an estimated savings contributed to this methodology for the railroad of $900,000 annually through reduced car detention time.

The car speed control project investigated 13 new concepts applied world-wide. Most of these concepts have never been used in the U.S. although some of the costly high performance foreign yards have applied the system. One such yard is the Maschen Yard in West Germany which has a maximum hump throughput of 6 cars/minute although the yard costs approximately $300 million. Is the higher cost the only factor that may discourage U.S. yards from applying this technology. With the estimated cost (both direct and indirect) to railroads for loss through car coupling impact in yards (perhaps $600 million annually), the speed control benefits may justify this cost. This evaluation may provide a guide for these design decisions.

Noise control has deserved much of our attention in recent years especially in view of new source standards regulations issued by the Environmental Protection Agency (EPA) in January 1980. The source standards for retarders, car coupling, switcher locomotives, and locomotive load cell test stands, were estimated by EPA to require a capital investment by the railroad industry for compliance with the rule-making to be approximately $110 million. Also, EPA estimated the total industry-wide cost of compliance to be approximately $24 million. Some industry estimates, of course, have been much higher. Our noise control report may assist railroads with an understanding of noise control.

Car presence detection in the yard, which is a critical element in supporting the feasibility of automatic systems for car control and monitoring, have been evaluated. Available data indicates that the reliability of existing techniques, may have been the limiting factor in automating the car monitoring function in the harshest yard environment . . . the flat yard. As a result of this research project, improved techniques were identified and verified at 3 railroad yards showing for the test period failure reductions of 48% for the rail mounted device and no failures for wayside device.

Rollability characteristics of free rolling cars coming down the hump has been identified by the AREA Yards & Terminals Committee as one area of research deserving the highest priority. Information available in this area was considered obsolete because of changes in equipment and facility design. Wrong assumption on rollability in the design process are costly to correct and limit yard performance. Data collected from 5 yards will improve rollability characterization. Also, new measurement concept will be recommended for providing a continuous velocity profile of the car rolling from crest of hump to end of classification tracks which will assist in developing complete rollability data.

Innovative concepts for the next generation yard (or 20 years hence) are being examined. Some potential concepts will be identified which may give us a clear idea of where we should be heading in developing and applying new technology. We want every assurance that railroads will benefit from the technological revolution being realized in other industries such as: Data Processing and Process Control. With yards notorius as bottlenecks in the system, the status quo is not good enough.

Yes, we feel we have accomplished significant results from our research at this juncture. However, we are anxious to witness the further implementation of this technology beyond the project participation applications. Afterall, unutilized technological development contribute nothing to productivity and safety improvements. Hopefully, this workshop will be a significant step toward this implementation.

# YARD TECHNOLOGY RESEARCH PART I

# YARD DESIGN RESEARCH: PURPOSE AND OBJECTIVES

John B. Hopkins

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## Introduction

In recent years the Transportation Systems Center has directed a major yard-related research effort for the Freight Systems Division of the FRA Office of Research and Development. The overall purpose has been to develop information, methods, and analytical tools which will be of value to the railroad industry in the process of planning and designing yard improvement projects. Many of the presentations at this workshop describe the results of this program. The purpose of my presentation is to place this work in perspective by emphasizing the reasons it was undertaken and the objectives originally established for it.

## The Importance of Classification Yards

The cost associated with possession of freight cars - whether owned, leased, or simply foreign cars in transit - is one of the largest expenses borne by railroads. Although there are many alternative ways in which this cost can enter the account books, some admittedly oversimplified calculations are helpful in suggesting the magnitude of the economic impact. When one looks at the time value of the investment associated with rolling stock, a freight car is seen to represent a cost of approximately $12 per day to the railroad responsible for it. On this basis, the national fleet of 1.7 million cars implies an annual cost to the industry in excess of $7 billion. Cars are in intermediate or terminal yards more than 60% of the time, suggesting that over $4 billion of annual industry car cost is associated with yards. If through design improvements the average yard detention time could be reduced by 5% (approximately 1 hour) for only half of the yards the value to the industry would be approximately $100 million per year.

In addition, in recent years attention has focused on the crucial role of yards in assuring reliable service to shippers. Excessive delays, leading to missed connections, can generate wide variability in transit time. Although the economic value of service quality is difficult to assess, clearly reliability of service is a major concern for many users.

It can therefore be argued that the classification process is truly central to efficient and profitable railroading. In addition, yards comprise a relatively specific and centralized target for improvement efforts, in contrast to some other railroad activities which are widely distributed over the entire network. Thus, the FRA and TSC identified yard technology and operations as a critical area in which to consider a major research effort.

## Relevance of Research

In a technically mature industry like the railroads, the importance of an area does not necessarily imply that it can readily be affected by research. However, examination of this subject clearly revealed a useful role for FRA/TSC. First, we became aware of the large amount of expected future yard construction, with approximately 10 major improvement projects anticipated each year - a $3 billion investment by the end of this century. Second, we learned of the complexity of the yard design process, and of the innumerable large and small decisions upon which success ultimately depends. Finally, it was suggested to us that as a result of this complexity major projects often do not yield the expected performance without at least a lengthy period of adjustment and modification. Since most individual railroads undertake such projects relatively infrequently and have a limited planning budget, only a few have been able to establish smoothly functioning and highly experienced design teams, and to allow them sufficient time for a thorough consideration of all reasonable alternatives. Even for these cases, retirement or lack of availability of a few key individuals may represent a serious loss of capability. Further, the intermittent nature of these projects generally makes it unprofitable for individual railroads to attempt to develop sophisticated design procedures or computer-aided computational tools.

FRA/TSC Objectives

As a result of these considerations, we established the basic objective of developing a set of practical design guidelines and procedures, accompanied by data tables, worksheets, computer programs, and other resources, which would significantly enhance the efficiency and effectiveness of the design process, and which would facilitate involvement in these activities by individuals having only limited experience in the subject. Our goal was a manual of yard design useable by anyone with a need to make choices among the myriad of possible design alternatives. It was intended that this would substantially increase the degree to which alternatives could be considered and the precision with which costs and performance could be predicted.

In order to assure the practicality, credibility, and overall value of the design manual, three subsidiary objectives were imposed: (1) The work was to draw extensively on a broad spectrum of individuals and railroads experienced in the subject, so that the final result would be realistic and focused on the most important industry concerns. (2) Although it was clear that computer-based design tools could be of real value, we were determined not to let computer modeling become an end in itself, or become so elaborate as to be difficult and expensive for railroads to utilize. (3) The utility and validity of the work was to be tested on real design problems faced by participating railroads, with the results of that process incorporated into the final product.

The effort is now essentially complete. Those familiar with the work will recognize the high degree to which these objectives have been met. This is in large part due to the active involvement of the AREA Yards and Terminals Committee, a number of railroads and suppliers, and more specifically, to the participation of many individuals from those organizations who have been most generous in sharing their experience and expertise with us. For this cooperation we are extremely grateful.

# AN OVERVIEW OF THE RAILROAD CLASSIFICATION YARD DESIGN MANUAL

By

Peter J. Wong
SRI International

## 1.0 Introduction

### 1.1 Background

Recent studies (MIT, 1972) on car utilization and freight service reliability have concluded that the railroad yard can have a large negative impact on service reliability, car utilization, and damage liability. Furthermore, it has been estimated that as much as 25 to 40% of the time freight cars spend in classification yards is closely associated with deficiencies related to yard layout and design. This is roughly equivalent to a loss of 55 million to 85 million car-days per year, an under-utilization of approximately 210,000 freight cars. Consequently, yard design can have a substantial impact on the ability of a terminal to process cars.

Many railroads have deferred maintenance and capital improvements in yards, preferring instead to devote resources to the rehabilitation of mainline track or the purchase of locomotives. One reason for this choice is that it is often easier to understand the impact of track and motive power on service revenues. However, it is now widely acknowledged that the yard is often the main culprit in service reliability problems, that freight car travel time is spent primarily in yards, and that yard costs represent a substantial portion of the total railroad transportation costs. (This last element is especially true for midwestern and eastern railroads.) Perhaps even more important, capital outlay for mainline trackage and locomotives can be appropriated on a year-to-year basis and deferred in severe economic times, whereas a yard rehabilitation project requires a large capital commitment which must be implemented in its entirety, in a multiyear intensive building program. Furthermore, the planning, design, and engineering decisions for a yard project are inherently more complex and difficult to understand, thereby impeding the decision process.

For all the above reasons, many needed yard projects have been delayed too long. Thus, there are likely to be great pressures to rehabilitate yards in the future, simply because many yards are old and need reworking to be efficient. Also, changes in present and future traffic patterns and future mergers between railroads will necessitate changes in existing capabilities of yards. Some inefficient yards at improper locations may be shut down. However, the remaining yards at critical traffic junctions must be rehabilitated to handle increased switching requirements.

A major new yard may cost well in excess of $50 million, and a minor rehabilitation can reach $10 million or more. Consequently, it is imperative that yard planning and design procedures be available to produce the best return on the investment. Because yards have a physical life in excess of 30 years, a well-designed new or rehabilitated yard can influence the ability of the railroads to recapture lost revenues and profits well into the twenty-first century.

### 1.2 Purpose of the Design Manual

Procedures for designing classification yards have evolved through trial and error over many decades. Thus, within a conventional framework of basic design principles, many crucial decisions may sometimes be based in part on personal intuition or persuasiveness simply because the required analytical tools are not available, and the cost of developing or acquiring them is not warranted for a particular project. The relative infrequency with which any one railroad builds a yard makes it difficult to maintain a core group of individuals who specialize in and can improve upon the design process. This is becoming a more acute problem as many of the most experienced yard designers reach retirement. On the other hand, scattered throughout the railroad industry there exists a large amount of yard design information and knowledge that could be of benefit to all railroads if it were aggregated and documented.

The fundamental objective of the design manual is to establish a set of practical guidelines, procedures, and principles, accompanied by a sufficiency of data, tables, computer programs, and other resources to improve significantly classification yard design and engineering and to enhance the efficiency of the design process. The design manual is applicable to the design of new or existing yards, both flat and hump yards, whether manual or automated. In particular, the design process has emphasized site selection, economic analysis, yard geometry and layout, hump grade profile design, yard capacity determination, trim-end conflict evaluation and computer systems.

In the yard design manual, we have attempted to compile and document yard design procedures and practices that heretofore resided only in the minds of a small set of experienced railroad yard designers. This yard design knowledge was formerly gained essentially through an apprentice system of on-the-job training. Relatively little formal documentation of yard design procedure and practices existed before this manual. In addition, the design manual describes newly developed computer-aided design procedures. More specifically, a set of computer programs have been developed to aide the yard designer in three critical problem areas of yard design:

- Design of hump grade and retarder placement.
- Estimation of receiving, classification, and departure track capacity requirements and engine/crew utilization.
- Design of pull-out end of yard.

These computer-aided procedures allow better designs to be obtained more rapidly than with conventional procedures.

Consequently, many engineering design methods are presented in two forms: a manual design procedure and a computer-aided design procedure. The computer programs are fully documented and a user's guide has been prepared for each. Thus, depending on the preference of the user, the particular application, and his or her familiarity with using computer programs, the choice may be to implement a design procedure in either a manual or computer-aided form. The computer-aided design procedures will be faster and more accurate than the manual design procedures in most instances.

It is anticipated that the design manual will be usable by any railroad, railroad supplier, or government planner who needs to make informed choices among a myriad of possible design alternatives. In particular, it is hoped that the procedures in the design manual will substantially increase the degree to which alternatives will be considered at the early design stages. This can allow consideration of a wider range of configurational, technical, and economic choices and make possible greater precision than is now customary in estimating potential costs and benefits. The goal of the design manual is to contribute to a reduction of design effort, reduced and/or more efficient expenditure of construction resources, and - most important - yard improvements that significantly enhance productivity and system levels of service.

## 1.3 Development of the Design Manual

The design manual was developed as a result of a three-phase classification yard design methodology project directed by the Transportation Systems Center (TSC) under the sponsorship of the Federal Railroad Administration (FRA). During Phase 1, the factors and elements to be included in the design methodology and their level of precision were identified, and a preliminary methodology for the basic yard design process was developed.

In Phase 2, the preliminary methodology developed in Phase 1 was applied to actual yard design problems. This was done in cooperation with three railroads in a case-study application: CONRAIL's Elkhart Yard rehabilitation of the hump and trim-end, Boston and Maine's East Deerfield Yard rehabilitation from a flat yard to a hump yard and the upgrading of the computer control system at the Richmond, Fredericksburg, and Potomac Railroad's Potomac Yard. The intent of Phase 2 was to test, refine, and modify the design methodology based on real-world yard design problems. Special effort went into assuring that the procedures are accurate and effective and can be applied in a practical case by knowledgeable railroad personnel.

In Phase 3, a final design methodology was developed as a result of the preliminary form prepared in Phase 1, the modifications made in Phase 2, and industry comment and feedback obtained throughout the project. The end result is a two volume yard design manual entitled:

"Railroad Classification Yard Technology

- Volume I: Yard Design Methods, and
- Volume II: Yard Computer Systems."

It should be emphasized that a substantial amount of industry participation and interaction has been incorporated into the project effort. Development of the manual has drawn extensively upon the experience and insights of numerous individuals. In particular, much of the material in this manual is a result of a close working relationship with Mr. James Wetzel (CONRAIL) and Mr. Barney Gallacher (Southern Pacific) on two case study projects. Also, contributions to the manual were made by Mr. Hubert Hall (Santa Fe), Mr. Merrill Anderson (Union Pacific), Mr. Charles Yespelkis (CONRAIL), Mr. Tom Connors (Union Pacific), Mr. Alfred Dasberg (retired, General Railway Signal), Mr. Bill Williamson (retired, Southern Pacific), Mr. James Page (retired, Penn Central), and Mr. Paul Van Cleve (Chessie). In addition, the American Railway Engineering Association (AREA) Subcommittee 14 on Yards and Terminals reviewed the material; their efforts were coordinated by Mr. Bud Price (Bessemer and Lake Erie).

## 2.0 Volume I: Yard Design Methods

### 2.1 General

Volume I on yard design methods is intended to be treated as a reference manual rather than a textbook. It primarily addresses the planning, economics, and engineering aspects of site selection, yard configuration, track capacities, track layouts, grades, switches, turnouts, etc. Not all yard engineering design aspects are treated. Specific detailed civil engineering construction topics such as soil preparation and drainage, design of towers or bridges, etc., were considered beyond the scope of this manual. The reader interested in these topics should consult standard railroad and civil engineering textbooks on these subjects.

The topics discussed within each chapter of Volume I are described below.

### 2.2 Chapter 1: Introduction

This chapter discusses the importance of yard to railroad services and productivity and the need for a yard design manual and new computer-aided design procedures. The background on the yard design methodology project which ultimately created the yard design manual is highlighted.

### 2.3 Chapter 2: Using the Design Manual

This chapter describes the organization of Volume I and the topics treated in each chapter. For specific design problems, a list of pertinent chapters is indicated as an aid to the user.

### 2.4 Chapter 3: A Brief Tutorial on Classification Yards and Their Operation

The design manual is not primarily intended to be a tutorial on yards and their operation. However, users not familiar with railroad and/or yard operations should read this brief chapter. Topics covered include flat and hump yard operation, processing of cars from inbound receipt to outbound departure, and information and paper handling that must accompany each car.

### 2.5 Chapter 4: Organizing the Design Effort

A yard design project is a very complex undertaking requiring the supervision and coordination of many individual tasks and skills across many railroad departments. This chapter addresses the organization of the design effort. Topics include the makeup of the yard design team and project management and coordination.

### 2.6 Chapter 5: Choosing the Location for a Yard Project

Many times the site of a new yard or the rehabilitation of any old yard is already known by management based on obvious operational, engineering, and economic criteria. However, for those situations where a suitable site has not already been selected, this chapter describes a site selection methodology. The methodology essentially consists of the following two phases:

- Phase 1 - Choose the proper system area (or region) where additional switching capability should be placed.
- Phase 2 - Within the identified system area (or region) select the specific site for new yard construction or an existing yard for rehabilitation.

### 2.7 Chapter 6: Economic Analysis of Yard Projects

An economic analysis of the yard project is likely to be performed several times at various stages of the yard project, i.e., site selection, initial cost feasibility, and rate-of-return justification. In the initial stages of the project, the data available are often limited in amount and accuracy, so that an approximate economic analysis is sufficient. However, as the project proceeds, the data become more accurate, permitting a more detailed analysis. This chapter describes a methodology leading ultimately to calculation of economic indicators such as rate of return, net present value, and years required to recover investment and capital costs.

### 2.8 Chapter 7: Estimating Yard Capacity and Crew Requirements

Early in the project, the specifications and compromises on yard performance, track capacity, and crew/engine resource requirements must be determined. This chapter describes two procedures to perform these tradeoffs: a traditional manual yard simulation procedure, and a procedure using a simulation model called CAPACITY.

### 2.9 Chapter 8: Deciding on Flat Versus Hump Yard

In many instances, the decision on hump versus flat yard can be made on obvious operational, engineering, and economic considerations. This chapter addresses this issue and provides guidelines for decision making. The relatively new concept of "mini-humps" is discussed in this chapter.

## 2.10 Chapter 9: Geometric Design of Flat Yards

The design of various types of flat yards is discussed in this chapter. Topics include: flat yard configuration, multiple switching leads, grades, switches, turnouts, and ladder designs.

## 2.11 Chapter 10: Planning the Overall Hump Yard Configuration

In this chapter, we are mainly concerned with planning the relationship and overall configuration of the receiving, classification, and departure yards, and location of support facilities in a hump yard. Topics covered include: in-line, versus parallel, yard configurations; configuration of receiving, classification and departure yards; placement of diesel service, car repair, and caboose facilities; and location of towers, yard offices, roadways, and tunnels.

## 2.12 Chapter 11: Hump Yard Track and Switch Layout Considerations

This chapter is concerned with the proper specification of track layout, turnouts, and switches for various parts of a hump yard. Topics include track and switch considerations for the hump and trim-end of the yard and a civil engineering tutorial on trackwork and switch hardware.

## 2.13 Chapter 12: Hump Grade Design and Retarder Placement

This chapter presents the basic design theory, considerations, and procedures for designing the hump grade and the placement of retarders. A traditional manual design procedure is described as well as a computer-aided procedure using a new computer model called PROFILE. Topics include: basic theory, car rolling resistance, vertical curves and grades, retarders, manual design procedures, and computer-aided design procedures.

## 2.14 Chapter 13: Hump Yard Trim-End Design

The design of the trim-end (pullout-end) of a hump yard is described in this chapter. A manual procedure for evaluating engine conflict and interference at the trim-end is described, along with a computer-aided procedure called CONFLICT. Topics include trim-end design alternatives for parallel and inline departure yards, operational alternatives, measures of effectiveness, a manual evaluation procedure, and a computer-aided procedure.

## 2.15 Appendix A: Capacity User's Manual and Documentation

This appendix documents and describes how to run the CAPACITY computer model. The CAPACITY model is a computer program to assist in evaluating yard capacity and crew resource requirements. Its use in the design process is described in Chapter 7.

## 2.16 Appendix B: Profile User's Manual and Documentation

This appendix documents and describes how to run the PROFILE computer program to assist in hump grade design and retarder placement. Its use in the design process is discussed in Chapter 12.

## 2.17 Appendix C: CONFLICT User's Manual and Documentation

The appendix documents and describes how to run the CONFLICT computer model. The CONFLICT model is a computer program to assist in the design and evaluation of alternatives for the trim-end or pull-out end of a hump yard. Its use in the design process is described in Chapter 13.

# 3.0 Volume II: Yard Computer Systems

## 3.1 General

With the advent of high computer technology, there will be an increasing availability of computer yard applications. The railroads of the 1980s will be faced with a greater than ever challenge of evaluating, selecting, and installing yard computer equipment. Thus, railroad companies will be in a constant process of examining options in hardware and software configurations over an increasing variety of yard operational applications. It is anticipated that more responsibility will be placed on the decision-makers within the railroad companies to conduct computer feasibility studies, develop alternative approaches, evaluate trade-off parameters, compare and select alternative configurations, and procure and implement computer operations.

The objective of Volume II of the manual is to develop a handbook for the railroad industry on the utilization and application of computer systems in classification yards. The purpose of the handbook is to provide basic information on computer hardware and software and their applicability to yard operations; procedures and methodologies of computer system design, selection, acquisition, and installation. The intended readership includes yard designers, yard management, yard operational staff, engineering managers, data processing specialists, and company executives.

The topics discussed within each chapter of the manual are described below.

### 3.2 Chapter 1: Introduction

This chapter discusses the background and purpose of the yard computer systems manual. The focus on the yard inventory and process control computer systems is explained.

### 3.3 Chapter 2: Computer Primer

This chapter is essentially a tutorial discussion of modern computers for those not familiar with computer hardware and software considerations. It provides basic background to read the remaining chapters. This discussion includes: major types of computers, computer hardware, computer software, modes of operation, network organization, and management and control.

### 3.4 Chapter 3: Inventory Management System Operational and Functional Description

This chapter discusses the gathering, processing, storage, transmission, and retrieval of inventory management information in classification yards. First, a railroad operational description is presented, then a computer functional description of yard inventory systems is presented.

### 3.5 Chapter 4: Process Control Operational and Functional Description

The most common applications of the process control computer in hump yards are automatic routing and switching of cars and automatic speed control. In this chapter a railroad operational description and a computer functional description of the process control systems is presented.

### 3.6 Chapter 5: Computer System Requirements

This chapter discusses the development of the computer system requirements specifications. The elements involved in the process includes: description of operational requirements, functional design, hardware and software characteristics, alternative system configurations, and performance characteristics.

### 3.7 Chapter 6: Evaluation of Benefits

This chapter discusses system selection by performing and economic tradeoff analysis. Topics include initial investments costs, life cycle costs, and benefit assessments.

### 3.8 Chapter 7: Computer System Acquisition, Installation, and Management

This chapter concerns acquiring, installing, and managing the yard computer system. Topics include: implementation schedules, site preparation, staff training, management organization, operating procedures, and system documentation.

## 4.0 Conclusions

It is anticipated that the yard design manual will have a substantial influence on the way yards are designed in the future. Moreover, it is expected that more operationally efficient yards will result, for the minimum capital expenditure. Thus, the influence of the design manual should directly affect the performance of yards and the profitability of railroads well into the turn of the century. In particular, in one case study yard where sufficient economic data was available, it has been estimated that the yard design resulting from the applied methodology will save the railroad $900,000 annually through reduced car detention time.

# NOISE CONTROL ASPECTS OF YARD DESIGN

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## Introduction

This presentation provides highlights of a recent assessment of classification yard noise characteristics, measurements, sources, and control methods. That research was conducted for TSC, acting under FRA sponsorship, by Wyle Laboratories, El Segundo, California. The full technical report ("Railroad Yard Noise Control Design Methodology," by E. Stusnick, M. Montroll, and V. Kohli) will be published shortly. The presentation is based on specific chapters of that report.

## Objective

The purpose of this study was to provide the yard designer and other interested parties with a basic understanding in the principles and objectives involved in controlling noise emission from railroad yards, either in the design of a new yard or in improvements to an existing yard. The material presented in the full report and summarized here allows the designer better to understand the information contained in the more advanced noise control handbooks and articles, in order to develop detailed noise control designs, and to interact with acoustic consultants in the development of such designs.

## Technical Background

A number of technical fundamentals must be made clear if one is to understand the terminology and principles of noise control. The starting point is characterization of sound itself. The factors of primary concern here are frequency, measured in cycles per second or hertz, and intensity, which is determined by the difference between the pressure at the crest of the wave and the pressure of the undisturbed air (normal atmospheric pressure). This pressure difference is called the amplitude of the wave.

The mks unit of sound pressure is the pascal (abbreviated Pa), equal to one Newton/m$^2$. The minimum discernible sound in quiet conditions has an rms pressure of about $2 \times 10^{-5}$ or 20 Pa. The threshold of hearing pain occurs for a pressure of approximately 200 Pa. Thus, the range of sound pressures likely to be heard extends over seven orders of magnitude ($10^7$). In order to compress this tremendous range into a usable interval and in accordance with the response of the human ear to changes in sound intensity, a logarithmic scale is normally used to measure rms sound pressure. The sound pressure level of a sound wave having rms pressure $p_{rms}$ is expressed in decibels (dB) and defined as

$$L_p = 10 \log_{10} \left[P^2_{rms}/P^2_{ref}\right] \text{ dB}$$

where $P_{ref}$ is a reference pressure normally defined as 20 μPa. In words, this expression says the sound wave has a sound pressure level of $L_p$ decibels relative to 20 Pa. Often the standard reference pressure is omitted.

A typical sound in normal conversation might have an rms pressure of 0.02 Pa, so that its sound pressure level would be

$$L_p = 10 \log_{10} \left[\frac{0.02}{20 \times 10}\right]^2$$

$$= 10 \log_{10} \left[10^6\right] = 60 \text{ dB}$$

Since the sound level scale is logarithmic, two levels do not combine additively. That is, the sum of two 60 dB levels is not 120 dB. Instead, the sum of two 60 dB sound levels is

$$L_{sum} = 10 \log_{10} \left[10^{60/10} + 10^{60/10}\right]$$

$$= 10 \log_{10} \left[2 \times 10^6\right] = 63 \text{ dB}$$

As noted, the ear does not respond to sound pressure changes in a linear fashion. Thus a doubling of the sound energy is not perceived as doubling of the loudness of sound. The psychological response to changes in sound level is quite complicated, but, as a rough rule-of-thumb, a 3 dB change in sound level is just noticeable, a 5 dB change is quite noticeable, and a 10 dB change is typically perceived as a doubling of loudness.

Most sounds are complicated in wave form and cannot be characterized by a single frequency. However, any wave can be described as a weighted summation of pure tones of various frequencies. The weighting factor for each frequency is a measure of how much sound power of that frequency is contained in the sound wave.

A plot of those weighting factors as a function of frequency is called the spectrum of the sound. For a pure tone, the spectrum would be sharply peaked. If many frequencies are present, the spectrum will be broadly spread across the audio frequency range. Such sounds are called "broadband" sounds.

The ear is much less sensitive to low frequencies than it is to high frequencies. For example, a tone of 50 Hz would need to have a sound level about 30 dB higher than that of a tone at 1000 Hz to be perceived as equally loud. This is commonly accounted for by describing a complex sound by its A-weighted sound level. This is a weighted summation of all the frequency components in the spectrum of the sound. The weighting function is directly related to the sensitivity of the ear. Most sound level meters contain electronic circuitry which automatically determines the A-weighted sound level of a sound wave.

Most sounds that occur in the environment are not constant, but vary with time. Several different measures have been defined to characterize the effect of such sounds. The exceedence percentile level, $L_x$, is the A-weighted sound level that is exceeded x percent of the time during the measurement period. For example, $L_{10}$ is the sound level that is exceeded 10 percent of the time. Commonly used percentile values (x values) are 90, 50, 10, and 1. The energy-equivalent sound level, $L_{eq}$, is the level that a continuous constant sound source must have in order to contribute to the environment the same amount of A-weighted acoustic energy as did the actual time-varying source. Day-night sound level, $L_{dn}$, is similar to the energy-equivalent sound level except it is defined for a 24-hour period and sound levels occurring during 9 nighttime hours (10:00 p.m. to 7:00 a.m.) are artificially penalized by the addition of 10 dB to the measured level.

## Principal Noise Sources in Yards

Sources associated with the process of classification and locomotive maintenance and repair typically dominate yard noise. Continual variation in levels of sound, both in time and location, are typical, including periods of more or less constant sound (such as that of idling locomotives) as well as momentary peaks (the sharp reports of car-coupling impacts). The sound level at a particular location depends largely on the source-to-receiver distance. Another factor is that some sources do not radiate sound equally in all directions. The spatial variation of noise levels throughout the yard and along the yard boundary can be quite significant. In addition, due to the mobility of certain sources such as working switch engines, the distribution of sound in and around the yard can vary continuously.

The major sources of noise within a railroad yard are:

- o Locomotives and switch engines;
- o Car-coupling impacts;
- o Retarders;
- o Locomotive service areas, repair and maintenance facilities, and load cells;
- o Refrigerator and other special purpose cars;
- o Wheel/rail interaction;
- o Horns, bells, whistles, and public address systems.

## General Methods of Controlling Noise

Methods of controlling noise can be divided into three categories:

- o Noise reduction at the source itself;
- o Control of the path through which noise propagates; and
- o Protection of the receiver from noise.

Reduction of noise at the source encompasses a variety of techniques. It may include innovative redesign of equipment, addition of noise-suppressing devices (mufflers or damping compounds), or modification of operating procedures (running equipment at slower speeds or curtailing noisy operations during noise-sensitive periods).

Control of noise by means of the sound transmission path is often the most viable method. Awareness of this approach is particularly important in the design of new classification yards. One elementary but important means is to take advantage of the reduction of sound level with propagation distance by ensuring sufficient separation between source and receiver. Another method of path control is to insert some form of barrier in the sound path to disrupt the passage of sound waves toward the receiver.

Noise control methods at the receiver location are quite varied. Receiver noise control for railroad employees, for example, may include having employees working in a hazardous noise area wear hearing protective devices such as ear plugs, or arranging the work schedule to limit the amount of time a person is exposed to high-level noise.

It can be seen that for any given noise situation, there are a wide variety of noise control techniques which can be applied. The choice of any particular approach ideally requires a consideration of factors such as capital outlay, operational throughput, serviceability, as well as degree of noise reduction required.

Specific Noise Control Techniques

Locomotives and Switch Engines: Engine exhaust is the dominant source of locomotive noise in the notch 8 throttle position. Specially designed mufflers can be effective; reductions in overall locomotive noise of 3 to 6 dBA have been achieved, but due to the large size of the mufflers, this technique is not currently considered practical. In the future, technical advances may well overcome this problem.

Even at idle and low throttle noise has been reduced by no more than 1.5 dB when exhaust mufflers were installed. Thus it appears that this is an ineffective technique for locomotives operating at idle or low throttle settings. Under these circumstances, noise can be controlled by shutting down idling locomotives when they are not needed. This procedure is already used in many yards as an energy-conservation measure, but is not always feasible. At low temperatures (below 50°F), the viscosity of the lubricating oil used in locomotives creates engine restarting problems. In addition, any time a locomotive engine is shut down and restarted there is some risk of damage.

Car-Coupling Impact: Little can be done directly to influence this noise source. Better speed control to avoid overspeed impacts, already desirable to reduce damage, can be helpful.

Retarders: Several different techniques have been tried. The use of barriers close to the retarder is one method. Barriers can effectively reduce the amount of noise propagating into certain directions, but parallel sets of barriers tend to redirect the sound more than reduce it. In addition, barriers present safety and maintenance problems since they interfere with the hump operator's view of the car motion and restrict the space available in which to repair the retarders.

Lubrication systems which spray small amounts of oil onto car wheels before entering the retarder can be effective in changing the frictional characteristics of the wheel and brakeshoe sufficiently to eliminate squeal. However, there is a danger that too much oil will be deposited so that the car will not be sufficiently slowed by the retarder. Also, oil spray systems present a severe maintenance problem since excess oil may eventually contaminate groundwater. Solid lubricants providing better control must be developed for lubrication to be fully acceptable. Another method is use of "low-noise" retarder brakeshoes. By varying the metallic composition of brakeshoes and properly designing their shape, the frictional characteristics can be changed sufficiently that squeal is less likely to occur. Newer compositions have recently been developed which appear to wear well, while at the same time reducing the incidence and level of retarder squeal.

Load Cells: Engine exhaust is the dominant source of noise during locomotive load tests. Since the load test cell stands are generally quite localized, noise barriers may be erected near the engine position to reduce the noise emission into nearby noise-sensitive areas. These barriers would have to be quite high since the position of the dominant noise source, engine exhaust, is about 15 feet above the ground, and because the noise is predominantly low frequency--a situation in which barriers are least effective.

Wheel/Rail Noise: The major technique for controlling noise from railroad cars is the use of good maintenance practices to remove flat spots from wheels and corrugations from the rail, thus reducing the impact component of wheel/rail interaction. In addition, by eliminating tight radius curves where practical, and using lubrication on those curves that cannot be eliminated, the occurrence of wheel squeal can be reduced.

# STATISTICAL REGRESSION ANALYSIS TO UNDERSTAND CAR ROLLABILITY

By

William A. Stock, Peter J. Wong, and Mary Ann Hackworth
SRI International

## 1.0 Introduction

SRI International is conducting a study of freight car rolling resistance in railroad classification yards. The study is based on acquiring and analyzing velocity and rolling resistance data from the existing process control computers at five yards: Hinkle Yard (Union Pacific), DeWitt Yard (CONRAIL), Northtown Yard (Burlington Northern), Argentine Yard (Santa Fe), and Linwood Yard (Southern).

This paper presents part of the results of the study, namely, a statistical regression analysis of the Hinkle Yard and DeWitt Yard data. The purpose of the regression analysis is to understand and quantify the causal factors which affect rolling resistance.

## 2.0 Background

Rolling resistance has traditionally been thought to be influenced by a number of factors including:

- Car weight
- Car type
- Bearing type
- Truck center length
- Car speed
- Wind
- Temperature
- Moisture
- Switches and curves
- Distance from crest
- Type of rail

In this paper, we present our findings regarding the above factors. Some are surprising and some were anticipated. Unfortunately, due to the nature of the data available to us, we could not reliably isolate the effects of certain factors. The technique employed in analyzing these factors is linear regression. This technique finds a relationship for how the <u>mean</u> rolling resistance varies as a function of a set of independent variables (basically the above factors).

The regression analysis results presented here, unless specified otherwise, include only first order terms, with rolling resistance as the dependent variable. Regression analysis considering first-order interactions among the indepdent variables, and considering resistance force as the dependent variable was performed. However, the interaction term and resistance force regressions did not add an appreciable amount of information to the results presented in this paper.

There is difficulty in isolating the influence of any single factor on rolling resistance since all factors influence rolling resistance simultaneously. Where we have quantified relationships, we have used an artifice called a nominal car and nominal conditions. This allows us to choose nominal values for all factors except the one being studied which we allow to vary. The reader should be cautioned that the nominal car does not exist except as an artifice.

These analyses were performed using data only from Hinkle and DeWitt Yards. We found a small, but nontheless statistically significant, difference in the rolling resistances between these two yards. This difference amounts to about 0.5 lb/ton; it persisted even when taking into account the explanatory power of all the available factors.* We have no explanation for this residual difference; it could represent a bias in the data provided us by the process control systems and by plans in one or both yards, or it could represent some unknown factor varying between the two yards that was omitted from the analysis.

Below we present some of the major results of the regression analysis.

## 3.0 Car Weight

The relationship between rolling resistance and car weight is an inverse relationship; namely, as cars become lighter, they roll harder. Results indicate that an "average" 30 ton box car has a rolling resistance of approximately 8.3 lbs/ton; whereas, an "average" 80 ton box car is approximately 5.4 lbs/ton.

## 4.0 Car Type

We have taken the nominal car to be a box car. Relative to this, we have found that "on the average:"

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*The qualification of these factors should be capable of explaining most, if not all, regional differences between the two yards.

- Gondola cars roll about 1.2 lb/ton harder than the box car.
- Flat cars roll about 0.55 lb/ton harder than the box car.
- Tank cars roll about 0.66 lb/ton harder than the box car.

The other car types considered - hoppers, refrigerator, and vehicular cars - were not significantly different from the reference box car.

## 5.0 Bearing Type

It has been traditionally assumed that roller bearing cars roll easier than journal bearing cars. Surprisingly, we did not observe any significant difference from a statistical standpoint. Journal bearing cars constituted about 17% of our regression sample - more than sufficient to detect any statistically significant difference.

## 6.0 Truck Center Length

We could not determine any statistically significant effect at truck center length on rolling resistance. This applied even on curves, where conventional wisdom has it that long wheelbase cars roll harder due to a binding effect.

## 7.0 Car Speed

There is a strong dependence of rolling resistance on car speed; namely, rolling resistance increases with car speed. Although a $V^2$ (velocity squared) dependence was found, the actual curvilinearity appears to be small under zero ambient wind conditions and even with a 10 ft/sec headwind. Thus, it is sufficiently accurate for most yard applications to ignore the curvilinearity when headwinds are small. (The wind effect is discussed in a later section.)

## 8.0 Wind

It is known that a headwind against the motion of the car can contribute significantly to the rolling resistance of a nominal car.* Results indicate that each foot/second headwind approximately contributes .2 lbs/ton to rolling resistance, for the nominal conditions.

## 9.0 Temperature

Cars roll easier with increasing temperature. The available data sample did not have extreme cold temperatures. A very slight, but nonetheless statistically significant, variation with $T^2$ (temperature squared) was noted. In the temperature ranges investigated "on the average" a car rolls .39 lb/ton heavier for every ten-degrees (Fahrenheit) drop in temperature.

## 10.0 Moisture

Traditionally, it has been assumed that cars roll easier in the rain. Deep snow, on the other hand, is felt to impede a car's rolling, particularly when it covers the rail. Our data from the process control computers indicated whether moisture was present, but did not differentiate between rain and snow. Also, the number of moisture days were small (about 3.4% of the data). There could also be a descrepancy between what was automatically recorded in the cut statistics and the moisture conditions on the ground. In any event, we found no significant moisture effect. It is not possible to say to what extent the above difficulties are responsible for the lack of a significant moisture effect.

## 11.0 Switches and Curves

We could not reliably isolate the effect of switches and curves. Although it appears that their effect is significant, a reliable quantification of their individual action was not possible based on the data available. This was due to the fact that the measurement sections which provided our switch and curve data were one and the same, in most cases, so that the effects of these variables could not be reliably isolated one from another. Further, these sections occurred just after the oilers, further complicating the analysis.

## 12.0 Distance from Crest

We found a statistically significant counter-intuitive trend for this variable: namely, we found an increase in rolling resistance further from the crest. The effect is slight; nonethless, it was evident in all analyses we performed. The effect may be related to the statistical difficulties we had with switches and curves.

## 13.0 Type of Rail

The two yards analyzed in this regression study had welded rail. Hence, no data were available to isolate the impact of welded, versus non-welded, rail.

## 14.0 Concluding Remarks

It should be remarked that just because the statistical regression analysis could

*This term is proportional to the square of the headwind, times the car's cross-sectional area, divided by the car's weight.

not find causal relationships between specific factors does not mean that causal relationships may be a result of the quality of the data being analyzed.

# FOCUSING ON SELECTED AREAS
# OF
# IMPLEMENTED YARD DESIGNS

# FOCUSING ON SELECTED AREAS OF IMPLEMENTED YARD DESIGNS

M. J. Anderson, Presiding

This panel has been hand-selected to include the railroads that have been most active in areas of yard design and technology.

Different railroads have different ideas on how to accomplish certain aspects of their yard and plant operations to expedite car handling. Some of these issues may be controversial items, but all certainly have their merit. The individuals giving these presentations have been associated with or in a position to obtain pertinent information as to the reasons their railroad approached and solved the design requirements on which they have been requested to speak. While there will be many questions to be reviewed by this panel, it will be in the best interest of everyone to first allow each individual to give his 10-15 minute report, and then open the forum to the floor on a question and answer basis for about 45 minutes.

Introductions:

J. I. Adams - Asst. Vice President-Administration, Family Lines Rail System.

The Family Lines Rail System and, more specifically, the Seaboard Coast Line Division, chose to install a dual hump lead at their Rice Yard in Waycross, Georgia. This specific design has been reviewed by many railroads but is usually considered not practical from an operational and engineering aspect. Considerations that usually eliminate this type of configuration from most railroads' plans are the operational problems of rehumps to align proper classifications and engineering problems of double master retarders, double scales, and scissor crossovers.

Mr. Adams will be presenting the operational, engineering, and economic reasoning which led to the installation of the double hump operation at Rice Yard.

M. E. Wilson - Chief Engineer, Design & Construction, Southern Railway System.

The Southern Railway has been a forerunner in the design and development of classification yards for several years. They have developed a network of major classification yards strategically located to enhance their system blocking and handling of cars. Also, there are several key items that are apparent in each of their yards, such as portions of track layout, operational and mechanical facilities.

Mr. Wilson will be presenting the operational and engineering technology that has been applied in the development of the Southern Railway's Classification Yards.

R. D. Penhallegon - Project Manager, Chessie System

The Chessie System Railroad has recently installed tangent point retarders at their new yard, Queensgate in Cincinnati, Ohio. While some large yards recently constructed have utilized tangent point retarders, others have not. This still is a controversial item as those who do utilize tangent point retarders maintain they are necessary for high throughput to handle their volume of traffic; while those who choose not to utilize tangent point retarders maintain they are too expensive to install and the trim operations determine the maximum number of cars they can classify.

Mr. Penhallegon will present the Chessie System's operational, engineering and economic reasoning which determined the use of tangent point retarders at Queensgate.

J. C. Strong - Engineer of Design, Southern Pacific Railroad.

The Southern Pacific built a classification yard at Colton, California which has now been operating for several years. At the time this yard was constructed, and even to this date, it was considered one of the most modern and expensive yards built. It has engineering and operational technology that was never utilized before. Some aspects have been adapted by other railroads in their yards while some design features have not been repeated. Some of the most interesting features are the "hump" that descends from the receiving yard, humping the cabooses and bad orders into their respective tracks, and departure tracks within the bowl.

Mr. Strong will present the Southern Pacific's viewpoints on the technology and reasoning that developed Colton Yard, and review its operational effectiveness since the yard has been put in service.

Dale Harrison - Special Projects Engineer, Atchison, Topeka & Santa Fe Railroad Company.

The Santa Fe has been actively working with Dowty Retarders and most recently has installed the Dowty system on three tracks at Oklahoma City. The Dowty system has been in use in England for several years; but U.S. railroads have been reluctant to install this system due to cost, maintenance and the general lack of knowledge the U.S. railroads have as to the operational effectiveness of the Dowty system. Hopefully, the Santa Fe's pioneering in this area will lead to a new method of handling cars in specific cases.

Mr. Harrison will be presenting the technical data that has been accumulated by the Santa Fe and will be discussing the theory and reasons the Santa Fe decided to utilize Dowty retarders at Oklahoma City.

# DUAL HUMP OPERATION AT RICE YARD

J. I. Adams, Family Lines

It is indeed a privelege to take part in this panel discussion of the Second Classification Yard Technology Workshop.

Being "Railroaders" in private enterprise, we are all concerned with maximizing the resources at our disposal in the most efficient manner. If we effectively utilize these resources, we in turn provide greater reliability in service for shippers and, of course, improve profitability.

One way in which those of us at Family Lines have attempted to do this is through the construction of new yard facilities at Rice and Osborn Yards. My topic today will be centered around the design feature - dual hump operation at Rice Yard.

Beginning in 1972 SCL began to experience considerable congestion, particularly over the corridors serving Florida and the Atlanta and Birmingham gateways; more specifically, Waycross and Jacksonville-Baldwin. It was obvious there was a need for an adquate terminal facility, strategically located, that would provide the means for a more orderly and dependable flow of traffic and, at the same time, reduce the high cost of terminal operations incident to congestion and delay.

The system traffic pattern and geographic location combined to establish Waycross as the facility site. Six separate SCL lines radiate from Waycross, resulting in direct access to all areas in the Southeastern United States. The traffic flow through Waycross demanded a high volume facility. Prior to the construction of Rice Yard, there were three flat yards at Waycross known as West Yard, Middle Yard and Herco Yard. By 1973 the flow of traffic had far exceeded the capacity of the three flat yards and a considerable amount of traffic, which would normally have been switched at Waycross, was being switched at other terminals. It was a logical progression, then, that the facility be built at Waycross.

Before the design of Rice Yard at Waycross was finalized, we took several steps to broaden our knowledge of available technology and to develop basic information on traffic flow, volumes, classifications to be made, etc. We talked with and obtained proposals from the two major manufacturers of automated yards in the United States. We visited several yards that were new at the time; yards as far away as Calgary, Canada, and West Colton, California. In addition, a manual simulation of the operation of a hump yard at Waycross was made, using records of actual traffic at the time. It is interesting that this simulation indicated a maximum inbound car count of approximately 2,600 cars daily, however, seven years later we find the count will occasionally exceed 3,600 in actual operation. Of course, as with any undertaking of this magnitude, this facility was designed with growth in mind. From information available to those involved in the planning of Rice Yard, it was believed that the maximum humping capacity of existing hump yards with single hump leads was something like 2,400 cars daily. This obviously was not enough to accomplish the job at Waycross. The possibility of two separate hump yards did not have much appeal, both becauseof cost and because of the nature of the traffic flow through Waycross. It simply did not lend itself to a north-south or east-west configuration. At the same time, it was recognized that a significant portion of the total traffic did tend to be north and south, and the idea was conceived that by designing the yard with two hump leads and arranging it so that it could be worked as a north and a south yard, a significant number of trains could be paired for dual humping. This was one method of increasing capacity and the other rather obvious method was the use of tangent point retarders in a configuration such as Southern Pacific used at West Colton. We weighed the advantages of the two systems and felt that for the specific requirements at Waycross, the dual hump lead was the more attractive. Experience to date points to the correctness of this decision.

The Rice Yard classification facility is an 850 acre complex, four miles long by approximately 2,000 ft. wide, containing 150 miles of track, including 460 turnouts. Construction of this 57.2 million dollar facility began on June 7, 1973, and revenue service commenced on April 18, 1978. Within 27 days, the hump production reached the 2,000 cars per day mark and by August the count reached 3,000 cars per day. During 1980 the peak day was 3,947 cars and, in a check over a several month period, the average cars humped per day exceeded 3,100. Approximately 60 trains a day are handledat Rice Yard and eight run-through trains pass through the terminal.

In order to provide the needed capacity, Rice Yard was designed with a relatively large classification yard consisting of 64 tracks, the longest of which holds about sixty 50-ft. cars, and the shortest holds approximately 20 such cars, with a bowl capacity of 2,600 cars. There is a receiving yard consisting of 12 tracks of nearly 200 carlengths and there are two departure yards; South Forwarding Yard consisting of four tracks of approximately 200 carlengths; and North Forwarding Yard consisting of 10 tracks of approximately 200 carlengths. The receiving and forwarding yard tracks are built on 20-ft. centers to facilitate mechanized inspections.

Now a brief description of how the yard functions; inbound trains are yarded in the receiving yard, engines detached and moved to the diesel service facility. Carmen on motorized carts bleed air, perform critical inbound inspection and repair defects, except couplers, trucks or heavy maintenance.

Clerical support forces verify the advance consist by closed circuit television. Inbound consists are updated, class codes are assigned and hump lists are prepared by the computer.

The Terminal Trainmaster, located in "A" Tower, coordinates activities of all departments and support personnel, directs overall operation and sets the humping priority schedule. Yardmaster at "A" Tower directs humping activities and is responsible for hump production.

Yardmaster at "B" Tower directs activities at the pull-out end of the bowl (classification yard), builds outbound trains, instructs mechanical forces concerning outbound inspection and sets the call figures for outbound trains. Call figures are set after coordination between the yard, the diesel service facility and the involved Division Chief Dispatcher.

Rice Yard incorporates the most modern features in yard design, supporting facilities and control systems, among which are the wide track centers in the receiving and forwarding yards. Mechanical forces are mechanized and motorized, thus improving inspection techniques, reducing inspection time and permitting repairs to be made in the yard, eliminating delays to traffic.

This computer controlled yard improves classification and expedites traffic movement on a system-wide basis. Operating personnel are provided with instant statistical information that has resulted in improved car utilization, train dispatching, locomotive assignments and general operation of the terminal.

With this brief description of Rice Yard, it is now time to direct our attention to one specific item of this yard design - DUAL HUMP LEADS.

Dual hump leads are provided at Rice Yard, both being accessible from the receiving yard and both feeding into the single classification yard. Both humps are equipped with retarders and a scale, and are provided with a scissors type crossover arrangement so that the two humps may be used in any one of five modes. The three principle modes are from the north hump lead to the full yard; from the south hump lead to the full yard; and dual humping with the north lead feeding the north half of the classification yard and the south lead feeding the south half of the classification yard. The ability to pull cars from the classification yard and transfer them to the forwarding yard or yards at a rate equal to or greater than the humping rate is of critical importance in the design of any hump yard. The bottleneck in a hump yard is more likely to be at the pull-out end than at the humping end. For this reason Rice Yard was designed with four trimmer leads or pull-out leads.

As you are all aware, hump occupancy is one of the key elements in an efficient hump yard operation. Our own experience with Family Lines hump yards at Hamlet, Radnor, Decoursey, Tilford and Birmingham, along with investigation of other newly designed yards, confirmed the need to improve hump utilization. Two common concerns with any single hump operation is the lost time between cuts and the down time necessitated by scheduled and emergency maintenance. Therefore, the decision to build a dual hump configuration was to provide an economical method to overcome these common problems.

Let's deal with the first problem - lost time between cuts. With the dual facility, in the single mode, this problem is overcome by having the second hump cut ready on the unoccupied lead, so that humping can begin immediately upon completion of the first cut, and is not delayed by waiting for engine to clear turnout or track circuit. In the dual mode, the second cut can commence humping at any time, without regard to the stage of the first cut.

The second problem - down time due to scheduled and emergency maintenance: The problem of scheduled maintenance is overcome by having the capability to hump in the single mode from one lead while maintenance is performed on the other lead. The same holds true for emergency repairs. An additional maintenance advantage is the ability to employ rail mounted equipment on one lead to support repairs on the other.

You may ask, "Does this work in the "REAL WORLD?" - and the answer is a definite, "YES!"

Our forces at Rice Yard have mastered the use of this new tool and have developed the criteria for selecting the proper mode. Dual humping is predicated on the arrival trains containing the proper classification mix and being yarded in the appropriate half of the receiving yard. It has been determined that, if a train contains more than 15% classifications for the opposite half of the bowl, the single mode should be selected.

Friday, April 10, 1981, was selected as a representative day. On this date, 3,633 cars were humped. In the dual mode 1,022 cars were humped to the north half and 954 cars were humped to the south half of the classification yard. In the single mode, 1,687 cars were humped to the full yard. This equates to approximately 65% hump utilization. Based on the industry statistics for hump yard operations, 65% hump utilization is a significant figure and far above the average.

Rice Yard is consistently able to maintain a current traffic status, with existing traffic flow patterns. However, we realize that with changes in train schedules and classification patterns, Rice Yard hump utilization can be improved.

I'm sure this brief overview will raise some questions and I shall be happy to attempt to answer them during the discussion period.

Thank you for your interest and participation in this Workshop.

# TANGENT POINT RETARDERS AND THEIR APPLICATION AT QUEENSGATE

R. D. Penhallegon
Chessie System

## 1.0 Introduction

The purpose of this discussion is to review the merits of the use of tangent point retarders in automated classification yards, and in particular, to relate Chessie System's experiences with tangent point retarders at Queensgate Yard.

## 2.0 Fan Design Alternatives

Most yards in the U.S. use a clasp retarder system employing target shooting logic. That is, the speed of a car through the switching area is controlled at discrete points based on the calculated rollability of the car and the distance it must travel to reach the distant clearance point or to couple safely into the last previously classified car on that track. In older yards, rollability is calculated intuitively by a retarder operator, while newer yards use a computer with the appropriate algorithms to automatically calculate rollability based on speed, weight, weather conditions, and other appropriate factors affecting rollability.

There are a number of possible retarder arrangements in the switching or fan area of a hump yard, depending on the number of classification tracks required, performance specifications, and physical constraints. Generally, however, yard designers attempt to minimize the crest to clearance distance to maximize classification track lengths and minimize the probability of misroutes due to catchups.

The typical classification yard has a master - group retarder arrangement. All cars are first controlled by the master retarder, after which they are directed into a group of six to ten tracks for final control by a group retarder. In this two step retardation scheme, car spacing is established by the master retarder, and the final target speed is controlled by the group retarder. Good performance in a two step control system requires that the group retarder exit speed be based on knowledge of a car's rollability, the distance to coupling, and the rolling resistance characteristics of every classification track. Rolling resistance of individual tracks is mostly a function of gradient, track geometry, and curvature.

With a two-point retardation layout, performance in terms of the humping rate is constrained by allowable exit speeds out of the group retarders, which in turn constrains speeds between the master and groups to avoid catchups. The usual humping rate for a conventional layout is 4 - 55 ft. cars per minute, or 2.5 m.p.h., although 5 - 55 ft. cars per minute is also achievable under a conventional layout if the cars are dispersed fairly widely.

A consistent hump rate of 6 - 55 ft. cars per minute or more into adjacent tracks requires an evolutionary improvement to the conventional two-point retarder layout to permit higher car speeds through the switching area. These higher speeds can be obtained by using tangent point retarders as part of a three point control system.

A tangent point retarder is simply a retarder at or beyond the tangent point of every classification track in the bowl. With this scheme, both the master and group retarders are used to maintain spacing, thereby permitting higher speeds in the switching area, subject to the physical constraints of turnouts and curvature. The tangent point retarder then controls the final exit speed from the switching area to permit safe coupling at the target distance. With a tangent point layout, rollability can also be measured a third time prior to final control of the car.

An inherent feature of the tangent point layout is that the last control point is located after the car has passed through all turnouts and curves, after skewed trucks have a chance to straighten themselves, and at a shorter distance to the target than the group retarder. Thus, with a tangent point layout, we could also expect more accurate overall car control for better penetration, fewer stalls short of coupling, and a smaller standard deviation of impact speeds.

Master and group retarders are typically full control clasp type retarders such as the WABCO Model 67 or GRS Model E160, both of which act against all wheels of a car. These models could also be used as tangent point retarders. For economic reasons, however, the usual tangent point retarder is a weight responsive type acting on one side only such as the WABCO Model 50B or GRS Model F4. Weight responsive retarders exert a retarding force proportioned to the weight of the car until the car is released. They tend to have less accuracy for control of exit speeds than a full control retarder, but their accuracy of ±.25 m.p.h. is sufficient for use as tangent point retarders. Because of their simpler design, they also tend to have fewer maintenance problems than the full control type.

## 3.0 Design Criteria For Queensgate Yard

Having described the theory behind tangent point retarders, I would like to describe how the design criteria for Queensgate Yard led us to the selection of a tangent point layout. Almost from the beginning it became obvious that there was only one possible site for Queensgate, and that whatever design was ultimately developed had to fit within a confined area. We started with a set of idealized schedules and classifications for both road and yard trains under the assumption that Queensgate could build and dispatch trains to satisfy any conceivable requirement. Meanwhile, we collected and massaged actual traffic data to determine future block sizes and accumulation patterns to meet the contemplated schedules. This exercise, along with some simple manual simulations led us to the basic design criteria for track lengths and capacities. Other important criteria which emerged from the preliminary study was an estimated workload of 2600 cars per day, the need to build approximately 85 classifications, the need to receive and dispatch up to 40 trains or yard cuts daily, and the approximate size of the receiving and departure yards. During this early stage of the design process, we also began to formulate the costs and benefits of the project, and of course, continued to refine these numbers throughout the design stage.

With our preliminary criteria in hand and a known location for the yard, Engineering began the layout of possible alternative track arrangements. It soon became apparent that we could not have a classification yard of more than 50 tracks, and that reswitching of approximately 600 cars per day would be necessary if we were going to build 85 classifications. Unfortunately, our schedule requirements and volumes would not permit multiple slough tracks for later reswitching.

At this point we began to take a hard look at geometric switching utilizing a "mini-hump". We had to locate the mini-hump, the north end of the departure yard, and the trim leads from the bowl as conveniently as possible to minimize trim engine activity. It turned out that the best location for all of this trackage was already occupied by a concrete viaduct carrying a city street across the yard site. Other locations had other disadvantages, and we finally recognized that Queensgate was not to have a mini-hump, but that all switching would have to be done over the primary hump.

Engineering completed their proposed layout of Queensgate, and after several modifications we had what appeared to be an acceptable plan. The next few months were devoted to an extensive computer simulation of yard operations and an analysis of the results. The computer simulation led to a few minor design changes, and also verified the need to be able to hump at 6 cars per minute into adjacent tracks. At a simulated rate of 5 cars per minute we could not handle the traffic, and we were able to provide economic justification for the additional cost of a tangent point layout.

Furthermore, we knew that some priority road trains had to be geometrically switched. We needed some assurance that cars would penetrate in the bowl to minimize the need to couple tracks between the first and second stage. A tangent point layout would also be helpful here.

The specifications for Queensgate evolved as follows:

a. A consistent hump rate of 6 - 55 ft. cars per minute into adjacent tracks;
b. Maximum of .01% will fail to roll to clearance;
c. Maximum of 2% will fail to close or reach the exit retarder;
d. Maximum of 0.5% will fail to roll to within 200 ft. of closure; and
e. Maximum coupling speed of 6.4 M.P.H.

Also, we specified a maximum of:

a. .01% catch-ups;
b. .001% corners;
c. .01% misroutes other than anti-catch-ups and corner protection; and
d. .0001% having a switch thrown under the cut.



Both GRS and WABCO agreed that only tangent point layout would meet all of these specifications.

## 4.0 Car Control In Tangent Point Yards

The Queensgate profile and track arrangement was simulated, with and without tangent point retarders, using the following data:

Cars #1 and #3 (good roller):
- 3#/Ton Crest to Master
- 2#/Ton Master to Group
- 2#/Ton Group to Tangent

Car #2 (bad roller):
- 16#/Ton Crest to Master
- 12#/Ton Master to Group
- 11#/Ton Group to Tangent

At a rate of 6 cars per minute, the time-distance study for the two point retardation plan shows a catch-up in the master retarder for Cars 2 and 3. If the exit speed of Car 2 is increased, Car 2 will catch up with Car 1 at the clearance point, causing either a cornering or misroute of Car 2. The only recourse here is to reduce the hump rate to 5 cars per minute or less.

However, with the addition of a tangent point retarder having a capacity of 2.4 of velocity head removal placed 30 feet beyond the tangent point, the time-distance study shows no potential catch-ups or cornering. Exit speeds for the master and group are calculated to maintain a constant run time from the crest to the clearance point, thereby having the affect of optimizing separation of cars at critical points in the switching area.

One supplier has also calculated the difference in expected impact speeds for a conventional yard versus a tangent point yard as follows:

| | Conventional | Tangent Point |
|---|---|---|
| Average impact speed | 4.0 | 4.0 |
| Standard deviation | 1.3 | 1.25 |
| Standard deviation on any individual tracks | 1.2 | 1.15 |
| Stalls | 3.0% | 2.5% |

Every 1000 cars humped yield these distributions:

Conventional

| Speed | Impacts |
|---|---|
| Over 7.9 mph | 1 |
| 6.6 - 7.9 mph | 21 |
| 5.3 - 6.6 mph | 132 |
| 2.7 - 5.3 mph | 662 |
| 0 - 2.7 mph | 154 |
| Stalls | 30 |
| | 1000 |

Tangent Point

| Speed | Impacts |
|---|---|
| Over 7.75 mph | 1.5 |
| 6.50 - 7.75 mph | 22 |
| 5.25 - 6.50 mph | 132 |
| 3.75 - 5.25 mph | 665 |
| 0 - 3.75 mph | 154.5 |
| Stalls | 25 |

These distributions indicate that we may fall short of never having an impact speed greater than 6.4 mph. However, all other things being equal, a tangent point yard should provide better control of impact speeds than would a conventional yard.

## 5.0 Conclusion

Although all groups at Queensgate are in service, the yard is not fully calibrated and the final results are not available. Tangent point yards are certainly not for everyone, but for Chessie at Queensgate, we continue to believe that a tangent point yard was the best economic alternative.

# THE USE OF THE KEY CONFIGURATION IN GRAVITY YARD DESIGN

J.C. Strong, Southern Pacific Transportation Co.

## DEFINITION

Essentially, the "Key Configuration" in a gravity yard, as envisioned by Southern Pacific, is the use of some of the bowl tracks in the Classification Yard in direct tandem with some of the departure tracks in the Departure Yard to form lengthily departure tracks for long trains.

## BACKGROUND

### Southern Pacific Gravity Yards

The "Key Configuration" is incorporated in Southern Pacific Transportation Company's gravity yard at West Colton, California. This yard, completed in 1973, was the last conventional retarder controlled gravity yard constructed on the SP System, and is the only one having this feature.

Other conventional retarder yard locations (and the years constructed) on the Southern Pacific are: Los Angeles (riders 1923; retarders 1950); Roseville, CA (1953); Houston (1956); Eugene, OR (1958); and Pine Bluff, AR (1959) on SSW Ry.

Smaller, so-called "Poor Man's" (Or Economatic) humpyards, developed in 1960 by Southern Pacific in conjunction with Abex, have been constructed (in years shown) at: Richmond, CA (1964); City of Industry, CA (1967); Beaumont, TX (1973); and Strang, TX (1976).

The locations of all of these gravity yards are shown on the Southern Pacific System map (Figure 1).

### Why West Colton Yard Was Built

The geographical relationships of the gravity yards in Southern California are shown in Figure 2.

Why was the yard at West Colton constructed where it is, considering that it is only 56 miles east of the major yard at Los Angeles and 36 miles east of the smaller City of Industry yard? There are four reasons:

(1) The Palmdale to Colton Cutoff, completed in 1967, rerouted large amounts of traffic around the busy Los Angeles Basin, thereby bypassing the only gravity yards between Roseville and Houston or Pine Bluff.

(2) Los Angeles Yard often had traffic surpassing its capacity, resulting in congestion and delays.

(3) Traffic via the Cutoff required three different crews over three different lengths of runs between Bakersfield, CA and Yuma, AZ, whereas a yard at Colton would allow two nearly equal length runs.

(4) Construction of a gravity yard at Colton would permit the closure or downgrading of three flat switching yards, as well as relieve Los Angeles Yard and City of Industry of much blocking of cars, with resultant savings.

## THE WEST COLTON YARD

The West Colton Yard is laid out in an east-west direction, and parallel to the Los Angeles to El Paso main line. (See Figure 3.) From west to east there are:

(1) The Receiving Yard with eight 10,000 ft. tracks, on 20 fr. centers to facilitate the mechanized inspection and light repairs.

(2) The hump Crest, with the adjacent administration and control building.

(3) The Classification Yard with 48 tracks (average length = 3,630 ft.), plus eight additional bowl tracks for sloughing, car holding, and car repair, adjacent to which there is the One Spot Car Repair Facility.

(4) The Departure Yard with eleven tracks (average length = 5,230 ft.), eight of which, when used in tandem with the eight "key tracks" in the Bowl, provide an average length of 10,450 ft. each.

### The Classification Yard

The classificaiton tracks in the bowl consist of two groups of twenty-four (24) tracks each, with room provided for one more twenty-four track group in the future.

Each group of twenty-four tracks, is broken down into sub-groups of eight (8) tracks, each sub-group being preceeded by a group retarder. Each classification track has a tangent point retarder at its upper end and a weight responsive, hydraulic unload skate retarder at its lower end.

### The "Key" Tracks

The center four tracks of each twenty-four track group are dedicated to the "key configuration" (designated by heavy lines in Figure 4.) Into one of these tracks can be directed those cars which will comprise the rear block of an outbound train. Meanwhile, the head block and any intermediate blocks of the same train are being humped into some of the ten adjacent classification tracks on the outside of each side of the key tracks.

### Building A Train

When all of the blocks for a train have been completed, a trimming locomotive pulls the head and intermediate blocks out of the bowl and couples them on that departure track which is a continuation of the key classification track holding the rear block of the same train.

The two separate cuts of cars then have their air hoses coupled and the brake systems charged with yard air. The brakes are then tested remotely from the trim tower utilizing an FRA approved system designed and patented by Southern Pacific. During the brake pipe reduction part of the test, the cars are checked by a carman for piston travel and inspected for any defects not previously found in the Receiving Yard. This carman utilizes a motorized cart which requires that each of the key tracks, each classification track on each side of the key, and all of the departure tracks be on 17 ft. centers to accommodate paved roadways between them. This width requirement is an important consideration in the "Key Configuration" design.

The car cuts remain on yard air until the road locomotives, and helper locomotive, if any, are coupled in, and the cuts shoved together by the road crew.

### Departing The Yard

At West Colton all long trains leave the Departure Yard in an eastward direction. For trains eastbound on the El Paso Line, or northbound on the Colton Cutoff, which together comprise about two-thirds of the outbound traffic from this Yard, this is a direct move. Trains westbound to City of Industry, the Harbor area, Los Angeles, and the Coast Line to San Francisco must traverse a 15$^{o}$ balloon track to reverse their direction. (Short westbound trains, such as locals, not using the key departure tracks in the bowl, can leave in a westward direction from the west end of the Departure Yard.

You will note (in Figure 4) that by-pass alignments, some grade separated, have been provided around the combination junction and balloon track area to minimize conflicts between trains traveling on the various routes.

### ADVANTAGES & DISADVANTAGES OF THE KEY CONFIGURATION

There are several advantages and disadvantages associated with the key Configuration.

#### Advantages

(1) Provides several long departure tracks.

(2) Eliminates the pulling of rear blocks of trains from the Bowl to the Departure Yard, with resultant trim engine time and conflict savings.

(3) Key tracks can be used as straight classification tracks and double-over tracks when not being used for long trains.

(4) Permit the mechanized inspection of trains prior to departure.

#### Disadvantages

(1) Made-up trains tie up bowl classification tracks if departures are delayed.

(2) Tracks in all of the (24 track) groups are not equally accessible to build departing trains in conjunction with the use of key tracks.

(3) Conflicts sometimes occur when cross-overs leading to the key departure tracks become tied up by the movements required.

(4) Trains coupled for departure on the outermost key tracks effectively block the trimming ladder on that side.

### SUMMARY

The major considerations involved in assessing whether the "Key Configuration" should be built into a gravity yard design are:

(1) Can the Classification Yard and the Departure Yard be constructed in tandem?

(2) Are large numbers of long trains going to be generated regularly enough to warrant the long key departure tracks?

(3) Is there sufficient width in the bowl to permit the wide track centers around the key tracks required for motorized inspection vehicles?

(4) Will the majority of the train traffic depart in the direction of the far end of the Departure Yard?

(5) Is there room for the balloon track required to reverse the direction of trains departing in the minor direction of traffic?

If the answers developed to the above five questions are affirmative, then the inclusion of a "Key Configuration" in the yard being designed is a possibility deserving consideration.

# Southern Pacific Transportation Company

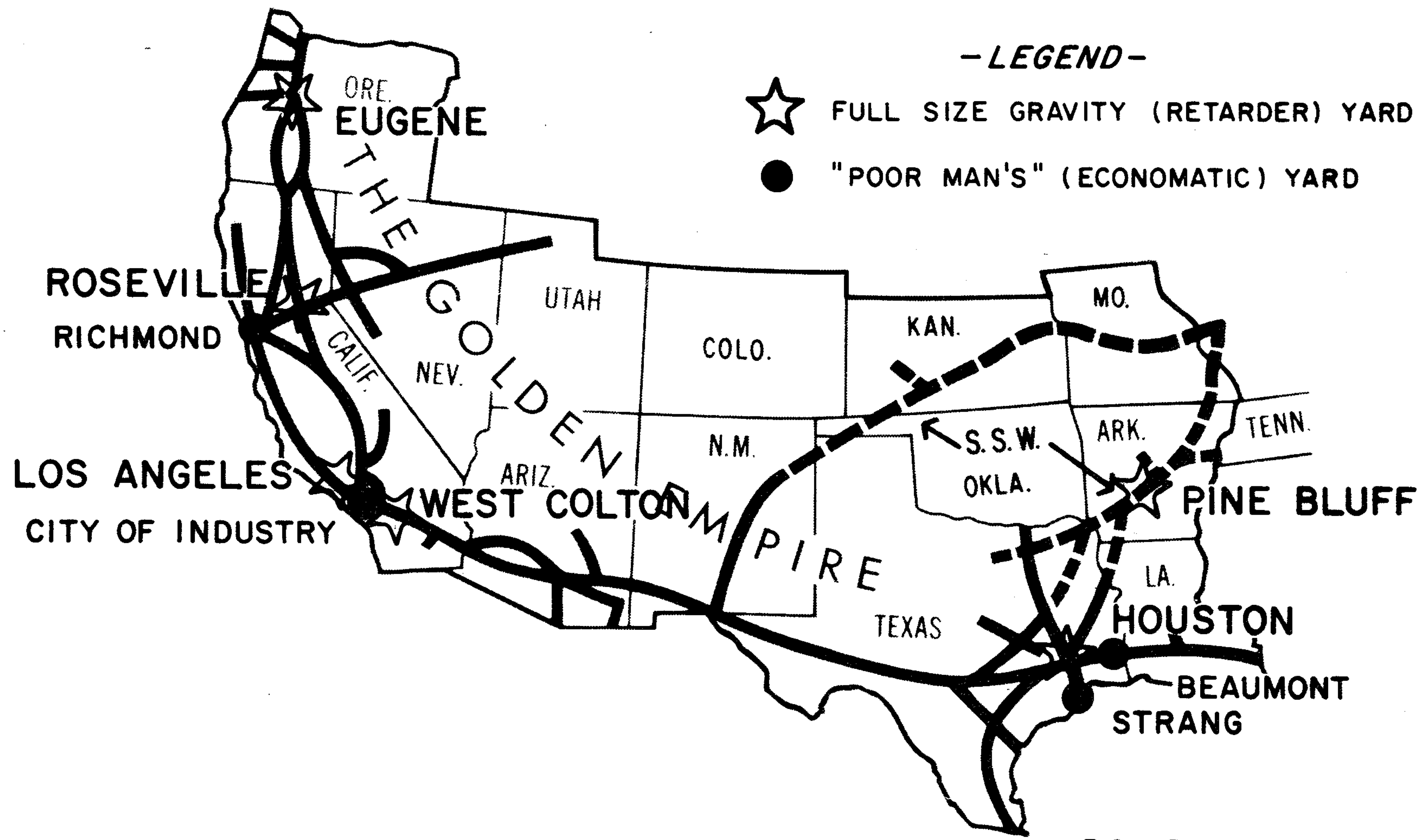
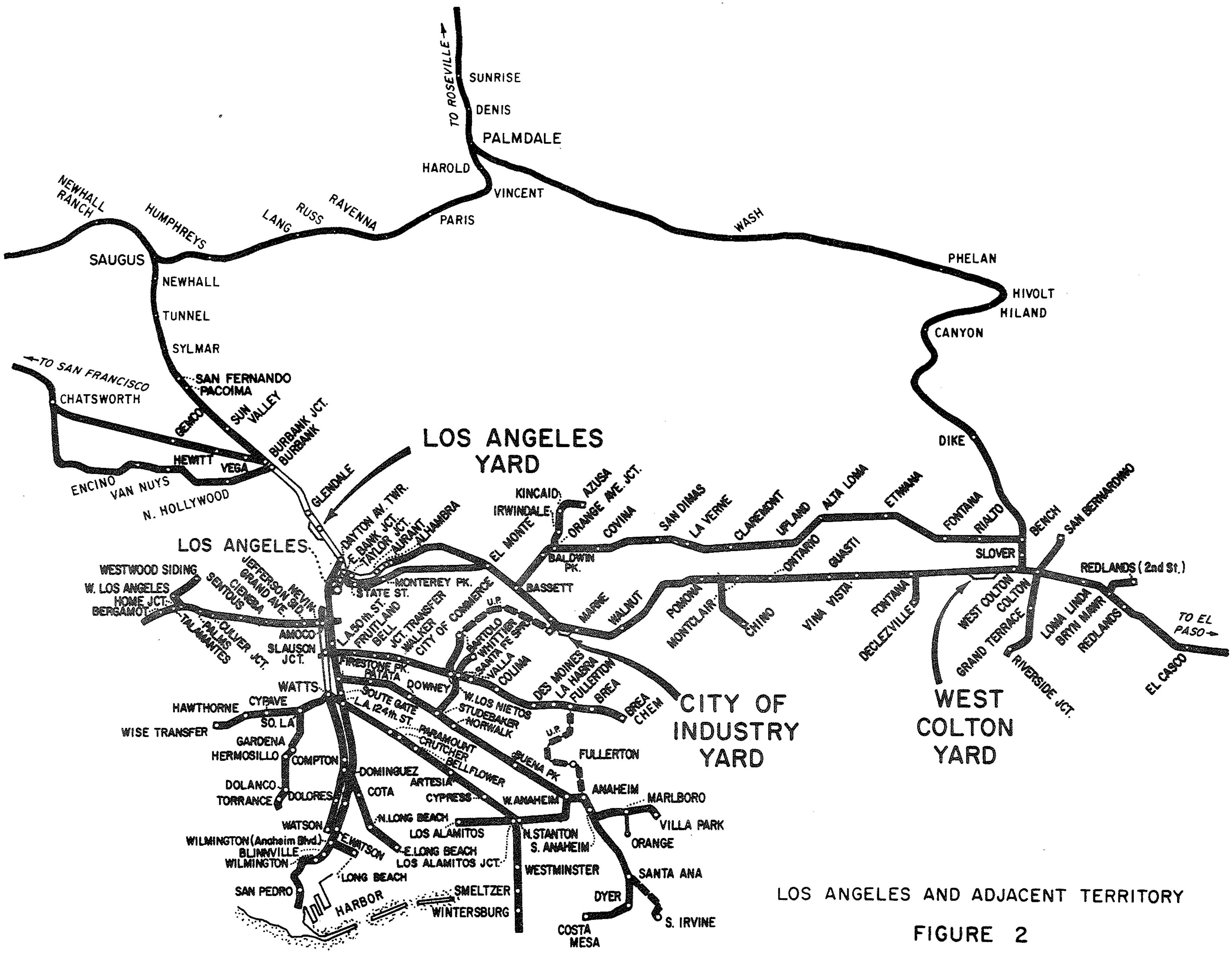
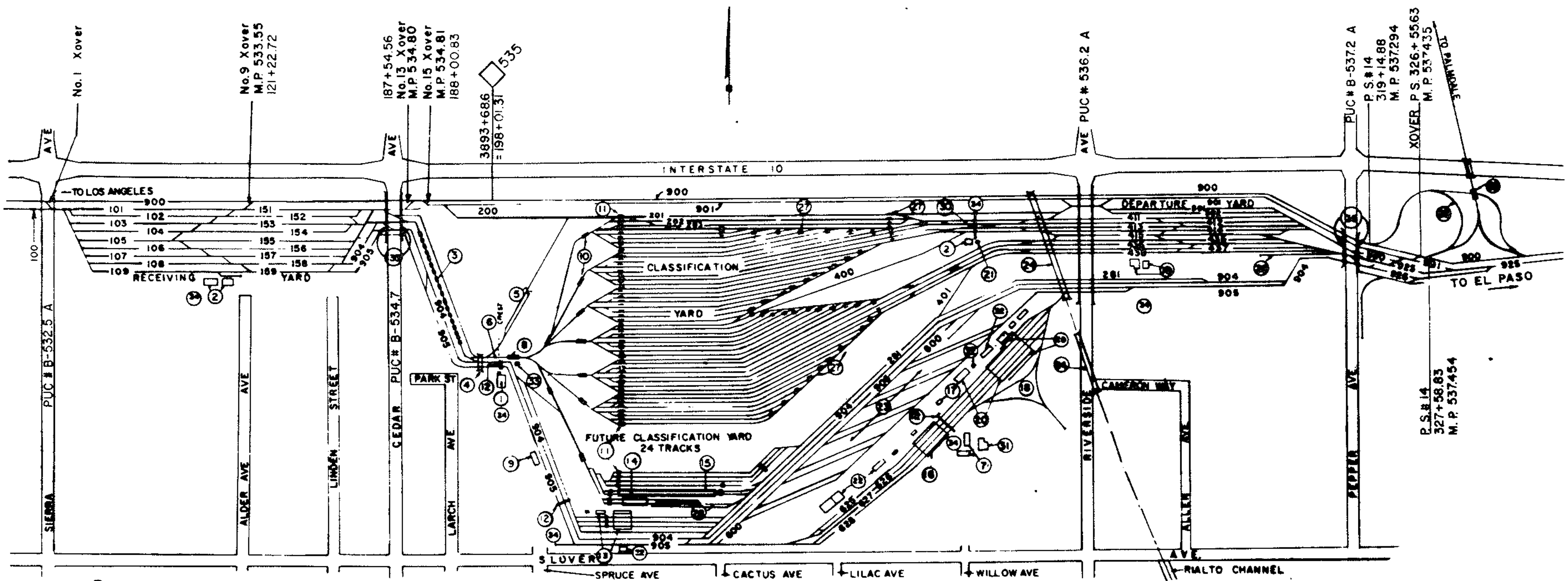



FIGURE I




LOS ANGELES AND ADJACENT TERRITORY

FIGURE 2




1. ADMINISTRATION BUILDING AND CONTROL TOWER
2. CAR INSPECTORS OFFICE AND FACILITIES
3. APPROACH RETARDERS
4. VEHICULAR UNDERPASS
5. NO HUMP SETOUT TRACKS
6. WEIGH IN MOTION SCALE
7. PERSONEL & TRAINING FACILITY
8. MASTER RETARDER
9. COMPRESSOR BUILDING
10. GROUP RETARDERS
11. TANGENT POINT RETARDERS
12. PEDESTRIAN UNDERPASSES
13. ONE SPOT CAR REPAIR FACILITIES
14. CABOOSE SERVICING FACILITIES
15. CAR UPGRADING FACILITIES
16. LOCOMOTIVE WASHER
17. ENGINEMAN'S REGISTER BUILDING
18. WYE TRACK
19. M OF W FACILITIES
20. DIESEL SERVICING FACILITIES
21. BOWL YARDMASTER'S TOWER
22. INDUSTRIAL WASTE FACILITIES
23. ENGINE READY TRACKS
24. FLOOD CONTROL CHANNEL
25. RAILROAD UNDERPASS
26. ENGINE AND CABOOSE SET-OUT TRACK
27. POWER OPERATED SKATE RETARDERS
28. P F E TRACK
29. BALLOON TRACK
30. PEDESTRIAN OVERPASS
31. AUTO & WORK EQUIPMENT
32. MECH DEPT OBSERVATION TOWER
33. HUMP CONDUCTOR'S OFFICE
34. EMPLOYEE'S PARKING
35. TOTE BOARDS

SOUTHERN PACIFIC TRANSPORTATION COMPANY
PACIFIC LINES

WEST COLTON CLASSIFICATION YARD

FIGURE 3

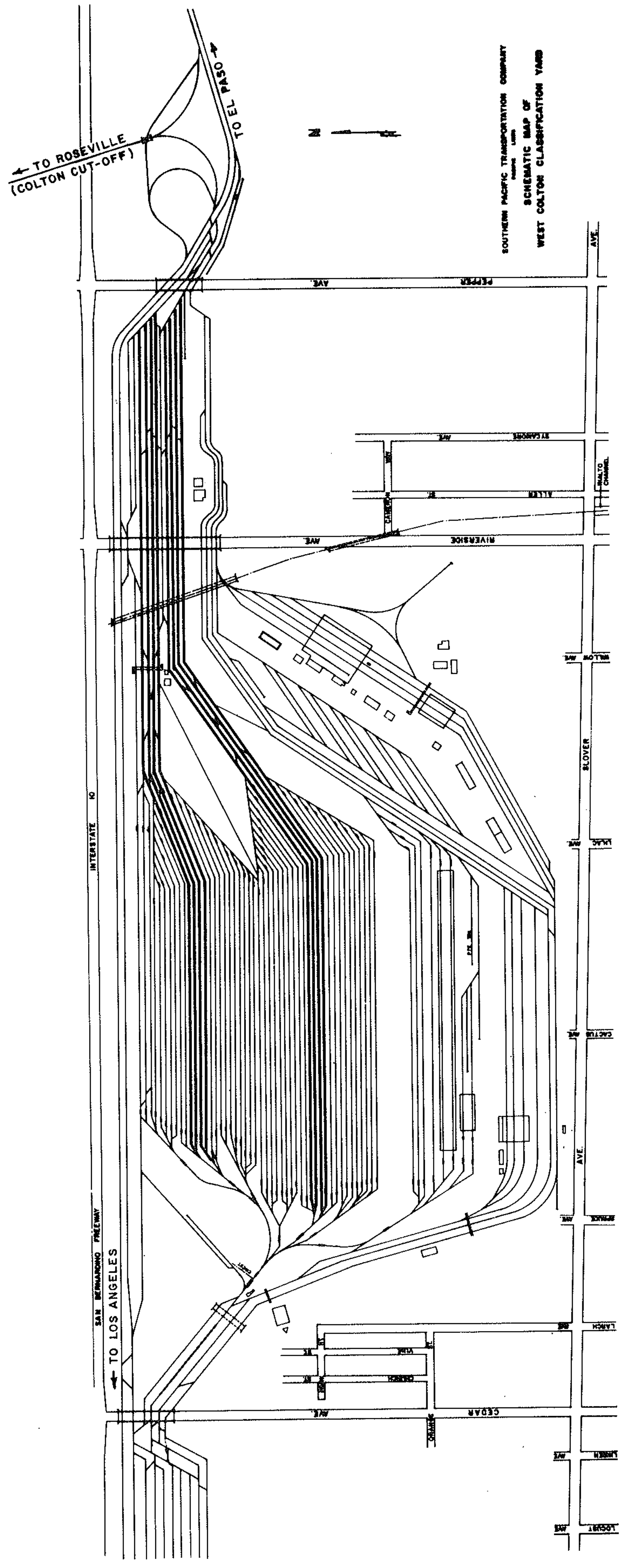

← TO ROSEVILLE
(COLTON CUT-OFF)
TO EL PASO →
← TO LOS ANGELES
SAN BERNARDINO FREEWAY
INTERSTATE 10
SOUTHERN PACIFIC TRANSPORTATION COMPANY
SCHEMATIC MAP OF
WEST COLTON CLASSIFICATION YARD
PEPPER AVE.
RIVERSIDE AVE.
SLOVER AVE.
CEDAR AVE.

FIGURE 4

PROJECT STATUS REPORT

Dowty Continous Hump Yard Control System
at
Santa Fe's - Flynn Yard
Oklahoma City, Oklahoma

Dale Harrison
Atchison, Topeka and Santa Fe Railroad

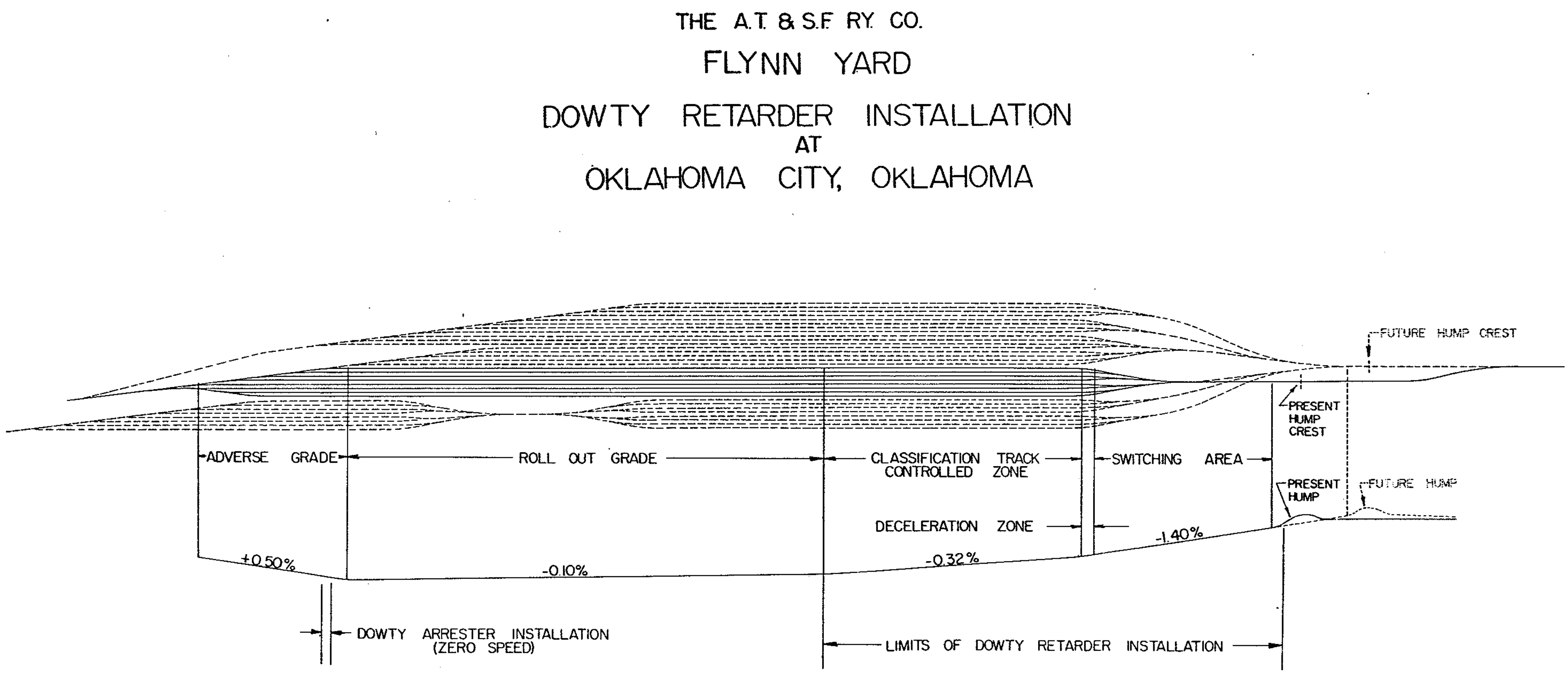



FIGURE 1

# SOUTHERN RAILWAY SYSTEM'S PHILOSOPHY OF YARD LOCATION AND PURPOSE

Marvin Wilson
Dean Crawley

Southern Railway System

As a matter of introduction my name is Marvin Wilson, Chief Engineer Design and Construction, for Southern Railway System, and this is Dean Crawley, our Senior Project Manager, who has been engaged in design and construction of five (5) of our so called hump yards, the latest being at Spencer Yard in Linwood, N.C. where he had complete charge.

On the screen you can see a map showing all of the lines of Southern Railway System which consists of 10,200 route miles located in thirteen (13) states all in the southeastern United States. On this map we have shown the location of seven (7) existing hump yards and one proposed.

I will now give you a brief description and history of each of these yards, to give you some idea of why they were located at each place, date construction was finished, size of yard represented by a diagmeterical sketch, cost of yard at time of construction, and aerial photographs where available.

These are presented in the same sequence as the yards were built, the first being John Sevier Yard built in 1951, thirty years ago, at Knoxville, Tennessee. It is located at the old existing yard alongside Holston River.

## TABLES OF TRACK LAYOUT

### SEVIER YARD LOCATED AT KNOXVILLE, TENNESSEE

In Service in 1951

Cost: $4,732,683

Size:

| | | |
|---|---|---|
| Classification Yard | 46 Tracks | 1687 Cars |
| Forwarding Yard | 10 Tracks | 1193 Cars |
| Receiving Yard | 12 Tracks | 1257 Cars |
| Total Capacity | | 4137 Cars |
| Total Mileage | | 78.9 Miles |

Location of All Connecting Lines

1) Asheville - Bristol
2) Maryville
3) Cumberland Gap
4) Jellico - Harriman (Cincinnati-St. Louis)
5) Chattanooga

Photographs of Yard

### NORRIS YARD LOCATED AT BIRMINGHAM, ALABAMA

In Service in 1952

Cost: $12,298,907

Size:

| | | |
|---|---|---|
| Classification Yard | 56 Tracks | 2284 Cars |
| Forwarding Yards | | |
| East Departure | 5 Tracks | 1423 Cars |
| West Departure | 7 Tracks | |
| Receiving Yard | 12 Tracks | 1234 Cars |
| Total Capacity: | | 5302 |
| Total Mileage: | | 92.6 Miles |

Location of All Connecting Lines

1) Chattanooga
2) Atlanta
3) New Orleans
4) Columbus, GA
5) Parrish - Sheffield - Columbus, Miss.

Photographs

### deBUTTS YARD AT CHATTANOOGA, TENNESSEE

In Service 1955

Cost: $10,626,552

Size:

| | | |
|---|---|---|
| Classification Yard | 60 Tracks | 2426 Cars |
| Forwarding Yard | 10 Tracks | 1438 Cars |
| Receiving Yard | 12 Tracks | 1655 Cars |
| Total Capacity: | | 5519 Cars |
| Total Mileage: | | 108.8 Miles |

Location of Connecting Lines

1) Birmingham
2) Knoxville
3) Atlanta

4) Sheffield - Memphis
5) Danville - Cincinnati

Aerial Photographs

INMAN YARD AT ATLANTA, GEORGIA

In Service 1957
Cost: $20,077,358
Size:

| | | |
|---|---|---|
| Classification Yard | 65 Tracks | 2418 Cars |
| Forwarding Yard | 16 Tracks | 2258 Cars |
| Receiving Yard | 16 Tracks | 2071 Cars |
| Total Capacity: | | 6747 Cars |
| Total Mileage: | | 112.5 Miles |

Direction of Connecting Tracks
1) Chattanooga
2) Greenville - Spencer
3) Macon, Georgia
4) Birmingham

Aerial Potographs

BROSNAN YARD AT MACON, GEORGIA

In Service 1965
Cost: $15,000,000
Size:

| | | |
|---|---|---|
| Classification Yard | 50 Tracks | 2360 Cars |
| Forwarding Yard | 8 Tracks | 1613 Cars |
| Receiving Yard | 8 Tracks | 1696 Cars |
| Total Capacity: | | 5669 Cars |
| Total Mileage: | | 88.9 Miles |

Connecting Tracks
1) Atlanta
2) Savannah
3) Columbus - Birmingham
4) Jesup - Brunswick
5) Valdosta - Jacksonville - Palatka

Aerial Photographs

SHEFFIELD YARD AT MUSCLE SHOALS, ALABAMA

In Service 1973
Cost: $15,280,786
Size:

| | | |
|---|---|---|
| Classification Yard | 32 Tracks | 1160 Cars |
| Forwarding Yard | 6 Tracks | 874 Cars |
| Receiving | 6 Tracks | 902 Cars |
| Total Capacity: | | 2936 Cars |
| Total Mileage: | | 49.87 Miles |

Connecting Lines
1) Birmingham
2) Chattanooga
3) Memphis

Aerial Photographs

SPENCER YARD AT LINWOOD, NORTH CAROLINA

In Service June 1979
Cost: $47,731,025
Size:

| | | |
|---|---|---|
| Classification Yard | 46 Tracks | 2156 Cars |
| Forwarding Yard | 8 Tracks | 1093 Cars |
| Receiving Yard | 8 Tracks | 1181 Cars |
| Total Cars: | | 4430 Cars |
| Total Mileage: | | 65.6 Miles |

Connecting Lines
1) Potomac Yard (Washington)
2) Atlanta
3) Asheville
4) Eastern North Carolina
5) South Carolina

Aerial Photographs

To prepare for improvements to yards a committee to study present operations and formulate a plan to attain the desired results should be appointed. This committee should have proper presentation from all departments involved. This would include:

TRANSPORTATION DEPARTMENT:
Line Operating Officers
Stations & Terminals
Planning Group

ENGINEERING DEPARTMENT:
Track Design & Construction
Building Design & Construction
Communications & Signals
Mechanical Services

MANAGEMENT INFORMATION SERVICES:
Industrial Engineers
Computer Services
Data Input

FINANCE DEPARTMENT:
Capital Expenditures
Budget
Accounting

LEGAL DEPARTMENT

REAL ESTATE DEPARTMENT

This would be a standing committee meeting on a regular schedule to discuss progress being made by each department and resolve any problems that would prevent accomplishing the desired result.

It is imperative that this committee be chaired by a person well versed in the purpose of the committee so that proper coordination can be brought about between all parties.

ENGINEERING CONSIDERATIONS FOR NEW YARD LOCATIONS

1- Land required- length, acreage, cost of purchase.

2- Length of tangent track- about 2 miles required.

3- Elevation of top of rail at each end of proposed yard.

4- Physical features in area such as public roads, power lines, pipe lines, streams, houses, zoning of area, airports, type of soils, general lay of land, and environmental requirements.

5- Double track needed at each end of proposed yard for several miles in each direction.

6- Building requirements of city, county, and state agencies.

7- Comparison of costs on other sites being considered.

8- Location of connecting tracks.

GENERAL CONSIDERATIONS FOR DETERMINING NEED & LOCATION OF A NEW YARD

1- Ability of present facility to adequately handle current business and projected future business.

2- Age and physical condition of existing facilities.

3- Possibility for expansion at present location.

4- Cost of acquiring additional property adjacent to present location compared to other sites.

5- Volume of traffic to be handled.

6- Relief new facility will provide to immediately adjacent yards and what far-reaching effects it will have on other yards.

7- Improved service to customers locally and other areas served by yard.

8- Industrial development potential of area that new yard will serve.

9- Savings to be derived from new facility--will it pay itself and give a return on the capital investment.

10- Effects on personnel if yard is moved to another location.

Southern has built seven (7) hump yards in the last 30 years and the costs have risen dramatically from $4.7 million to $47.7 million which is about 10 fold increase. Naturally most of this can be attributable to inflation but the quality of the construction and materials have improved. We are doing a better job with road bed soil problems, improving drainage by adding more drainage structures, using more sub ballast, all new crossties, heavier tie plates, and welded rail. There was a time when yards were made out of light weight relay jointed rail, but this has changed with yard construction equal to main line in may instances. This has been brought about with the 100-ton cars and desire for uninterrupted freight schedules and need for less expensive maintenance.

Hump yards on Southern will average humping about 125 cars per hour, 3200 cars per day, or about one train per hour according to how you want to look at the statistics. Cars are blocked according to destination to be delivered reducing further delays at other small terminals. This results in very efficient car handling.

When several alternatives are available to eliminate difficulties at one or more terminals, only through construction of a major hump yard can wide spread benefits accrue. You must be able to justify a rate of return at least equal to the current value of money invested. The facility must be able to pay its way.

# YARD TECHNOLOGY RESEARCH PART II

# ASSESSMENT OF CAR SPEED CONTROL SYSTEMS

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J. S. Eckerle, and P. J. Wong
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## SECTION 1--INTRODUCTION

The operation of freight trains necessitates remaking of trains from time to time. Known as classification, such an operation is carried out in a classification yard. Because a railroad car is powerless once it is detached from the locomotive, external power and a speed control system are needed to perform the classification operation. In a flat classification yard, the locomotive supplies the power by an acceleration/deceleration maneuver, thus "kicking" each car into its destination track. The speed control is provided by the kicking speed of the locomotive. In a hump yard, the power comes from both the hump locomotive and the earth's gravitational field. The use of gravitational energy greatly improves the efficiency of the classification operation.

In the United States, car speed control in a hump yard has traditionally been provided by clasp-type retarders. Although the fundamental hardware of the clasp retarders has remained the same for decades, the control of these retarders has developed from manual operation to very sophisticated computer operation. The computerized operation has improved the efficiency and safety of this conventional speed control scheme; it has also increased the capital cost of the system. In the meantime, radical new speed control devices and systems have been developed in many other countries. It is the objective of this Federal Railroad Administration (FRA) project to identify, from all recognized classification yard speed control systems, the most promising ones that could be demonstrated and integrated into the U.S. yards.

A study of the information compiled from a literature search shows clearly that, in order to make a sensible comparison of the various speed control systems, a distinction must be made between a speed control device and a speed control system. A speed control device is defined as a piece of hardware capable of altering the speed of a free rolling car. The outward appearance of this device can be very simple (e.g., a Dowty retarder), or it can be quite complex (e.g., a linear induction motor car mover). On the other hand, a speed control system encompasses everything that helps control the speed of cars from crest to the end of classification tracks in a hump yard; thus, retarders, wheel detectors, track circuits, computer and its software package are all part of a speed control system. This distinction between a device and a system led to a three-tier approach to the evaluation of the speed control systems: (1) device evaluation, (2) qualitative system assessment, and (3) quantitative system analysis.

## SECTION 2--DEVICE EVALUATION

Our device evaluation included thirteen speed control devices:

1. Full control clasp retarder
2. Weight responsive hydraulic retarder
3. Inert retarder
4. Siemens (Germany) electrodynamic retarder
5. Thyssen (Germany) rubber retarder
6. Dowty (Great Britain) retarder
7. ASEA (Sweden) spiral retarder
8. Faiveley (France) hydraulic retarder
9. Hydrabrake retarder
10. Cable-powered trolley
11. Hauhinco oscillatory cable device
12. JNR (Japan) linear induction motor car mover
13. S.N.C.F. (France) self-propelled car mover.

The first three clasp retarders listed are sufficiently well known to need no further elaboration. The electrodynamic retarder derives its retardation from both friction and eddy current dissipation. It has fewer moving parts than the clasp retarders with the exception of the inert type. The rubber retarder absorbs energy via deformation of a rubber rail. Its operation is quiet but is expected to be temperature sensitive. Durability of the rubber has not been determined. The Dowty retarder is one of four that rely on the forced flow of hydraulic fluid to achieve retardation. After three generations of development, the current Dowty retarder is a highly compact and reliable device. The operating principle of the ASEA hydraulic retarder is identical to that of the Dowty. It is a bigger unit that can absorb seven times the energy of a Dowty unit. Its current design, however, does not meet the A.R.E.A. criterion that no obstacle shall protrude more than 2-1/2 inches above the railhead. The most sophisticated of all hydraulic retarders, the Faiveley retarder is still in its development stage, and its cost and reliability are unknown. The Hydrabrake retarder is not suitable for yard usage, since it does not incorporate internal logic as do the other hydraulic retarders. The cable-powered trolley is a low-profile carriage to move cars on the classification tracks. Like all cable systems, it requires external power and sophisticated sensing and control systems. The Hauhinco pusher trolley has its pusher arms mounted on an oscillating endless cable, allowing the system to move more than one car at a time within its span. The linear induction motor (LIM) car mover is a highly complex, self-contained carriage consisting of five units of different functions. The cost of this system is expected to be higher than that of a tangent point retarder system. The S.N.C.F. self-propelled is a forerunner of the LIM car mover. Although its complexity hardly matches that of the LIM car mover, the French railroad has decided to halt further development of it, presumably because of its complexity and cost.

Of the thirteen devices, five are deemed to be potentially useful in a U.S. yard, at least in their current states of development. The devices are the three types of clasp retarders, the Dowty retarder, and the Siemens electrodynamic retarder.

## SECTION 3--QUALITATIVE ASSESSMENT OF SYSTEMS

To accomplish its speed control function, a hump yard usually uses at least one type of speed control device. This study reveals that the speed control system in a modern hump yard generally belongs to one of four generic types:

1. System 1: The conventional clasp retarder system using target shooting logic.*
2. System 2: The quasi-continuous control system.
3. System 3: The hybrid system of clasp retarders and quasi-continuous control devices.
4. System 4: The hybrid system of clasp retarders and car movers.

System 1 is the system used in the United States, but it refers to the most modern yards in which tangent point retarders are used in addition to the master and group retarders. Representative yards in this category are West Colton of Southern Pacific and Barstow of Santa Fe. System 2 refers to either a pure Dowty yard or a pure ASEA retarder yard. In such a yard, hundreds or even thousands of these hydraulic retarders are distributed along the tracks so that they exert a quasi-continuous control over a free-rolling car. Representative yards are Scunthorpe yard of Great Britain and Helsingborg yard of Sweden. System 3 uses master and group retarders to control headway in the switch area and quasi-continuous control devices on the classification tracks. An example of this system is found in the Malmö yard of Sweden. System 4 employs master and group retarders to control headway in the switch area and positive car moving devices on the classification tracks to ensure proper coupling. The Shiohama yard in Japan and Germen Federal Railway's Maschen yard are typical examples.

System 1, which will also be called the advanced clasp retarder system, employs a target shooting scheme, because the control points along a track are few and far apart. In its most sophisticated form, a car's rolling resistance is measured prior to its entry into each of the three retarders. This rollability value is then used to determine the amount of energy to be removed by the retarder so that this car will reach a point along the track at either a target time or a target speed. If the car's rollability changes after the retarder, then no correction can be made until the car reaches the next retarder, if there is one. Changes in a car's rollability have been known to occur and can be caused by anything from uneven track conditions to shifting winds, a skewed truck, or internal variations in the axle bearings. Another factor that could degrade the performance of a conventional system is contaminated wheels, which can render the clasp retarders ineffective. When this occurs, the car rolls uncontrolled through the yard and can cause serious accidents. Less serious but no less a problem with the clasp retarders is the wheel squeal. Because of its highly sophisticated signaling and control, this system could be susceptible to electromagnetic interferences (EMI). An advantage is that the conventional system has by far the lowest capital cost. It may still be the most cost-effective system after accounting for the potentially high maintenance and operating costs. (Unfortunately, reliable cost estimates in these two categories are not available.) The abundance of operating experience that U.S. railroad companies possess in regard to this system is invaluable.

System 2, the quasi-continuous system, is a radically different system from the conventional system. Because of its closely spaced control points, the quasi-continuous system is not affected by changes in a car's rolling resistance. Since the quasi-continuous system does not rely on friction, it is not vulnerable to contaminated wheels. EMI is not expected to be a problem. The system has two other advantages. An obvious one is that the potentially more uniform coupling speed that results from an extended control region* along a classification track should reduce car and lading damage. A more subtle advantage, which applies more to the Dowty retarders than to either the ASEA or the Faiveley retarders, is that the system's performance is not noticeably degraded when a few retarders among the hundreds along a track are out of service. This aspect of the system coupled with the ease of replacement of the Dowty capsules in the field, results in nearly zero downtime for the system. This, of course, means a savings in yard operation. The disadvantages of the quasi-continuous system are high capital cost, little operating experience in the United States, and the retarders' susceptibility to the noise problem.

System 3, the hybrid system with clasp retarders in the switch area and a quasi-continuous system on the classification tracks, has the dual advantage of an improved coupling performance and a reduced risk of runaway cars. It requires a high capital investment and has compounded the noise problem. This system is more adaptable to a renovated conventional yard than a new yard. It is often installed as an adjunct to an old hump yard where the grade in the bowl is steep because of the higher rolling resistance of the old generation cars.

System 4 is a hybrid system using clasp retarders in the switch area in conjunction with a positive car moving device on each of the classification tracks. This system almost ensures proper couplings at all times. The car moving device may be an S.N.C.F. (French National Railroad) car mover, a JNR (Japanese National Railway) linear induction motor car mover, or any of the cable devices. The extreme complexity of the first two car movers makes them unlikely to be cost effective. Despite the lower cost of the cable devices compared with the other two, System 4 still has a high capital cost. Two of the ultramodern yards in Europe--the Limmattal yard near Zurich and the Maschen yard near Hamburg--have comparable cable devices on their classification tracks. The cost of these two yards, in 1973 dollars, is approximately $3 million and $2 million per classification track, respectively. These figures can be compared with approximately $800,000 per track for either the West Colton yard or the Barstow yard--two state-of-the-art yards using conventional speed control systems. (The cable hauling system in foreign yards contributes greatly to the cost difference.) The cable device is also known to require high maintenance. The clasp retarders in the switch area still inherit most of the disadvantages associated with the conventional system. Finally, most cable systems can only receive cars within a narrow speed range, and, as a result, a tangent point retarder or its equivalent is still needed on each classification track.

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*The term "target shooting" refers to the objective of getting a free-rolling car to a specific point on the track at either a target time or a target velocity.

*A quasi-continuous system usually has the retarders installed on up to one-third of the classification tracks.

The advantages and disadvantages of these four speed control systems are summarized in Table 1. The qualitative assessment demonstrates that the conventional clasp retarder system should remain a strong contender among the competing systems. The quasi-continuous control system, particularly the Dowty system, is the most promising foreign system. Its success in the United States will depend on whether its potential operational advantages can be demonstrated in an actual yard. Attention will be focused on the Flynn yard, now under construction near Oklahoma City. The hybrid system incorporating Dowty retarders on the classification tracks will be cost-effective only under certain circumstances (e.g., in the renovation of an old yard with steep grades). It is anticipated that the hybrid system incorporating car movers on the classification tracks will not be adopted in the United States.

## SECTION 4-- QUANTITATIVE ANALYSIS OF SYSTEMS

### 4.1 METHOD OF APPROACH

The ultimate comparison of the various speed control systems must be made on an economic basis. Part of the economics should be the dollar benefits associated with improved performance. While the acquisition of capital, operating, and maintenance cost data of the various systems is no easy task, meaningful performance data are even more difficult to obtain. The difficulties of making quantitative performance comparisons of the various systems are illustrated in the following paragraphs.

A possible source for performance data is actual yard experience. The performance of a speed control system in a particular yard depends on many factors, including the size of the yard, the design goal (which reflects the operating philosophy of the railroad company), and the vintage of the system. A direct comparison of the performance data of, for example, an advanced clasp retarder yard in the United States with a Dowty yard in Great Britain is therefore inappropriate. Computer simulation affords the opportunity to compare speed control systems under identical conditions, but none of the existing computer models would do the job. The computer models developed by the vendors are simply design tools. The feasibility of a multitrack model using the Monte Carlo method was demonstrated by deVries and Kerr.* Such a model could be modified to calculate the performances of several systems, but the cost of running the program would be prohibitive.

After many months of deliberation, a unique computer program was developed that would incorporate not only the dynamics of the rolling cars and the principal features of the retarder control logic, but also the stochastic nature of the classification process. This program, known as SPEEDCON, is documented in a Federal Railroad Administration Final Report FRA/ORD-80/90, December 1980.

Briefly, the SPEEDCON program takes into account four random variables:

- Crest rolling resistance.
- Random variations of rolling resistance along a track.
- Track fullness on the class track.
- Probability that a car will be routed to a particular track.

*G. H. deVries and C. N. Kerr, "Improvement of Coupling-Up Performance in Automatic Marshalling Yards: A Simulation," ASME Paper No. 77-RT-8, January 1978.

TABLE 1--COMPARATIVE MATRIX OF THE FOUR IDENTIFIED SPEED CONTROL SYSTEM

| Speed Control System | Advantages | Disadvantages |
|---|---|---|
| System 1 (clasp retarder) | Low capital cost<br>Abundant operating experience | Susceptible to change in rollability<br>Vulnerable to contaminated wheels<br>Squeal noise<br>Susceptible to EMI |
| System 2 (quasi-continuous) | Less affected by change in rollability<br>Immune to contaminated wheels<br>Potential savings in reduced lading damage<br>Potential savings due to zero system downtime | High capital cost<br>Little operating experience in the United States<br>Not immune to noise problem |
| System 3 (clasp plus quasi-continuous) | Improved coupling performance<br>Reduced risk of runaway cars | High capital cost<br>Compounded noise problem |
| System 4 (clasp plus car-mover) | Superior coupling performance | Very high capital cost<br>High maintenance<br>Vulnerable to contaminated wheels<br>Requires tangent point retarders or equivalent |

The program determines the probability of stall and the distribution of coupling speed by analyses of single-car motions and calculates the percentage of misswitched cars by making pairwise comparisons.

With the development of the SPEEDCON program, quantitative comparisons of different speed control systems becomes at least feasible. First, for each speed control system that is qualified for quantitative analysis, a baseline yard is designed according to a set of common specifications. The specifications include the base rolling resistance distribution of cars; the number of classification tracks; the hump speed; the ranges of wheel sizes, car lengths, and car weights; and the curve and switch resistances. Relevant parameters of each baseline yard, such as the track geometry and the retarder locations, are then input to the SPEEDCON program, which in turn calculates the performance parameters of the corresponding speed control system. The calculated performance can then be used in the economic analysis of the system.

The quantitative evaluation procedures described are applied to three specific yards, one designed to use the advanced clasp retarder system, another to use the Dowty system, and a third to use a combination of the two. The selection of the three systems is based on the results of the qualitative analysis. The size of the baseline yard (32 class tracks), is an arbitrary choice. Each speed control system may have its optimum yard size, hump speed, and so on, so to determine the optimal values of these parameters the quantitative evaluation procedures must be applied repeatedly. Unfortunately, such an optimization investigation was beyond the allocated funds of this project. Nevertheless, the sample calculations we performed demonstrated the methodology that was developed and the kind of results that can be expected. The results, however, are valid only if the many assumptions made in the analysis are taken into account. Most of these assumptions were necessary because of the lack of crucial data, but they should in no way invalidate the methodology.

## 4.2 DEVELOPMENT OF SYSTEM DESIGNS

After careful deliberation and consultation with knowledgeable people in the railroad industry, a yard design specification was prepared. This document was sent to a number of foreign and domestic vendors, first for comments, followed by a request from SRI to design hypothetical yards in accordance with the design specification. The rationale behind this request was that it would be best for a vendor specialized in a particular system to design the corresponding yard. Unfortunately, none of the domestic vendors agreed to participate. Left with no option, the SRI team undertook the task of designing a yard (from crest to end of bowl) using conventional clasp retarders.

A number of foreign vendors did respond to our request. Because our qualitative assessment identified Dowty system as the most promising new system, the yard design submitted by Dowty was selected for quantitative evaluation.

Despite our original intention to have both the conventional yard and the Dowty yard designed under a set of common specifications,* Dowty did not conform to our specifications in designing their yard in several respects. The major instance of nonconformity involved the specified assumption of the base rolling resistance of a car during its entire roll. SRI designed the clasp retarder yard so that the design hard roller starts out at 18 pounds/ton at the crest and decreases to 12 pounds/ton after passing the group retarder. Dowty designed a yard where a design-hard roller starts out at 12 pounds/ton, decreases to 5.4 pounds/ton at the start of the deceleration zone on the class track, and decreases a gain to 4.4 pounds/ton at the end of the 0.3 percent grade on the class track. (The choice of the design-hard and design-easy rollers was left to the vendor.) When the Dowty yard was simulated using a base rolling resistance that changed as specified, the apparent performance suffered.

## 4.3 ROLLING RESISTANCE ASSUMPTIONS FOR THE QUANTITATIVE RESULTS

The performance results (to be discussed in 4.4) were obtained from the SPEEDCON computer model with assumptions concerning the car rolling resistance population. The primary assumptions are:

- The probability distribution of car rolling resistance leaving the crest is assumed to be that of data taken at Elkhart in December 1957.
- After the group retarder (or equivalent location in the hypothetical Dowty yard), the rolling resistances become easier; the Elkhart histogram is used, but all rolling resistance values are reduced by one-third. This is our attempt to simulate the commonly accepted premise that warming of the bearings after the car has been in motion for awhile reduces its rolling resistance.
- Denoting the rolling resistance histograms described above as the conservative rolling resistance assumptions, SPEEDCON was also run with a set of optimistic rolling resistance assumptions. Under the optimistic assumptions, all cars between the crest and group retarder (or equivalent location) have rolling resistance values equal to two-thirds of the comparable values in the Elkhart histogram; and beyond the group retarder (or equivalent location), they have rolling resistance values equal to four-ninths of the comparable values in the Elkhart histogram.
- The SPEEDCON program provides for a rolling car to suddenly change its rolling resistance from its specified value at the exits of master and group retarders; this change is unknown to the conventional speed control system. The model for this behavior is as follows: one-third probability that a car will increase its specified rolling resistance by +19%, one-third probability that a car will decrease its specified rolling resistance by -19%, one-third probability that a car rolling resistance does not change from its specified value. This provision was included to measure the "robustness" of the advanced clasp retarder system, i.e., the system's tolerance to either measurement errors in a car's rolling resistance or changes in the rolling resistance after a measurement is taken.

## 4.4 CONDENSED RESULTS OF QUANTITATIVE ANALYSIS

The results of SRI's quantitative analysis, which stipulates among other parameters a 32-track yard with a hump speed of 200 feet per minute, are as follows:

- The capital cost of the advanced clasp retarder system, at $7.8 million, is the lowest. A comparable Dowty system or a hybrid system

*The hybrid yard, being a combination of the two, does not require a separate design.

incorporating Dowty retarders on the classification tracks costs at least a third more.

- With some uncertainty about the maintenance cost of the advanced clasp retarder system, a quantitative comparison among the three systems becomes difficult. Nevertheless, the available information indicates that all three systems will have the comparable maintenance and operating costs. The annual figure is approximately 3 percent of the capital cost of the advanced clasp retarder system.
- Two sets of performance calculations were made using SPEEDCON. One set assumes a conservative rolling resistance distribution (more hard rollers); the other set assumes a more optimistic rolling resistance distribution.
- Using the conservative rolling resistance distribution, the advanced clasp retarder system shows 0 percent misswitch, 0.03 percent stall in the switch area; 16 percent stall on classification tracks, and 7 percent overspeed (>6 mph) coupling. Comparable figures for the Dowty system are 0.15 percent, 3 percent, 41 percent, and 3 percent, respectively. Comparable figures for the hybrid system are 0 percent, 0.03 percent, 41 percent, and 3 percent. (The primary cause of the relatively poor performance of the Dowty yard was discussed in 4.2.)
- Using the optimistic rolling resistance distribution, the advanced clasp retarder system shows 0 percent misswitch, 9 percent stall in the switch area, 8 percent stall on the classification tracks, and 4 percent overspeed coupling. Comparable figures for the Dowty system are 0.02 percent, 0.46 percent, 23 percent, and 10 percent. Comparable figures for the hybrid system are 0 percent, 0 percent, 23 percent, and 10 percent.

More comprehensive results of the quantitative analysis can be found in the referenced FRA report.

## SECTION 5--CONCLUSIONS AND RECOMMENDATIONS

Of the four generic state-of-the-art speed control systems discussed in this paper, three are potentially viable:

- The conventional clasp retarder system using an advanced retarder control algorithm.
- The quasi-continuous control system (Dowty system).
- The hybrid system of clasp retarders and Dowty retarders.

The cost analyses of three baseline yards incorporating these three systems show that while the maintenance and operating costs of all three systems are comparable, the capital cost of either the Dowty system or the hybrid system is at least a third higher than that of the clasp retarder system. The quantitative performance evaluation of these three systems indicates that the advanced clasp retarder system has the best overall performance. The relatively poor performance of the Dowty system is at least partially the result of the use of unusually low design values for car rolling resistance.

While the quantitative analyses of three specific speed control systems yield some important information on the sensitivity of a system's performance to the assumed rolling resistance distribution, careful use should be made of the limited quantitative results in the future selection of speed control systems. One reason for this caution was mentioned earlier: The three baseline yards were not designed on exactly the same basis despite SRI's efforts to ensure uniformity. Another reason is that the relative merit of a speed control system depends on the size of the yard and the required throughput. For a certain size and throughput, the performance of one system may be far superior to the others. For this reason, when a new yard or a renovation project is contemplated, the three recommended systems must each be considered carefully; none of them can be automatically excluded.

SRI's principal recommendations of future effort are:

- Fundamental research on car rolling resistance.
- Development of more sophisticated clasp retarder control algorithms.
- Acquisition of field performance data.

# CASE STUDY FOR THE YARD COMPUTER SYSTEM METHODOLOGY

By

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SRI International

## 1.0 Introduction

This case study is being conducted to provide data and experience to enhance the production of the Yard Computer Handbook, Volume II of the Federal Railroad Administration Yard Design Project. The study is being conducted at the Potomac Yard of the Richmond, Potomac and Fredericksburg Railroad.

The Potomac Yard is a rail freight terminal handling north-south traffic for six tenant railroads. Facilities include northbound and southbound receiving and classification yards, an engine storage yard, a piggyback yard, and repair facilities. The holding capacity is 4,500 cars, with 54 northbound and 39 southbound classification tracks.

The project has been divided into five tasks:

- Task I - Conduct a capacity analysis of Potomac Yard.
- Task II - Determine the functional requirements of the yard.
- Task III - Develop, analyze, and recommend alternative hardware configurations.
- Task IV - Develop functional specifications.
- Task V - Develop implementation planning.

## 2.0 Task I: Capacity Analysis

The SRI-CAPACITY model was used to simulate current peak traffic for both the northbound and southbound yards. It was then used to simulate combined traffic over the single northbound hump. The Task I report recommended the following improvements to increase the efficiency of the northbound yards:

- Install process control equipment to allow humping at a rate greater than 3 cars/min (4 to 5 cars/min, 2,500 cars/24 hr).
- Realign the receiving yard to minimize hump engine interference.
- Add classification tracks, to the extent that space is available, to lessen the frequency of multiple pulls and shifts.
- Redesign the planning approach used to establish schedules to reduce conflicting engine movements.
- Increase the use of the northbound receiving yard.

An additional option would be to use the double hump lead of the northbound yard for simultaneous (A-B model) humping. This would require a distinct division in the northbound classification yard between northbound (tracks 1 to 24) and southbound (tracks 25 to 54) traffic. To make this division, some tracks might have to be added. Inbound trains would have to be yarded so that no north-to-south or south-to-north crossovers would restrict simultaneous humping.

Improved operations are expected by increasing the capacity and throughput of the northbound yard. This increase will require an upgrading of both the present yard inventory system and the process control system.

## 3.0 Task II - Determine Functional Requirements for an Upgraded Yard

The task was completed in three steps: SRI (1) defined the current operation of the yard information system, (2) redesigned the clerical operations and computer system interfaces in an upgraded yard, and (3) outlined the expected functional requirements of the computer systems in an upgraded yard. The recommendation of Task I and discussions with Potomac Yard personnel provided direction for the third step.

The current operations at Potomac Yard were analyzed to specify the clerical and MIS functions. This step was a prelude to formulating a detailed functional design of clerical operations in an upgraded computer system. Figure 1 shows the current clerical functions organized by the movement of waybills. Clerical and MIS functions are currently parallel, independent operations. The purpose of the clerical functions is to process cars through the yard, and the MIS functions provide a

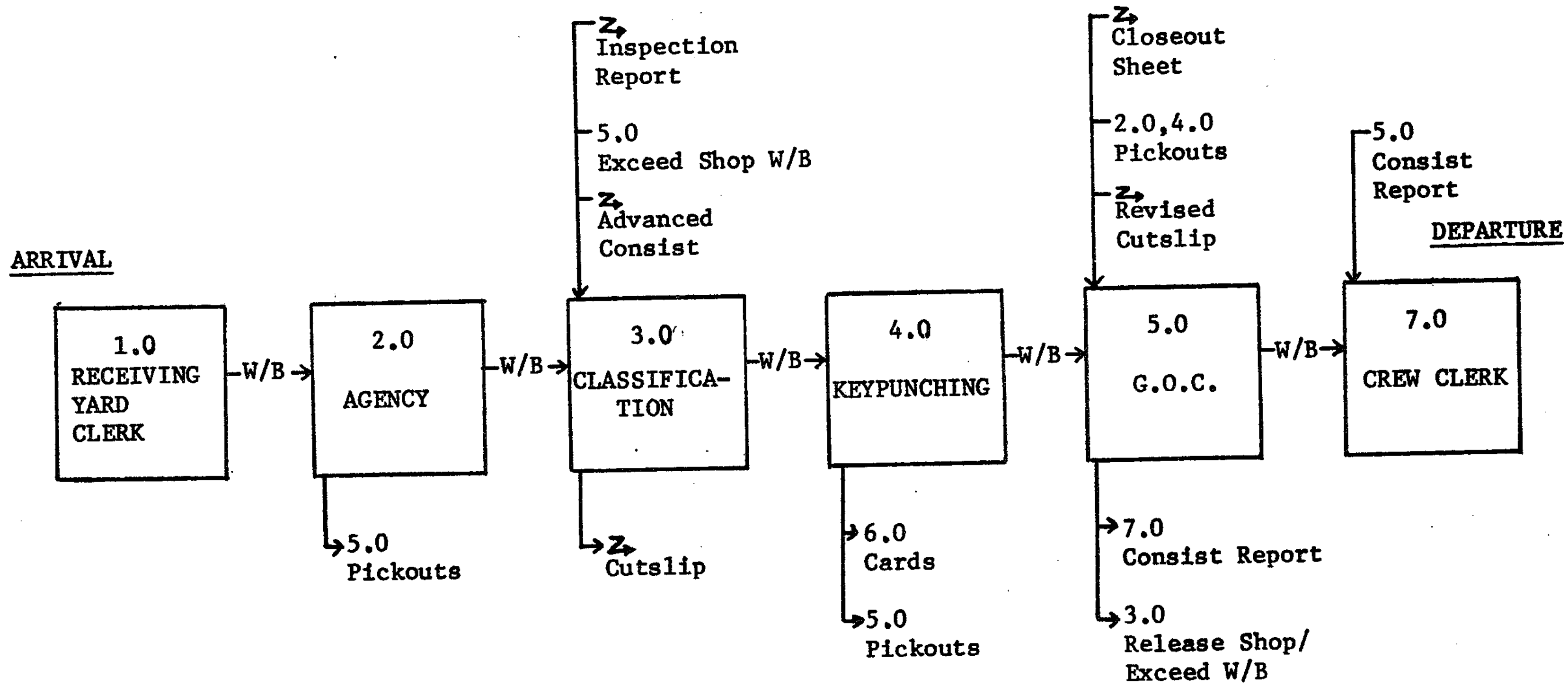



Figure 1 Current Waybill Procedures

record of yard operations. The only direct contact the clerical staff has with the MIS computer is to verify and upgrade consist records. Inventory and other MIS functions are currently processed only after the fact. Batch programs are run one after the other in chronological order.

The next step in defining functional requirements was to establish a detailed design of the expected new clerical functions. Figure 2 is a flow chart of the expected clerical operations. The upgraded design will incorporate a new data processing philosophy. That is, the MIS functions will be to keep MIS records up to date. Thus, clerical and MIS functions will become interdependent, and each clerical operation will be completed concurrently with a parallel MIS function. To provide an accurate real-time inventory, any event in the yard that affects inventory must be posted directly to the computer. The MIS computer will thereby become more than a delayed record keeper.

As part of Task II, a preliminary PC design was developed in conjunction with Potomac Yard personnel. We assumed that PC functions are to be limited to the hump and that no independent PC computers will operate elsewhere in the yard. An exception being considered is monitoring of skate retarders and track lock/onlock. Figure 3 shows the relationship of PC functions to field equipment, yard personnel, and inventory functions.

The function of the yard inventory subsystem is to maintain a track standing inventory of the yard. This function is performed by the present Potomac Yard MIS computer system. The current inventory system must be functionally upgraded for the proper operation of the envisioned PC system. Functions that must be added are real-time inventory for all areas of the yard, the capability of producing classification guides, and the use of terminals to input information from field locations. The relationship of inventory functions to the communication functions, PC functions, and yard personnel is depicted in Figure 4.

Upgrading of communication functions must be completed for real-time inventory. Advanced consists must be received directly by the communication computer from all tenant computers. Only in this manner will the information be available for immediate verification and updating upon train arrival. This procedure provides up-to-the minute information for a real-time inventory and allows classification guides to be produced immediately. Empty car inquiry to tenant railroads can be made with advanced consists before train arrival. Figure 5 shows the interface between each of the three major systems - PC, yard inventory, and communications.

## 4.0 Task III: Develop Alternative Hardware Configurations

In Task III, the expected functions of each yard computer system were allocated among different hardware designs to develop alternative configurations, keeping in mind the current computer systems. Each configuration differed in hardware components and/or in functional design and capacity. The recommended configuration was further refined after an analysis of hardware and software redundancy.

Hardware configurations can be developed in a systematic manner by exploring the distribution of functions among units of independent computer hardware. Under current Potomac Yard configuration, MIS functions are distributed between two computers. One configuration would be to add an independent processing unit for PC functions. In another configuration, the PC and inventory functions would be combined in one unit of hardware; the remaining MIS communications functions would reside in an independent computer system. A third alternative would be to use a single PC/MIS computer for all yard functions. Figure 6 depicts the functional allocation of each alternative configuration.

Each unit of computer hardware, although designated to a specific, limited number of functions, may be structured in a number of ways. Usually, all the designated functions are resident within one piece of computer hardware. One variation is to use a number of systems to perform the similar tasks to distribute the processing load and minimize the loss of any single processor.

Another variation is to use distributed processing, whereby different computers are used for specific functions they do best. An example would be the use of smaller microprocessors for retarder speed control. In this case, the main PC computer would give the microprocessor a desired exit speed and the microprocessor's internal logic would control retarder pressure to provide smooth deceleration.

Another variation is to use a smaller front-end processor to provide communications control and queuing for the MIS computer. In the design of a distributed system, independent functions must be found that require few communications back to the main computer so that the detached processors will work independently and interruptions that hinder system efficiency will be minimized.

Many other variations of hardware configurations have been used when the system is being designed for a number of yards under some degree of central railroad control. At Potomac Yard, the design is simplified because only a single independent system need be considered. Nevertheless, this single

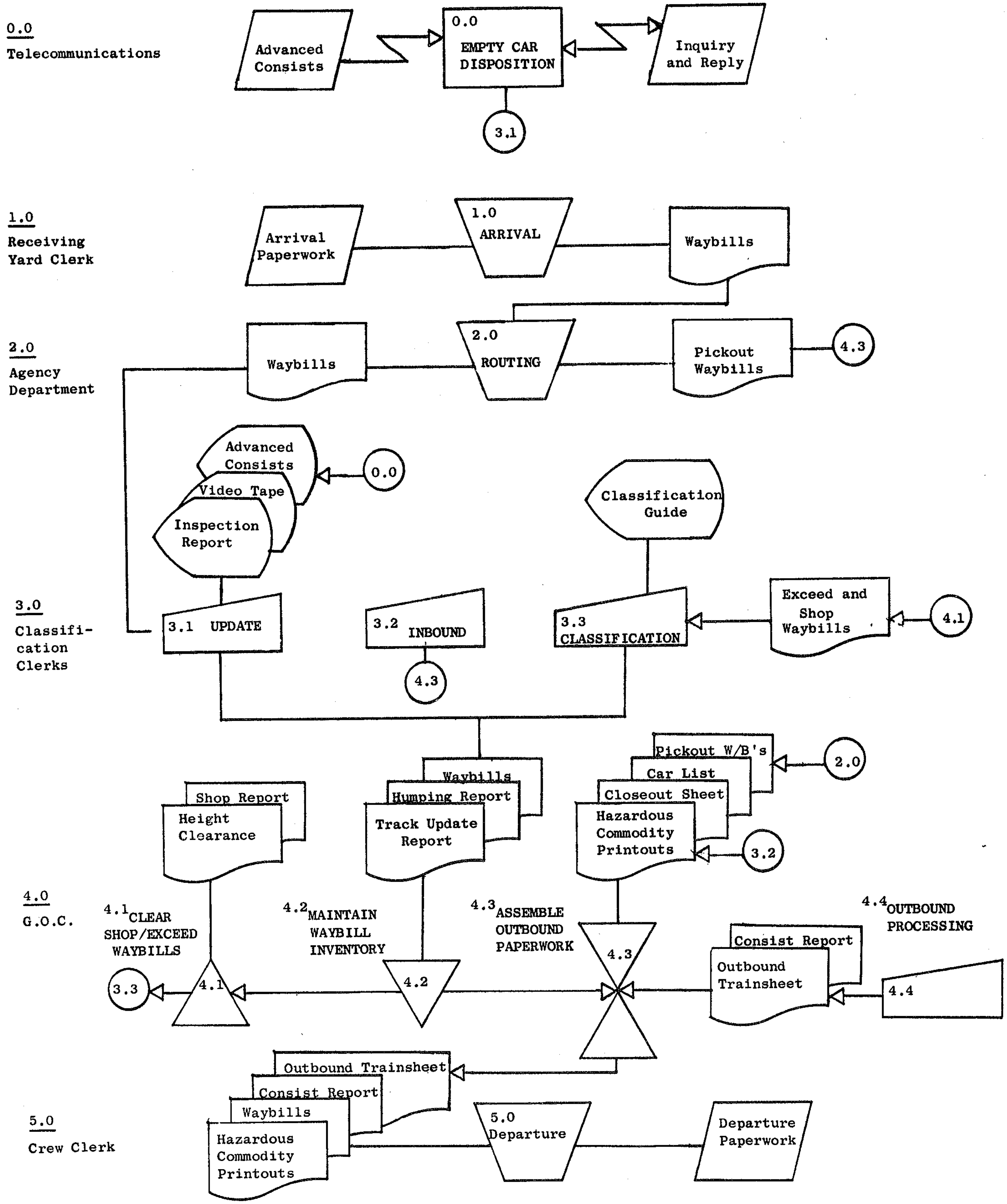



Figure 2 NEW CLERICAL OPERATIONS

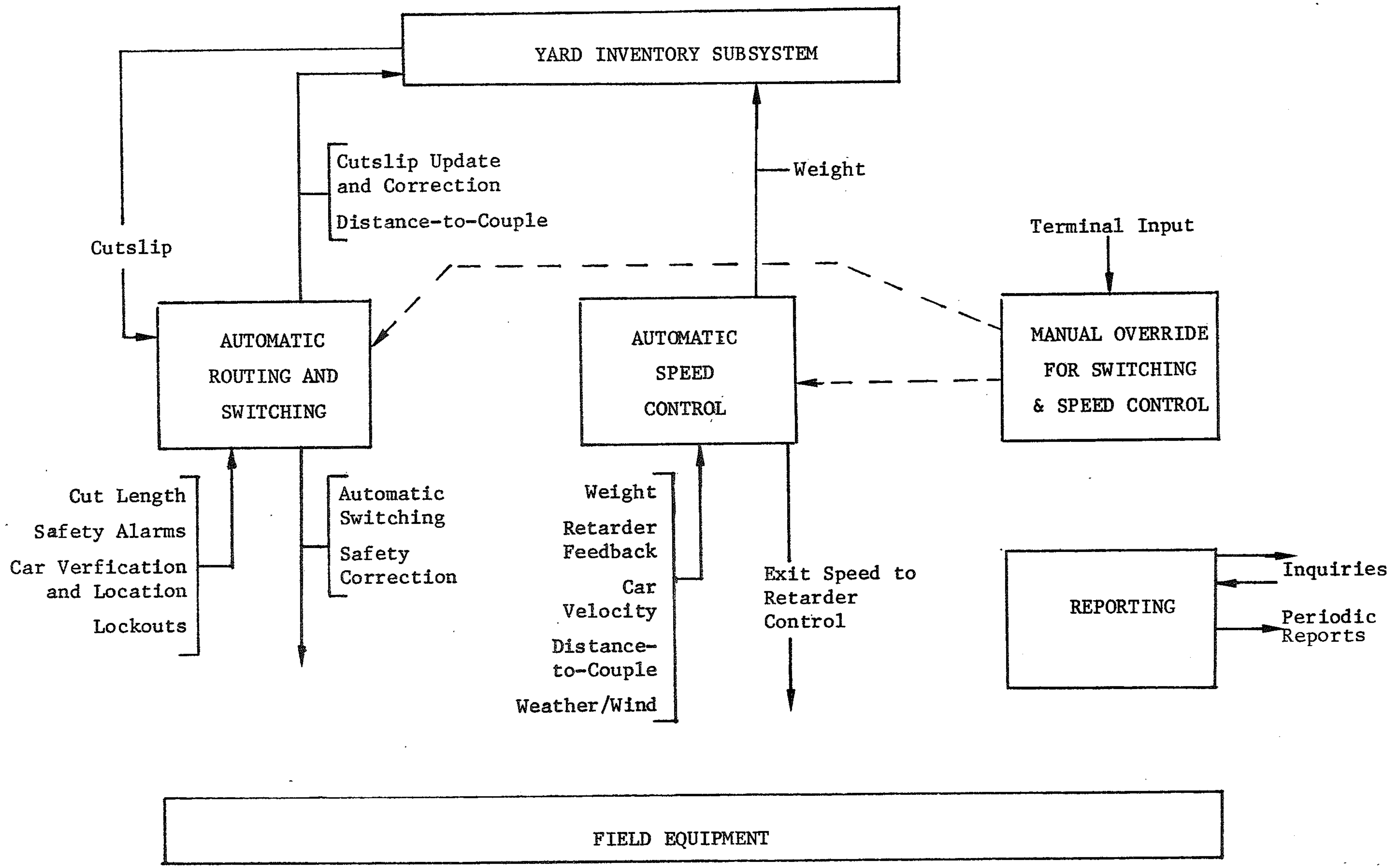
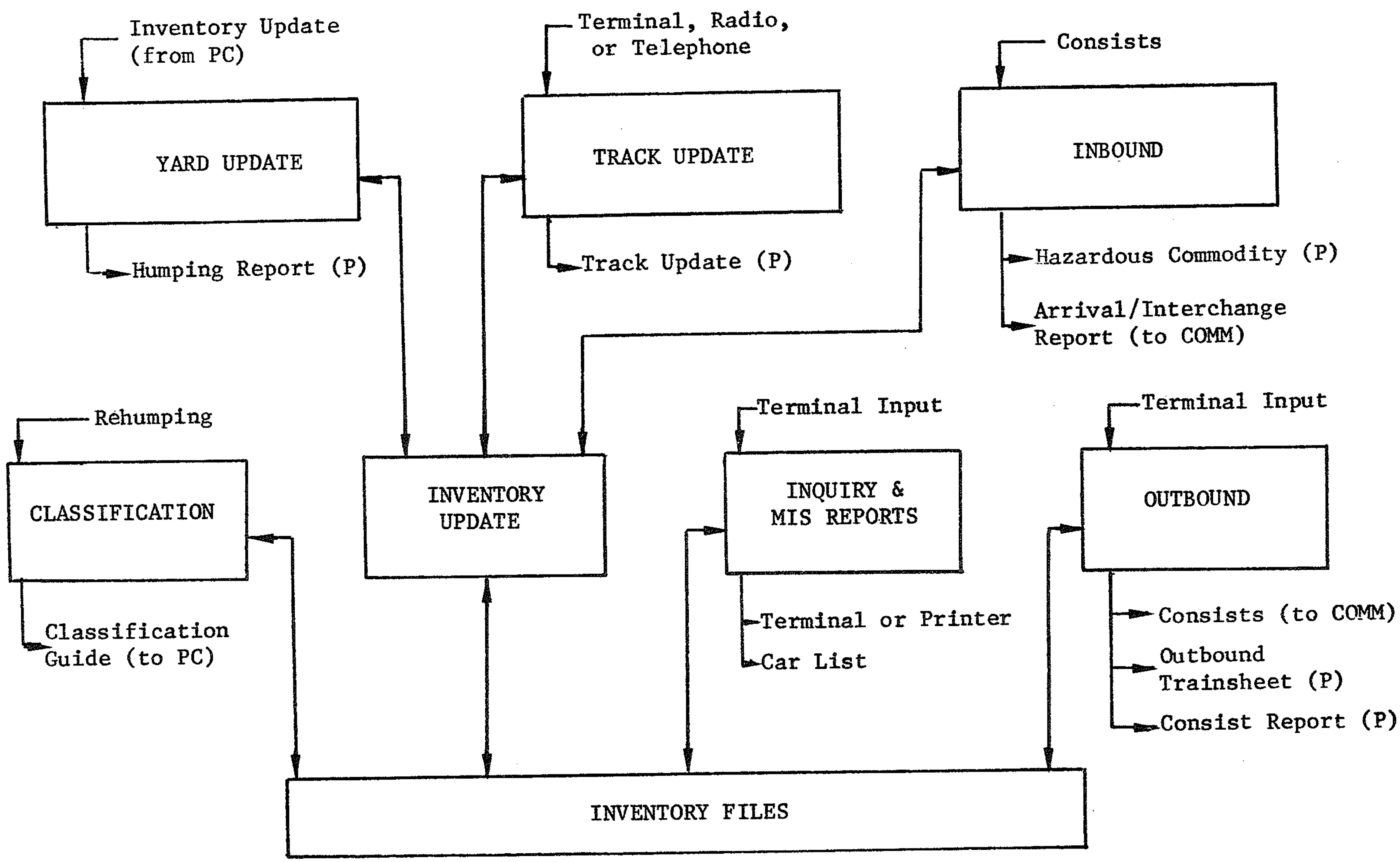



Figure 3 Process Control Computer




Note: (P) = Printed Output
(PC) = Process Control System
COMM = Communications Subsystem

Figure 4 Yard Inventory Subsystem

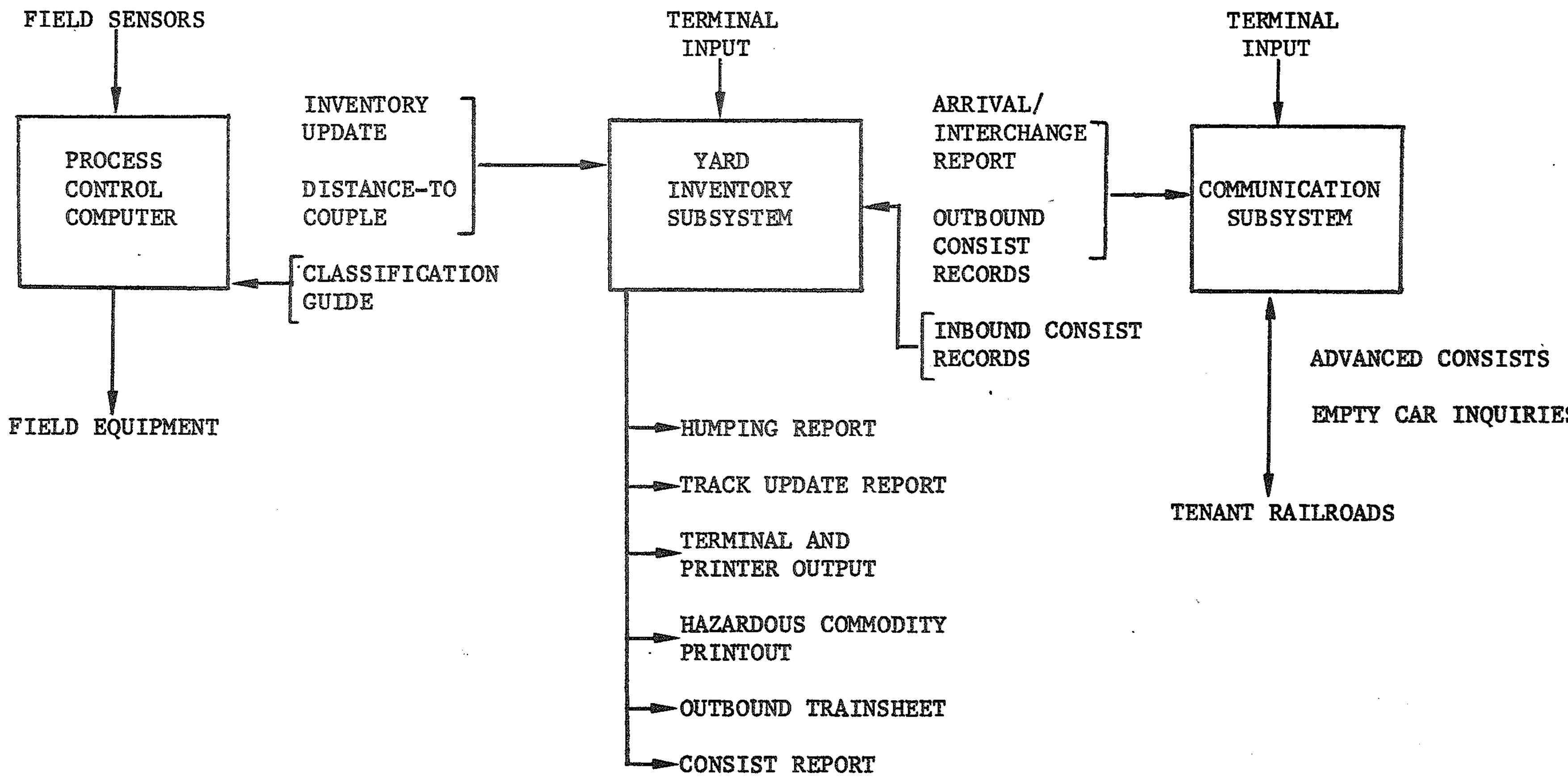



Figure 5 System Interfaces

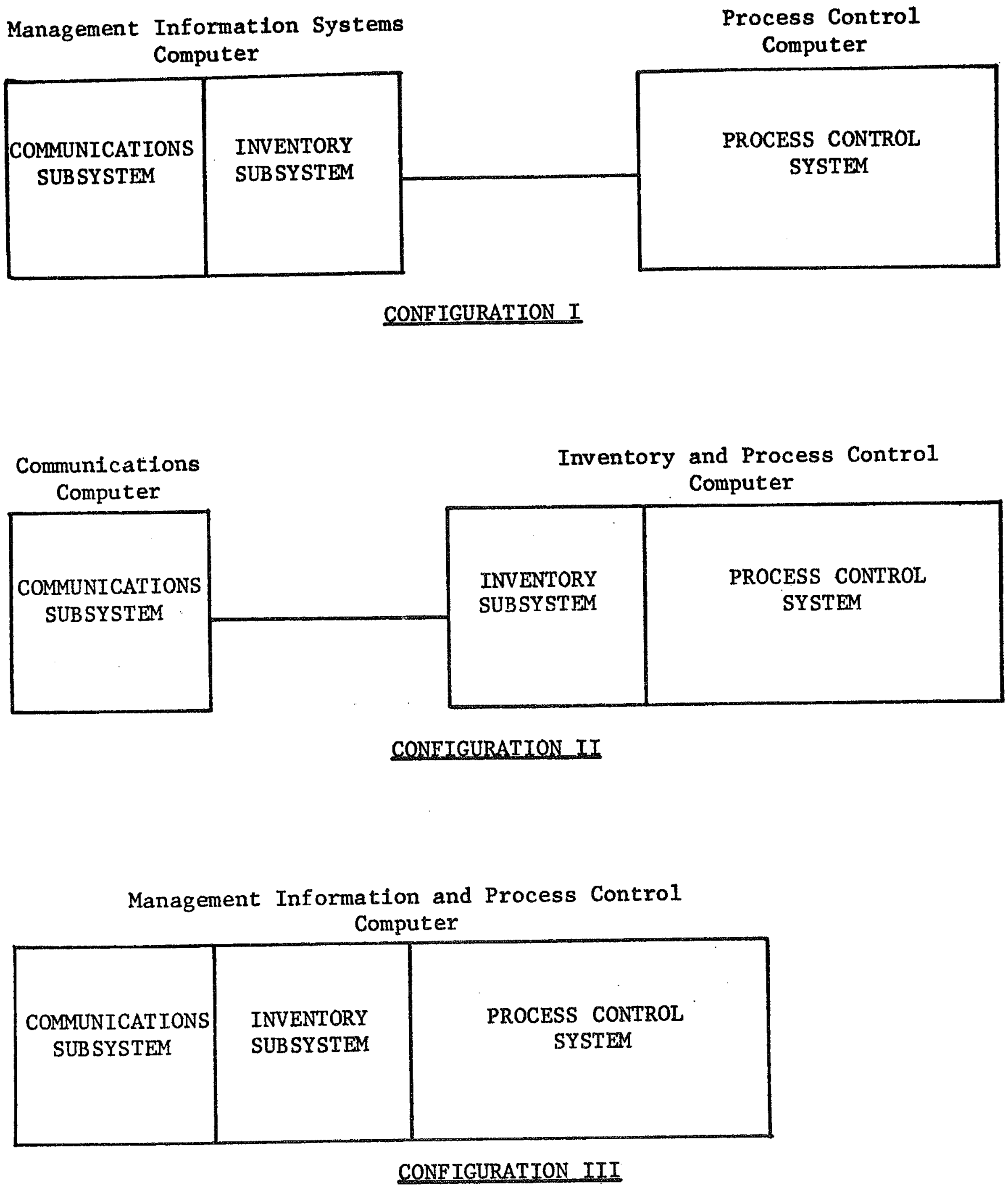



Figure 6 Functional Allocations of Each Alternative Configuration

system is required to communicate efficiently to a number of different tenant MIS computers.

### 4.1 Alternative Configurations

In Configuration I, the MIS functions would remain on the present or similar computers while the PC computer system would be developed as a turnkey package by an independent PC systems vendor. Because having changes made by an outside vendor is expensive, the system should be designed for its expected maximum growth.

The greatest advantage of this configuration is that the hardware and software currently used at Potomac Yard could be easily modified to interface with the PC computer. All but a limited number of PC functions would reside in the MIS computers, which would allow the PC computer to be a small, independent module that would not often be changed. Major changes (data base, reports) could be made easily in house because the PC computer would not be disturbed. Because the PC computer would be limited to a smaller size, a second redundant computer could be afforded. Vital information kept in MIS computers is expected to be available most of the time. No vital information is kept in the PC computer; failures of the PC system being more likely because of the reliance on field equipment.

Under Configuration II, car inventory functions would reside in the PC computer and the MIS computer would operate independently, containing only communications functions. The current hardware could be used for the remaining communications functions. As cars moved through the yard, the inventory in the PC computer would change. When a car left the yeard, the inventory record would be transferred to the MIS computer for advanced consist transmission.

It is expected that PC development will be done by a contractor who will deliver a turnkey system. Because the inventory system is locked into a packaged PC system, it will be difficult to modify software to expand inventory volume or change reporting details and options. Modifications done by the PC vendor would be slow and costly. If changes were made by the Potomac Yard staff, the responsibility for the unmodified software would become unclear. This would also require additional work from a small staff. An advantage of this configuration is that if the communication computer is inoperable, classification guides may still be generated from inventory.

Grouping inventory and PC functions into the same computer is usually done when most MIS and inventory functions reside in a system-wide MIS computer. In the case of Potomac Yard, considerable MIS processing is required and it can be best peformed in a processor separate from the PC applications.

Configuration III is the use of a single PC/MIS computer for all yard information functions.

Use of a single computer for both MIS and PC functions is the least flexible alternative. The disadvantage of this configuration is that asimilar functions would be residing in the same computer, and significant engineering and systems software problems are likely to result.

Additional problems would arise because the current MIS software would have to be moved to a new processor or the PC software would have to be moved to the NCR computers. Moving a PC vendor's packaged software to the NCR computers would be difficult and costly. A real-time operating system would be needed, and would not efficiently run MIS applications. Similarly, moving MIS software to a new computer and redesigning hardware interfaces would be difficult and costly. Redundancy would be expensive and complicated.

### 4.2 Recommended Configuration

The best hardware configuration for Potomac Yard would be Configuration I, the development of independent MIS and PC computer systems. This structure would cause little disruption to current operations and software and would allow the PC computer to be an independent turnkey system. It is envisioned that functional specifications for the PC computer would be given to a contractor for development and hardware selection, and those specifications would include redundancy requirements.

In the design of yard computer systems PC functions are not expected to change. Once field and computer hardware and software have been completed, no changes should be made because they may adversely affect the system. Any functions that require periodic changes should reside in another computer.

The MIS functions could remain in the current NCR computers. The required additional functions and interfaces could be developed by Potomac Yard once the preliminary design of the PC computer has been completed. The upgrading of the MIS system could be completed before installation of the PC computer. It is envisioned that MIS requirements for reports, communications, and inquiries will continue to change. The flexibility of having all MIS functions in one computer system would allow these changes to made easily at any time. This is in clear contrast to the design of the PC computer.

Because Potomac Yard has no system wide MIS computer, its MIS computer must perform many functions locally. The MIS must communicate with each tenant promptly and in a unique format. Therefore, an MIS communications processor would be required.

Configuration I is attractive because the PC computer performs only the minimum functions necessary and the MIS computer performs all others. As a subordinate to the MIS computer, the PC computer can be much smaller, reducing cost and complexity and allowing funds to be spent on backup hardware to assure better reliability.

## 4.3 Reliability

Reliability is a very important consideration for the Potomac Yard computer system. As the yard operations rely more and more on the functions of the yard computers, the continued operation of the computers becomes more critical. Of the greatest importance is the continuous operation of the PC computer because its failure delays the actual physical movement of cars. A temporary failure of the MIS computer(s) has no direct influence on yard throughput.

A number of methods can be used for increasing the availability of yard computers. An obvious approach is to use a backup computer. A secondary system is then available to be quickly put into place during system failure. A backup computer that can provide full redundancy is called a fail-safe system. If the second processor does not have equivalent capacity, it is called fail-soft. In the latter case, when the primary computer fails, less critical functions must be shed for a degraded operation.

A number of alternatives are available to provide redundancy for the PC computer. The decision must be made considering the cost of alternatives versus the cost of losing the northbound hump. The PC computer has been designed with limited functions so that hardware can be smaller and less expensive to back up.

Many of the failures on the northbound hump will be failures of field equipment. The cost of installing duplicate field equipment is prohibitive. When failures do occur, it is hoped that they can be isolated to allow operation of a subset of the yard.

Potomac Yard currently has an MIS computer configuration of two NCR computers. This system has been developed over a number of years, and a major consideration in the configuration selection was the software investment in the current system. One processor is used for external communication with tenants. The other is used for the current MIS programs. These computers communicate through a direct processor-to-processor communications channel and share a number of disk drives.

Potomac Yard personnel believe that neither NCR processor is used fully. A new virtual memory time-share operating system will soon be implemented and should save additional resources. These factors indicate that a high percentage of critical tasks can be performed with only one processor in operation.

To properly design a new fail-soft system, a priority ranking of all new and old programs must be made. This list will be used to designate the programs that will continue to run when one processor fails. One order of priority might be:

- Generate classification guide.
- Receiving yard inventory.
- Receive advanced consists.
- Inbound program.
- Receive inventory update from PCC.
- Classification yard inventory.
- On-line inquiries (real time).
- Departure yard inventory.
- Outbound train consists.
- Send advanced consists.
- Interchange reports.
- On-line inquiries (history).
- MIS reports.
- Shop reports.

## 4.4 Software and File Redundancy

Although the PC computer will be designed for maximum availability, the PC system will still rely on a number of MIS functions. It is expected that, in normal operation, the MIS system will periodically provide new classification guides as assembled from the receiving yard inventory and the classification table. Continuous humping, therefore, will rely on the completion of these MIS functions in a timely manner. This dependence can be eased by having redundant functions and files in the PC computer.

Two schemes may be used to establish this redundancy. The first is to store a number of classification guides for upcoming trains in the PC computer, and the second is to store the receiving yard inventory and the class table in the PC computer. Because the repair time is expected to be short and the MIS system can be quickly reconfigured to a downgraded single computer that can provide classification guides, only a small number of guides need to be kept to ensure continuous humping. The final inventory is later updated to the MIS computer(s). These records may be stored on the PC computer disk or as punched cards.

## 5.0 Task IV: Develop Functional Specifications

The general level functional specification has been divided into two sections. The MIS functional specification describes software modifications and additions that will be made by in-house data processing personnel. A number of software changes must be completed before the installation of a process control computer. Other changes are suggested, but need not be implemented before the PC computer. Table 1 outlines software modifications to the Management Information System at Potomac Yard.

The process control specification is used at this point to describe the suggested process control system. This document can be used to acquaint prospective system vendors of the needs of Potomac Yard. This document describes functional requirements, existing yard layout, and the existing field equipment. Table 2 lists proposed process control functions.

The specification also documents existing MIS hardware, computer interface requirements, requirements for additional computer hardware and field equipment, maintenance and reliability requirements, and the eventual responsibilities of the vendor and Potomac Yard in the project.

## 6.0 Task V: Develop Implementation Planning

A planning document for system implementation and installation was completed for Task V. This document describes each step required in the implementation cycle. The relationship between steps is depicted in a PERT flow diagram. This diagram can be used to develop an implementation schedule. Table 3 lists the steps of the implementation cycle.

The first four steps of implementation: planning and staffing, implementation scheduling, economic justification, and functional specification, require that detailed planning be completed for all stages of the project.

Detailed manpower and resource schedules are required to insure timely completion of the project. From this point, the steps of MIS implementation require the design and completion of software modifications and additions as required for the PC computer. A procurement process is begun for the process control system. Once a vendor is selected, Potomac Yard is reponsible for the development of operating procedures, user training and site prepration leading to installation.

Table 1

SOFTWARE MODIFICATIONS TO MANAGEMENT INFORMATION SYSTEM

Required Before Installation of PC Computer

Determine classification guide

Automatic swing (dependent on operational criteria)

Verification of car order and upgrade of advanced consists with waybill information for all trains

Communications and translation to/from tenants (advanced consists, interchange, empty car inquiry)

Communications to/from PC computer

Receive inventory updates directly from PC computer

Other

Real-time inventory for all areas of the yard

- Record moves made independent of the northbound hump (in departure yards, southbound hump) in timely manner
- Input inspection reports via CRT terminal

Monitor train preparation

- Input inspection reports via CRT terminal

Hump sequence (humping order of inbound trains as determined by operational criteria)

Failure recovery software and procedures

Add additional information from PC computer to MIS records

- Track standing inventory (track occupancy from PC computer)
- Car records (weight from PC computer)

Additional Reports

- Track overflow report (distance to couple from PC computer)
- Alert tracks that need to be pulled or shoved
- Print inventory update report
- Prepare consist report

## Table 2

## PROCESS CONTROL FUNCTIONS

A. <u>Automatic Routing and Switching</u>

Classification guide received from MIS

Cut length detection

Car ID verification

Pin-pullers, list or display

Automatic switching-crest to clear point

Double hump lead

Safety alarms and correction/avoidance--

Conflict, cornering, catchup, stalls, short track circuit, equipment failure, car out of order

Immediate individual inventory update to MIS computer as car clears

Distance to couple, occupancy measurement

B. <u>Automatic Speed Control</u>

Weight scale input

Distance to couple input

Weather input

Calculate rollability

Master Retarder-speed calculation (single and multiple car cuts)

Group Retarder-speed calculation (single and multiple car cuts)

C. <u>Manual Routing and Switch Alignment</u>

Manual reroute switching

Add or delete missing or extra cars

Swing car to B/O or rehump

Swing when track closed

Set switches for backing over the hump

D. <u>Trim End</u>

Track lock/unlock (last switch set away from blue-flag track)

Table 2 (continued)

E. Reports and Alarms

Track status (blue flag)

Track occupancy (distance to couple)

Speed control error log

Speed distribution report

Equipment failure log

Manual switch operations and route changes

Hump utilization

Hazardous cars

Stall, cornering/catchup error log

Extra cars, missing cars, resequenced cuts

F. Returned to MIS Computer

Weight or weight class for each car

Distance to couple for each track

Inventory update (flag misroutes and swing to B/O and hold tracks)

Track status (lock/unlock, overflow, etc.)

Extra or missing cars

Table 3

IMPLEMENTATION CYCLE

Common Steps

- Organization Planning and Staffing
- Development of Implementation Schedule Checklist and PERT Diagram
- Economic Justification
- Functional Specifications
- System Documentation
- User Training

Management Information System

- MIS System Design Specifications
- MIS Software Development, Test, and Installation

Process Control

- Gather Vendor Data
- Procurement Process
- Development of Acceptance Test Specification
- Feedback for PC System Design
- Develop Operational Procedures
- Site Preparation
- System Conversion
- Acceptance Test and System Installation

# ASSESSMENT OF CAR PRESENCE DETECTOR TECHNIQUES

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## INTRODUCTION

Sensors used to detect the presence and location of railroad cars in classification yards are an important, and often overlooked, component in the automated yard classification system. The reliability of the overall computer based system depends to a large extent on the reliability of the detector.

This paper summarizes a study that was directed toward verification of the suitability of currently used presence detection devices to meet current and future demands for applications in railroad classification yards. The objectives of the study include reviewing the application requirements for car detection in classification yards and the techniques used to satisfy those applications; establishment of the mean life of detectors in use and the principal causes of failure; and identify and evaluate potential improvements in detectors in sufficient detail to ensure that a comprehensive specification for presence detectors can be prepared for use by the railroad industry.

## APPLICATION OF PRESENCE DETECTORS IN CLASSIFICATION YARDS

All classification yards are composed of a receiving section, a classification section, and a departure section. Although track configuration may vary depending upon type and traffic volume being handled, the basic function of switching cars into their proper classification and dispatching these cars in their proper position in outgoing trains is common to all classification yards. In flat yards, cars are moved from the receiving yard to the classification yard and ultimately to the predesignated class tracks by a yard engine. In a hump yard, the yard engine moves cars to the crest of an elevated section of track (hump) and then the car will move down the hump to a class track by gravity force alone.

The use of presence detectors in flat yards include detection of a train arriving at the receiving yard, or leaving the departure yard, activation of weight scales in the yard, detection of the presence of a car or cars on, or traveling over a power operated switch section of track, to prevent switch activation until the switch is clear, and turning on and off devices such as closed circuit television and automatic car identification (ACI) units. Attempts have been made in at least two flat yards to automate car inventory control, but to date have not been successful, in part due to the reliability of the rail mounted wheel detector. In these systems, detectors have been located through the yard at class tracks and ladder track locations. The signals from these detectors are used by the inventory control computer to automatically maintain the location of every car throughout the yard. It is anticipated that in the future, some form of this type of automation system will be installed in many of the larger flat yards increasing the application of presence detectors in flat yards.

At the present time, there is a much greater application of detectors in the automated hump yard than a standard hump yard or a flat yard. Figure 1 is a profile of a typical hump yard. The crest of the hump is elevated between 15 and 20 feet above the normal yard elevation. The yard hump engine pushes cars to the crest (either single cars or cuts of three cars) and they proceed by gravity down the hump through a series of switches to a preselected classification or class track. Typically, each class track will ultimately make up either an outbound train, industrial drag, or block to be coupled with another block of cars. In modern hump yards, once the car passes the crest, a computer is used to control the speed and switching functions. It becomes obvious that speed control is an important factor in humping operations to ensure adequate spacing between cars and to ensure cars will coast to their destination on the class track and couple at an appropriate speed (generally four miles per hour).

From Figure 1, the major functional requirements for car presence detection can be identified, i.e.:

- Turning On and Off Devices
    - Closed Circuit Television
    - Speed Detecting Radar
    - ACI Scanners
    - Weigh Scales or Weigh Rails
- Speed Measurements
- Power Switch Protection
- Car Counting
- Car Presence Detection
    - Yard Arrival
    - Yard Departure
    - Other

Three basic requirements can be identified from the review of applications of presence detectors, i.e.:

- Area detector or point detection
- Train speed range over which detector

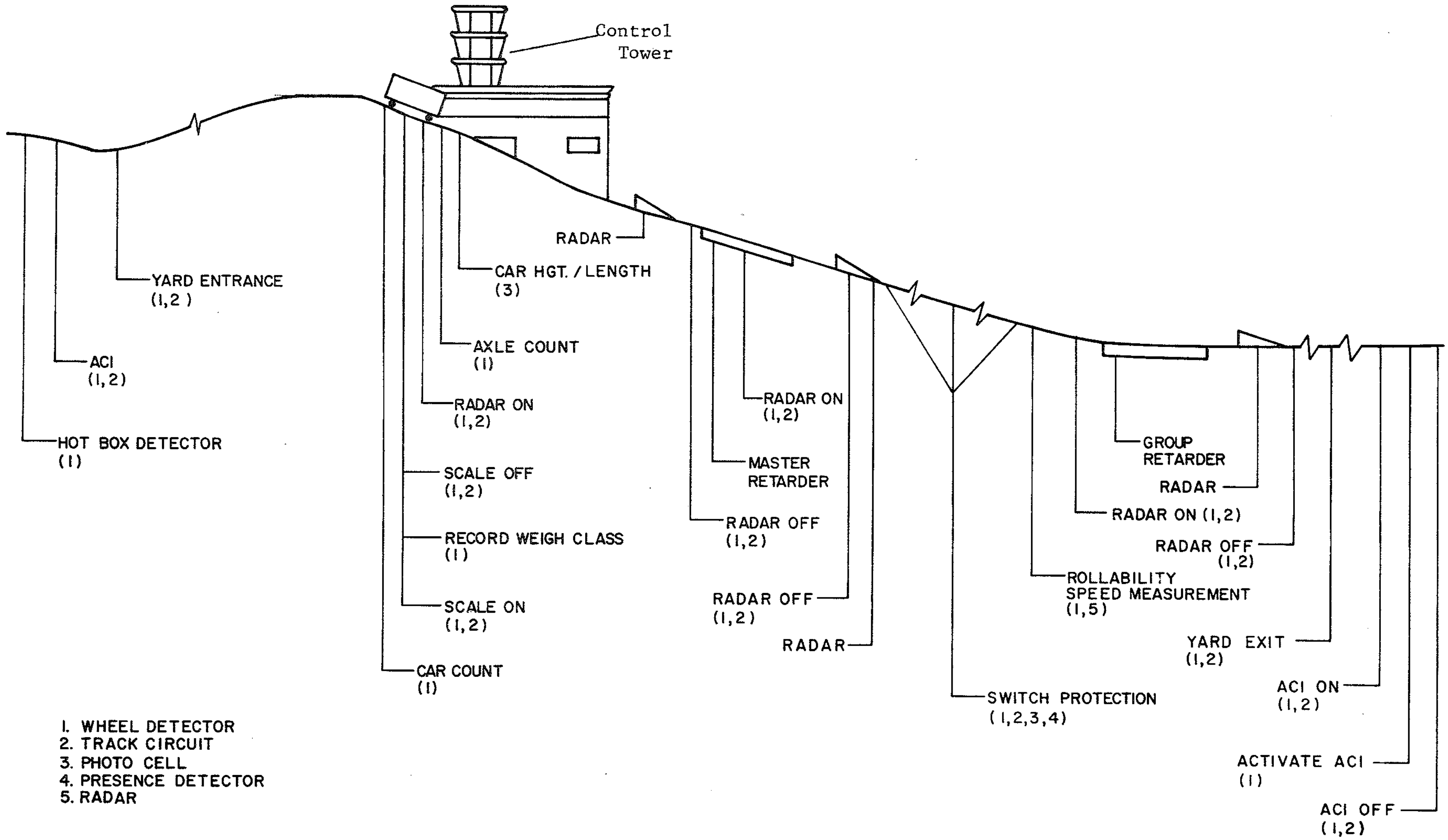



Figure 1 Application of Sensors in Hump Yard

TABLE 1

APPLICATION REQUIREMENTS FOR
CAR PRESENCE DETECTORS

| FUNCTION | REQUIREMENTS<br>BI-DIRECTIONAL | SPEED RANGE | DETECTION AREA | FAILSAFE |
|---|---|---|---|---|
| TURNING ON/OFF RADAR | | | | |
| FLAT YARD | YES | 0-20 | POINT OR AREA | NO |
| HUMP YARD | NO | 3-20 | POINT OR AREA | NO |
| TURNING ON/OFF TELEVISION | | | | |
| FLAT YARD | YES | 0-20 | POINT OR AREA | NO |
| HUMP YARD | MAYBE | 0-20 | POINT OR AREA | NO |
| TURNING ON/OFF WEIGH RAIL | | | | |
| FLAT YARD | YES | 0-20 | POINT | NO |
| HUMP YARD | NO | 1-20 | POINT | NO |
| TURNING ON/OFF ACI | | | | |
| FLAT YARD | YES | 0-20 | POINT OR AREA | NO |
| HUMP YARD | YES | 0-20 | POINT OR AREA | NO |
| SPEED MEASUREMENT | | | | |
| HUMP YARD | NO | 3-20 | POINT | DESIRABLE |
| POWER SWITCH PROTECTION | | | | |
| FLAT YARD | YES | 0-20 | AREA | YES |
| HUMP YARD | NO | 3-20 | AREA | YES |
| CAR COUNTING | | | | |
| FLAT YARD | YES | 0-20 | POINT | NO |
| HUMP YARD | MAYBE | 1-20 | POINT | NO |
| CAR PRESENCE | | | | |
| FLAT YARD | MAYBE | 0-20 | AREA OR POINT | DESIRABLE |
| HUMP YARD | MAYBE | 0-20 | AREA OR POINT | DESIRABLE |

must operate

- Directionality

A further requirement common to all detectors is to detect every wheel, or car, or number of cars, depending upon sensor type. This implies high sensor accuracy with no unusual characteristics of a car causing a sensor to misdetect the car.

The distinction between area and point direction is the ability to detect the presence of a car or train over an area of track, such as in switch protection compared to detection at a single location (point) such as at a weigh scale.

Safety requirements also play a key role in specifying sensor criteria. For example, switch protection applications require fail-safe operation. This implies that the detector must be designated to automatically compensate in the event of failure. The type of compensation desirable in an automated yard is a failure signal message to the crest control computer. In the case of the detector itself, fail-safe operation requires that the sensor provide a continuous signal of car presence whether the car is present or not. Other applications, although not requiring fail-safe operation, are considered critical on their application. In critical applications, it is often desirable to provide the fail-safe characteristic to ensure immediate knowledge of failure and thus minimize yard delays.

Table 1 summarizes the various applications for presence detectors and the basic requirements of these applications. In addition to these general requirements, sensor damage due to environmental influences such as snow, ground freezing, rain, lightning, vibration and shock must be minimized. Since these requirements apply to any detection function, they are not included in Table 1, but necessarily are an important consideration in detector performance.

## DETECTOR TECHNIQUES

Four basic techniques for railcar presence detection are most commonly used in railroad classification yards, i.e.:

- track circuits
- inductive loop presence detectors
- wheel detectors and axle counters
- photocells

Track circuits and wheel detectors/axle counters can be further classified by their principle of operation as follows:

### Track Circuit Types

DC track circuits
Coded DC track circuits
AC track circuits
Coded AC track circuits
Audio frequency track circuits
High voltage impulse track circuits

### Wheel Detectors and Axle Counters Types

Permanent magnet inductor
Permanent magnet switch
Transmitter/receiver
Inductive coil
Mechanical

The principle of operation of the track circuit is generally well understood and no further discussion is offered in this paper. There are, however, a number of different principles applied to wheel detectors and therefore, a brief description of their operation is presented to distinguish the different types of sensors.

### Permanent Magnet (Induced Voltage) Wheel Detector

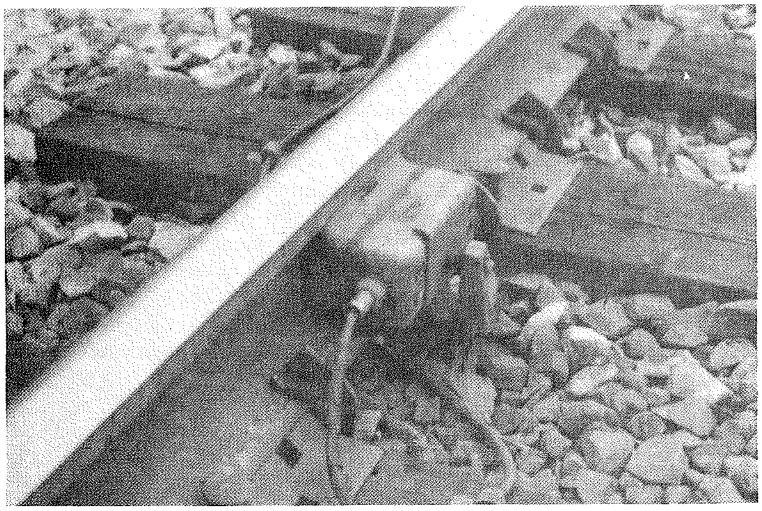
This type of detector contains a permanent magnet which provides a flux field and an inductive pick up coil. It is attached to the rail by direct bolting or by a bracket. The positioning between magnet and rail top is important during installation to ensure adequate field strength in the area through which the wheel rim will pass. Passage of the wheel rim cuts the magnetic field lines and induces a voltage in the coil. The coil output voltage is directly proportional to speed and goes to zero at zero speed. Minimum detectable speed of the detector is suggested to be 5 mph by the manufacturers. Laboratory tests indicate that speeds to 2 mph can be measured with proper installation. The predominant application of this sensor is in hot box detection, although they are finding more applications in hump yards where average car speeds are in the 3 to 5 mph range recommended by the manufacturer. Figure 2a is a picture of this type of sensor installed in a hot box detector application.

### Permanent Magnet (Relay) Wheel Detector

This rail mounted detector utilizes two permanent magnets and a switch. The switch is held in position (normally open) by the stronger magnet. As a wheel passes through the field of this magnet, the field strength is reduced and the switch is attracted to the second magnet closing the circuit. Although no power is required to operate the switch, signal power is required across the switch to provide a signal during closure. The distance from the sensor to the top of the rail is important in this type of sensor for point of closure and should be maintained within 0.125 inches. The switch is activated prior to the wheel reaching the center of the switch. The distance is adjustable from 2.5 inches to 8.0 inches. This type of accuracy is generally suitable for most yard applications other than speed or distance measurements.

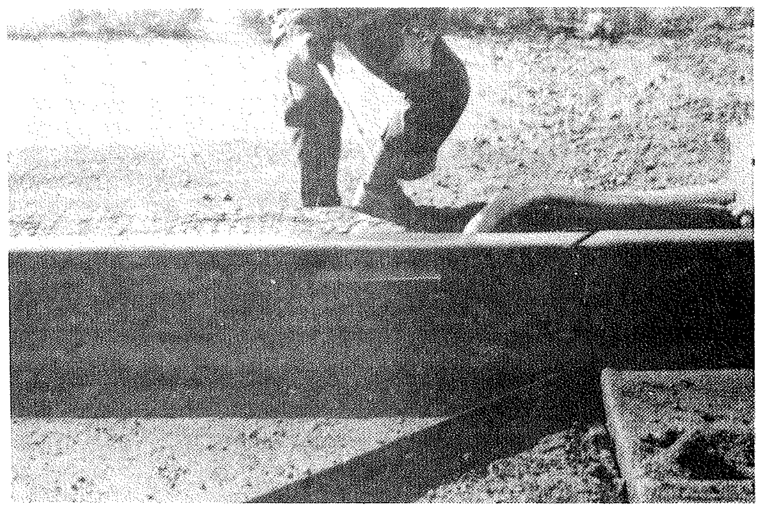
### Inductive Coil Wheel Detector

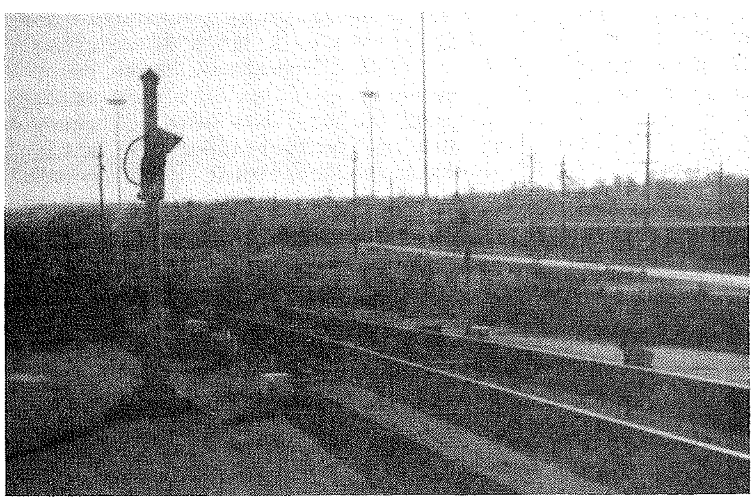
The term inductive coil and loop have been used to describe the principle of using an inductive coil in a resonant circuit. When metal objects are brought in proximity to the inductive coil, the inductance changes -- changing the resonant frequency. This change may be detected by



a)
Permanent Magnet
Wheel Detector

b)
Trans/Receiver
Wheel Detector at
Weigh Scale





c)
Photo Cell

Figure 2 Presence Detectors

frequency shift or phase shift. The wheel detector uses a point coil attached to the track whose inductance is influenced by the presence of the wheel. Two different types of detectors were evaluated that utilize this principle. The first contained three inductive coils connected electrically. Electrical unbalance voltage between the coils when in the presence of a wheel provide signal output. This type of detector cannot be housed in metal and the plastic case is vulnerable to damage. Adjustment is also very critical and readjustments due to small shifts in position due to vibration are quite common.

The second device reviewed uses an inductive coil and permanent magnet. The magnet creates a field in close proximity to the coil to minimize the need for a plastic enclosure. The influence of a wheel in the field changes the resonant frequency of the coil. This frequency is compared to a reference frequency of the coil. This device is not as sensitive to mounting position, reducing the time between adjustment. The detector will activate with the wheel 3 to 8 inches from the center of the detector depending upon the mounting position.

### Inductive Loop Presence Detector

The inductive loop presence detector differs from the inductive coil in that a loop is installed around a section of track or a figure eight loop installed in an area between the tracks. Presence of metal over the loop in the form of a railroad car changes the resonant frequency of the loop circuit and usually the phase shift is detected. The sensor thus provides a signal when the car or portion of the car is in the presence of the detector. This type of device detects the presence of a car in the area of the loop rather than at a single point such as a wheel. A typical loop configuration is shown in Figure 3.

### Transmitter/Receiver Wheel Detector

This device which has also been termed an axle counter (as have several of the other wheel detectors), consists of a small transmitter mounted to one side of the rail web and a receiver mounted on the opposing side. The received signal is activated when a wheel passes on the rail between the two. They are available as single or bi-directional detectors. Figure 2b illustrates this type detector installed as a wheel counter at the crest of the hump.

### Photocell

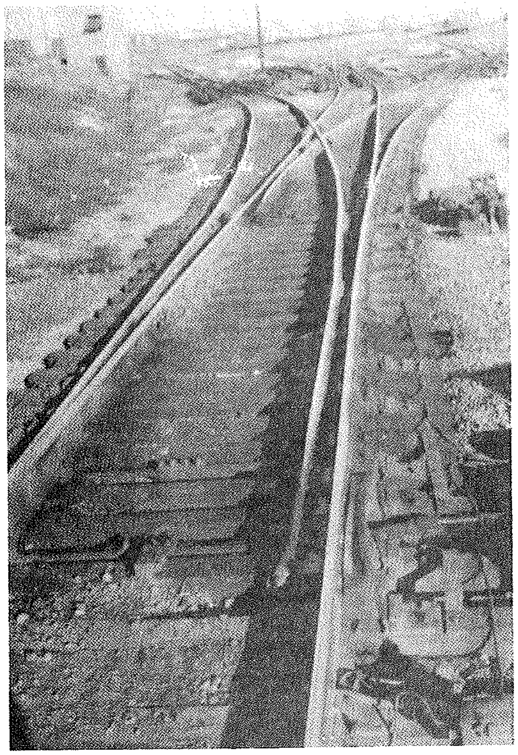
The photocell consists of an optical transmitter and receiver. The passage of a car between the two breaks the light beam, indicating car presence. Since they are not located on the track but alongside, they are not vulnerable to damage by dragging equipment. The railroads report these devices to be quite reliable. They are used for measuring car length, car height, and in one yard surveyed, for switch protection. Light sources for photocells include modulated incandescent and modulated or pulsed infrared beams. The incandescent light sources are more sensitive to ambient light while the infrared beam is unaffected by ambient light. Incandescent lamp life is rated from 2,000 to 60,000 hours, depending upon voltage level. Infrared systems use a light emitting diode lamp for longer life. The devices operate in fog, rain, and snow but at reduced range between transmitter and receiver. Ranges up to 1,000 feet are available.

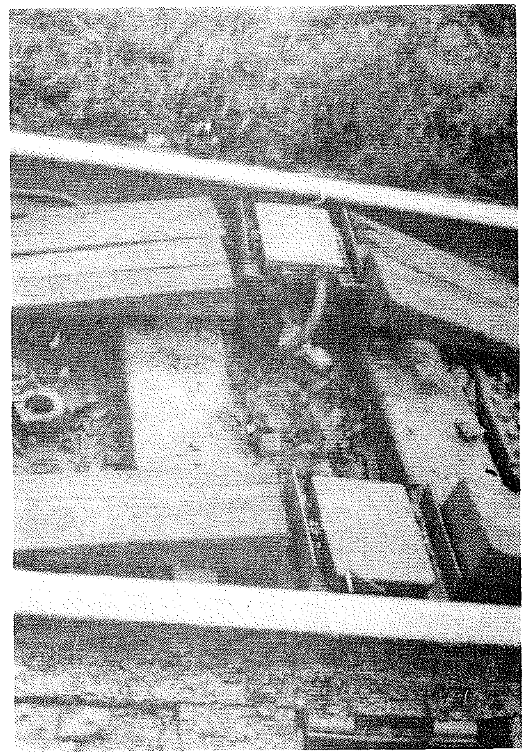
### Other Techniques

In addition to the common usage detectors, a number of different techniques that might be suitable for car detection were noted from a literature survey and patent search. Table 2 summarizes these techniques. Reference 1 discusses the principle of operation of these approaches and summarizes their advantages and disadvantages for application if classification yards.

## EVALUATION OF FIELD FAILURES OF PRESENCE DETECTORS

In order to develop predictions of detector life and causes of failure, failure data were collected from seven railroad yards. Five yards were flat yards and two were hump yards. Four of the five flat yards utilized rail mounted wheel detectors for inventory control while the fifth flat yard used rail mounted wheel detectors for activation of Automatic Car Identification Systems (ACI). For the inventory control systems in the flat yards, an outside vendor maintained all wheel detectors and billed the railroad with a daily description of the work activity. Therefore, these records were quite complete. In the flat yard utilizing ACI systems, failure data were collected by the Department of Transportation over a time period during which the Department of Transportation was evaluating an ACI system. The data had been pre-

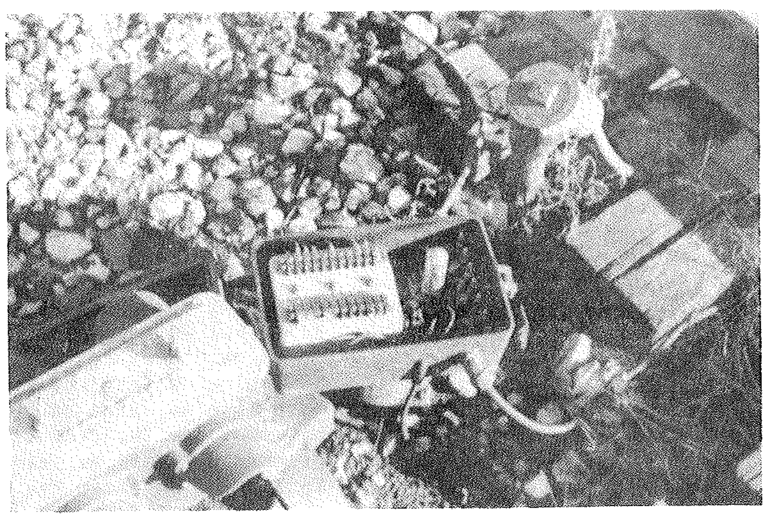




Loop

Inductive Loop Presence Detector

Mech. Wheel Detector



Inductive Loop Power Supply

Figure 3 Presence Detectors

TABLE 2

DETECTOR PRINCIPLES OF OPERATION

In Present Use by R.R.

- Permanent Magnet
- Transmitter Receiver
- Inductive Coils and Loops
- Permanent Magnet Switch
- Mechanical
- Optical
- Radar (used to measure speed)
- Television
- Track Circuits

Approaches Suggested Through Literature

- Acoustic
- Strain Gage
- Hall Effect
- Piezoelectric
- Magneto-Restrictor
- Magnetometers
- Ultrasonic Ranging
- Wiegand Wire

Approaches Suggested Through Patent Search

- Field Effect Semi-Conductor
- Air Pressure Wave
- Infrared Trans/Receiver
- Capacitive
- Rail-Deflection Contactor
- Pressure Sensitive Resistor
- Pneumatic
- Wire in Tube
- Microwave

The failure data obtained in hump yards do not reflect failure by specific application but only by sensor type. The data were collected through reviewing the yard signal department's daily maintenance log book. Occasional small repairs may not have been logged, but for the most part the log books of the hump yards were found to be very complete.

All field failure data were stored in a digital computer for analysis. It was necessary to code the data for storage and retrieval purposes. Most failures could be categorized by the following causes:

- Adjustments
- Cables damaged
- Yard induced damage
- Railroad crew induced
- Lightning

Figure 4 illustrates the results of analyzing failures by failure code and type yard. The percentage of failures per year are shown as a function of failure cause and clearly illustrates the influence of yard type on rail mounted detectors. The failures of track circuits and inductive loop presence detectors are somewhat misleading in that the cost of these failures is quite low. The average costs per failure (including adjustments) are summarized as follows:

| | |
|---|---|
| Wheel Detectors (flat yards) | $319/failure |
| Wheel Detectors (hump yards) | $356/failure |
| Mag. Wheel Detectors (inductive type) | $ 65/failure |
| Inductive Loop Presence | $ 60/failure |
| Photocells | $ 54/failure |
| Radar | $ 32/failure |
| Overlay Track Circuits | $ 40/failure |

These numbers neglect yard delays or any damage to lading from manual operation. Only maintenance and adjustment costs (at $30 per hour) and component replacement costs were included. It does point out, however, that higher failure rates can be tolerated on some devices from a cost point of view.

In addition to analysis of data by failure cause, failures were analyzed as a function of time to obtain failure rates. Figure 5 is a Weibull plot of failure versus time. Similar plots were constructed for each sensor type. Utilizing this analysis approach, the MTTF (mean time to failure) for each sensor was determined. In addition to failure data, the mean time to adjust (MTTA) was also determined. Table 3 summarizes the results of these analyses.

## ALTERNATE APPROACHES TO CAR PRESENCE DETECTION

The studies conducted of failure causes of rail mounted wheel detectors indicated a vulnerability to damage from dragging equipment, being struck by the wheel flange, derailments in flat yards and yard-induced damage during snow removal or during rail, tie or ballast maintenance. The vulnerability was found to be related to both physical size of the detector and the proximity of the detector from the railhead. Laboratory evaluations were conducted of the feasibility of an alternate approach to a rail mounted wheel detector using a strain gage bolt that is smaller in physical size and does not depend upon sensing the wheel flange or on railhead mounting position.

Figure 6 illustrates a typical strain gage bolt installation on the rail. Laboratory tests indicated the capability of this technique to detect rail deflection during the presence of a wheel over the sensor. Although addition refinements and optimizations of the strain gage stud configuration would be required to make it suitable for field applications, the evaluations indicate the feasibility of reducing the physical size of rail mounted presence detectors to minimize their vulnerability to damage in flat yards.

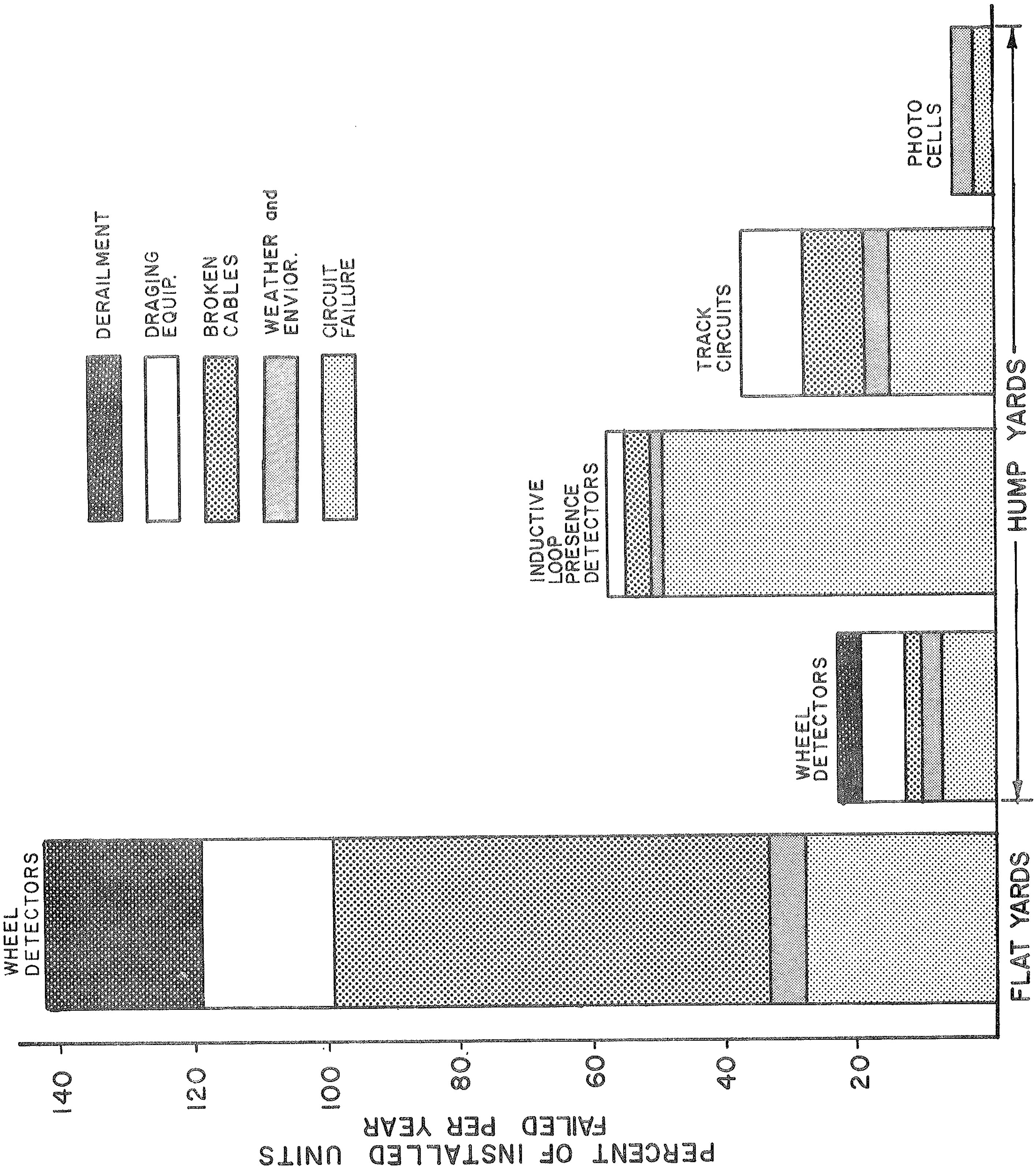



Figure 4 Percent of Failed Presence Detectors Per Year by Failure Cause

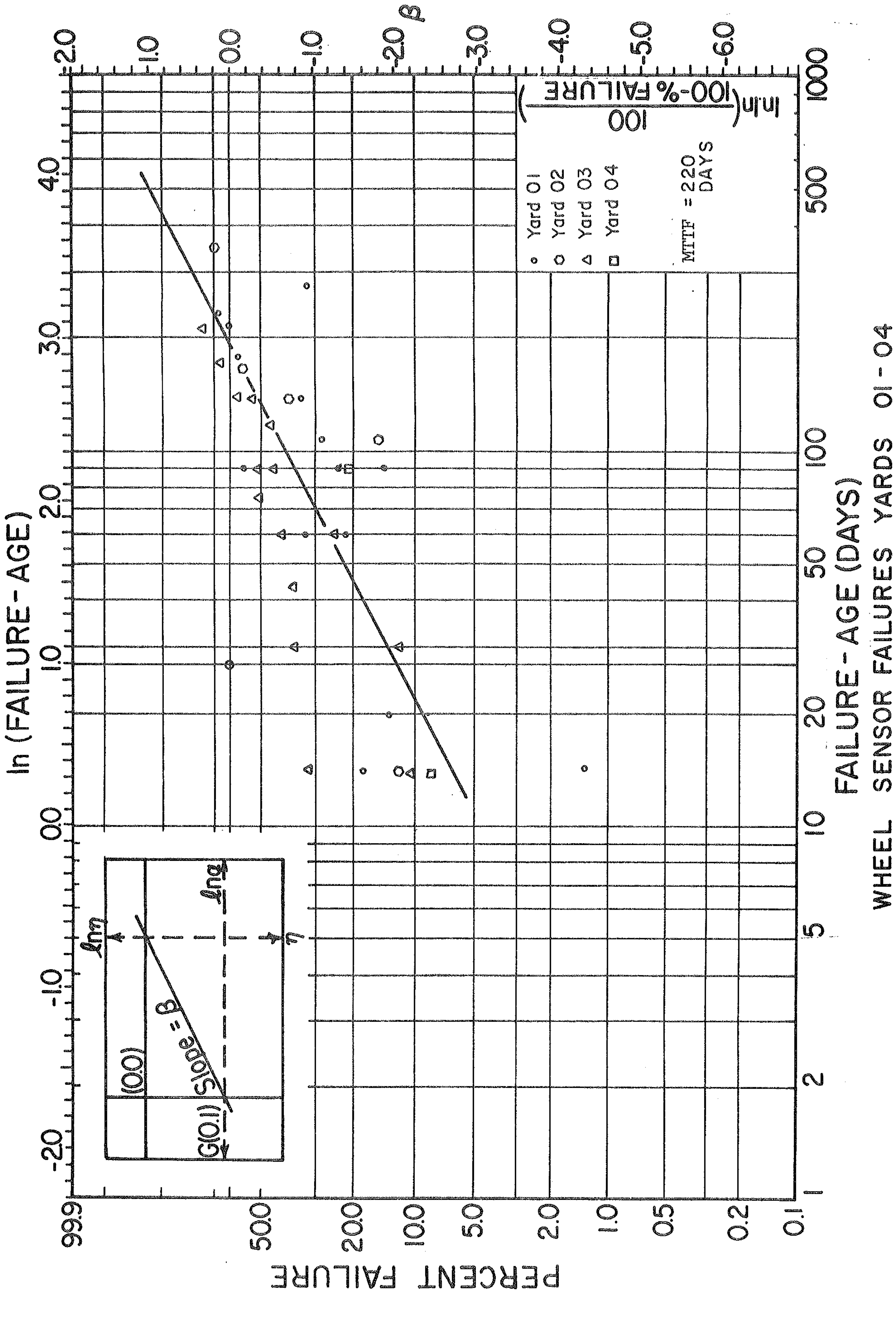



Figure 5 Failure Distribution
of Wheel Sensor

| DEVICE | MTTF DAYS | MTTA DAYS | TOTAL DAYS | AVG $/F | AVG $/ADJ | TOTAL $/F |
|---|---|---|---|---|---|---|
| INDUCTIVE WHEEL DETECTOR | 280 | 122 | 122 | 319 | 27 | 346 |
| PERM.MAG. WHEEL DETECTOR | 4436 | - | 6400 | 65 | - | 65 |
| PERM. MAG. SWITCH WHEEL DET. | 1213 | 6931 | 1489 | 203 | 15 | 218 |
| TRANS/REC. WHEEL DETECTOR | 729 | $.69\times10^6$ | 1049 | 509 | 23 | 532 |
| RADAR SPEED | 267 | 146 | 136 | 115 | 16 | 131 |
| PHOTO CELL DETECTOR | 1871 | - | 2700 | 68 | - | 68 |
| INDUCTIVE COIL PRESENCE DET. | 347 | 349 | 251 | 80 | 14 | 94 |
| H.F. TRACK CIRCUIT | 624 | - | 900 | 40 | - | 40 |

TABLE 3

FAILURE RATES PRESENTLY USED SENSORS

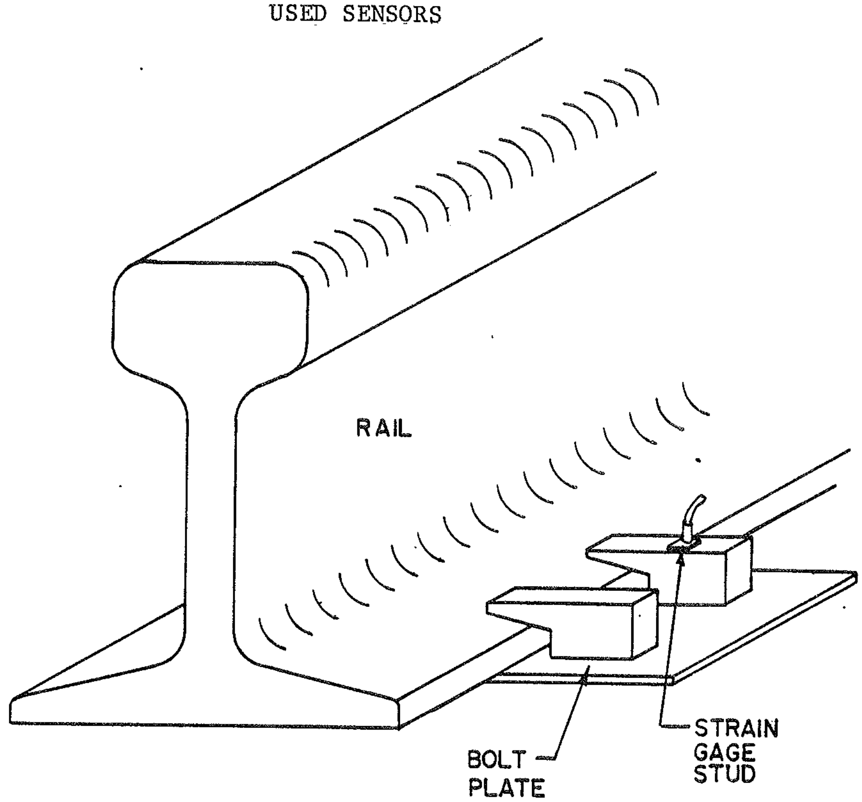



Figure 6 Strain Gage Stud Presence Detector

Field failure rates were found to be low for trackside mounted photocells. Photocells in usage at present are of the incandescent lamp type. Laboratory and field evaluations were conducted on an improved version of these devices using pulsed infrared photocells. Laboratory tests included:

- functional
- high and low temperature
- sunshine
- sand and dust
- immersions

Following successful completion of these tests ten photocells were installed in two different yards of the Grand Trunk Western R.R.

The photocell installation in both yards replaced railmounted wheel detectors. In the Durand Yard 60 percent of the wheel detectors were replaced per year due to damage. In addition, the wheel detectors were readjusted monthly. In the Pontiac Yard the replacement rate was approximately 20 percent per year with monthly adjustments.

The photocells in the Durand Yard went into service in November 1980 and no adjustments or repairs were required through the monitoring period of July 1980. The installation in the Pontiac Yard commenced in January 1980 and has required no servicing or adjustments through July 1980. No failure rate data could be established for either installation since no servicing was required. The testing has demonstrated that the infrared photocell is a high reliability, low failure rate presence detector suitable for applications in a flat yard.

Flat yard application of railmounted detectors resulted in a very high failure rate of detectors from damage due to dragging equipment, derailments and yard induced damage. Although reductions in failures from these causes could be realized by installing deflectors, there were also indications that reduced physical size of a detector would minimize vulnerability. In order to develop a recommendation regarding physical size of wheel detectors for installation in flat yards, a number of dummy devices of reduced physical size were installed in a flat yard for evaluation.

It was concluded from these field evaluations that reduced physical size of railmounted devices is desirable to reduced vulnerability in flat yard applications. Although an optimum size was not developed during these tests, minimizing the physical size of railmounted detectors should be a design goal in a specification for presence detectors.

## RAILROAD CAR PRESENCE DETECTOR SPECIFICATION

Based on the results of this study, a specification was developed as a reference document for the selection of reliable car presence detectors for use in railroad classification yards. The specification is presented as Appendix A to Reference 1.

Three general areas are defined for locating presence detectors in classification yards, i.e.:

- on the rail
- between or around the rails
- wayside or above the rails

Although the general requirements for car presence detectors are quite similar, environmental influences such as vibration and shock differ depending upon location. The most difficult environment is encountered for detectors mounted on the rails and the least severe occurs wayside of the rails or above the track and cars.

The following areas are also covered in the specification with recommended limits:

- operating temperature range
- sunshine
- rail and water immersion
- humidity
- corrosive environment
- contamination and dust
- rail vibration
- rail shock
- electromagnetic interference
- lightning
- failure and maintenance requirements

## CONCLUSIONS

Failure data collected from classification yards indicate annual failure rates in hump yards from 10 to 60 percent depending upon sensor type and application. Many of the failures involved the replacement of a printed circuit or a broken wire and were not considered serious to the humping operation although reduced humping rates often resulted. Where automated inventory systems were attempted in flat yards, wheel detectors experienced failure rates in excess of 140 percent per year necessitating removal of the automated system.

A review of presence detector techniques and applications indicated that with proper selection and installation failure rates can be reduced to under ten percent per year in hump yards and under 25 percent in flat yards. In addition to reductions in maintenance and replacement costs, higher reliability devices will permit higher classification yard efficiency levels.

Wayside detectors, in particular the infrared photocell, have demonstrated in both laboratory and field tests a very high degree of reliability. These devices, however, are limited to applications where sufficient space is available between tracks to install the sensor mounting while permitting personnel passage during train track occupancy. When railmounted devices are required, field tests indicate that reduction in physical size of the sensor is beneficial in improving reliability. Laboratory evaluations have indicated that future developments of detection techniques can result in smaller, more reliable track-mounted devices.

As the trend toward classification yard automation continues, and the applications for car presence detectors increase, the use of a Car Presence Detector Specification, as developed during this study as a reference document, should prove beneficial in the selection of reliable devices.

REFERENCES

1. Wilson, D.S., Petersen, N.J., "Evaluation of Approaches to Car Presence Detection", FRA/ORD-81/01, Feb. 1981.

# FEASIBILITY OF A VELOCITY DATA-ACQUISITION PACKAGE

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## SECTION 1--INTRODUCTION

The term velocity data-acquisition package refers to a yet-to-be-developed portable instrument that can be attached to a railroad car being humped near the crest of a classification yard. This instrument will be able to measure the car's velocity, its acceleration, or simply its position versus time as it rolls from the crest into the bowl track. Since the latter two quantities can be easily converted into velocity, we shall refer to this yet-to-be-developed instrument as a velocity data-acquisition package.

As we shall discuss in more detail in Section 2, the acquisition of a large number of such car velocity records will allow one to derive a variety of yard operational parameters such as coupling speed distribution. Most of these parameters should be of great interest to yard personnel charged with the responsibility of improving a yard's performance.

This paper reports the analysis and the results of a feasibility study* that represents the first step in the development of such a velocity data-acquisition package.

## SECTION 2--RATIONALE FOR THE DEVELOPMENT OF A VELOCITY DATA-ACQUISITION PACKAGE

It is well known in the railroad industry that the performance of the classification yards has a great effect on the economics of the railroad freight operation. Surprisingly, there exists no systematic scheme to measure the performance of a yard. The lack of such a measurement standard, in our opinion, reflects the complexity of the problem. As a matter of fact, the parameters that define the performance of a yard are not universally agreed upon. However, the parameters that define the performance of one important aspect of yard operation, namely, the yard's speed control system, have previously been identified in an FRA-sponsored project.† They are:

- Hump speed
- Percentage of overspeed couplings
- Percentage of uncoupled cars
- Percentage of misswitched cars.

Data on these parameters are sparse and sometimes inaccurate because the cost of collecting data in the field is very high. This is especially true if the effort spent on data collection is used to produce only one set of information, such as the coupling speed distribution. The development of a velocity data-acquisition package will allow yard operators, with an effort not much greater than that required to produce one set of information, to obtain all of the above data plus a large body of car rolling-resistance data.

To see how this is so, let us assume that we have a large number of car velocity versus distance-from-crest records, V(x). Much useful information can be derived from these records. Following are three examples:

- Let us denote the distance from the crest to the point of coupling by L. L should be easily identifiable from the V(x) trace as the point where the car's speed decreases abruptly from a finite value to zero. By compiling all the V(L) within a certain range of L corresponding to a certain track fullness, the coupling speed distribution at that particular track fullness in that yard is obtained. The tedious work of compilation can be performed by a computer.
- On any segment of straight track of length $\Delta L$ and grade G, the relationship between a car's loss of velocity head and its tangent rolling resistance R is given by

  $$V^2(x_2) - V^2(x_1) = 2\ g(\Delta L)\ (G - R).$$

  Because $V(x_1)$ and $V(x_2)$ are readily available from the V(x) trace, R can be solved. By compiling values of R for many cars over the same segment of track, we obtain a rolling-resistance histogram.
- If we integrate V(x) appropriately we can obtain the distance traveled by a car as a function of time. By composing pairs of these x-t curves we can obtain the headway information, from which the potential of a misswitched car can be identified.

By manipulating the V(x) curves in various ways, many other parameters are obtainable. The following is a partial list:

- Hump speed.
- Coupling speed distribution irrespective of track fullness.
- Coupling speed distribution for a particular track fullness.
- Percentage of overspeed couplings.
- Percentage of uncoupled cars.
- Percentage of stalled cars.
- Variation in a car's rolling resistance on different segments of a track.
- Rolling-resistance distribution as a function of car speed.
- Rolling-resistance distribution on any segment of a track.
- Rolling-resistance distribution of cars in any weight category.
- Rolling-resistance distribution of cars with any size wheels.

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*This study was sponsored by the Office of Research and Development of the Federal Railroad Administration (FRA).

†R. L. Kiang et al., "Assessment of Car Speed Control Systems," Federal Railroad Administration Final Report FRA/ORD-80/90, December 1980.

- Rolling-resistance distribution of cars with a certain type of bearings (journal versus roller).
- Switch resistance distribution.
- Curve resistance as a function of the track's radius of curvature.
- Quantification of curve memory.
- Energy absorbed by retarders.
- Headway between any two cars.
- Number of potential misswitches.

The base data of all the information listed above is a set of V(x) traces. These could be measured by track-side instruments. However, instrumenting all the tracks from the crest to the end of the bowl is impractical. With the advance of electronics and miniaturization, we can develop a lightweight, relatively low-cost instrument package that can be easily attached (by magnets, for instance) to a car at the crest. As the car rolls down the hump, this instrument would measure speed continuously up to the time of couple. The speed data would be stored in the package, which would be retrieved by a second operator in the bowl track area, and the package could then be reused.

This instrument package would contain three principal components: a sensor that measures certain physical parameters convertible to car speed, a timer, and a recording unit. It is to be noted that although the described instrument package actually measures V(t), it is a trivial task later to convert V(t) into V(x) on a high-speed computer.

## SECTION 3—OBJECTIVE OF THE FEASIBILITY STUDY

The objective of this feasibility study was to select the most promising method(s) for measuring the velocity profile V(x) of a railcar between the yard hump and a coupling on any track in the yard. These in turn would be recommended for future work that would include breadboarding the selected method(s) and conducting field verification testing.

## SECTION 4—CANDIDATE METHODS AND THREE GENERIC TYPES OF MEASUREMENTS

Candidate measurement concepts considered in this study are given in Table 1. We shall briefly describe each of these.

The on-board Doppler radar method will use a radar unit much like the hand-held radar gun frequently used in the yard. The radar will be aimed at the "moving ground" beneath the car. A similar device designed to measure the speed of a moving truck or tractor is commercially available. The on-board ultrasonic Doppler operates on the same principle as the Doppler radar, but uses acoustic waves instead of electromagnetic waves.

The wheel rotation counter counts the rotation of the railcar wheel. The completion of one (or a partial) revolution of the wheel can be detected by an optical device, a magnetic switch, or a gravity switch, all of which are available commercially. Alternatively, the distance traveled by the car wheel can be measured by counting the revolutions of a small "fifth wheel"* in

TABLE 1—MEASUREMENT METHODS CONSIDERED

| Method | Sources Other Than SRI | Quantities Measured |
|---|---|---|
| On-board Doppler radar | | V(t) |
| On-board ultrasonic Doppler | | V(t) |
| Wheel rotation counter | | |
| Optical detection | | $t_1, t_2, \ldots, t_n$ |
| Magnetic switch | | $t_1, t_2, \ldots, t_n$ |
| Gravity switch | | $t_1, t_2, \ldots, t_n$ |
| "Fifth wheel" on car wheel | | $t_1, t_2, \ldots, t_n$ |
| "Fifth wheel" on rail | | $t_1, t_2, \ldots, t_n$ |
| Acceleration measurement | | a(t) |
| Wayside system | | |
| Wheel detectors | | $t_1, t_2, \ldots, t_n$ |
| Doppler radar | | V(t) |
| Acoustic Doppler | Dr. John B. Hopkins of TSC | V(t) |
| Infrared beam | Hewlett-Packard distance meter | V(t) |
| IR correlation scheme | Army ETL | $t_1, t_2, \ldots, t_n$ |

contact with the tread of the railcar wheel. The fifth wheel can also roll on the rail instead of on the tread of the railcar wheel (see Table 1).

In the acceleration measurement method, we envision the use of a sensitive accelerometer to measure the longitudinal acceleration (or deceleration) of the car. (By longitudinal we mean in the direction of travel.)

The wayside system using wheel detectors is self-explanatory. However, as we mentioned earlier, instrumenting all the tracks from crest to the end of the bowl with wheel detectors is impractical. This scheme is included for completeness. The use of wayside Doppler radar is not new in an automated yard, but using it to track a car from crest to couple has a number of serious obstacles, such as maintaining line of sight. The use of an acoustic Doppler, an idea advanced by Dr. John B. Hopkins of the Transportation Systems Center (TSC), is similar to the previous method in principle. As the name implies, it uses an ultrasonic device. The infrared beam concept requires the use of a commercial distance meter marketed by Hewlett-Packard. The system claims to have a range up to 5 mi and a velocity accuracy of 0.167 ft/sec; its price is approximately $14,500.

The infrared (IR) correlation scheme is a unique method developed and laboratory tested by the Engineer Topographic Laboratory (ETL) of the U.S. Army. An IR emitter, two IR detectors, and a recorder are used. The reflected signals from the roadbed are recorded on separate channels of the recorder and are later correlated to determine the transit time of a particular feature on the roadbed from the leading to the trailing IR detector. In one sense, this scheme is analogous to the fifth-wheel-on-rail method, with the distance between the two detectors being equivalent to the circumference of the fifth wheel. The main difference between the two concepts is, of course, that the fifth wheel requires physical contact and the IR correlation does not.

Despite the large number of methods involved, each measures only one of three fundamental quantities:

- Acceleration measurement, a(t),
- Velocity measurement, V(t), or
- Time-sequence measurement, $t_1, t_2, \ldots, t_n$.

*The term fifth wheel is borrowed from the automotive industry, in which the use of a fifth wheel trailed behind an automobile is commonly used to measure true distance traveled.

The last column in Table 1 indicates the quantity being measured by each method. The identification of three generic types of measurements simplifies our task of deriving the required measurement accuracy for each concept via an error analysis (which will be discussed in Section 6).

## SECTION 5--THE SIGNIFICANCE OF THE REQUIRED ACCURACY OF CAR ROLLABILITY DATA

Among the many yard performance parameters, ranging from coupling speed to stall distance, that this data-acquisition package is intended to provide, we have identified car rolling resistance as a parameter that usually demands the highest accuracy in any of the measurements, be it acceleration, velocity, or time-sequence. As a result, determining the accuracy requirement for a car's rolling resistance, often expressed in lb/ton, becomes a necessary first step in specifying accuracy requirements for the velocity data-acquisition package.

Before discussing the derivation of required accuracy of car rolling resistance, we would like to comment on the significance of this parameter in both yard design and yard operation. One of the most important design parameters that a yard designer needs is the rolling-resistance distribution of the expected car population that will be handled in the yard. Uncertainties in this distribution and how it varies from crest to bowl will have profound effects on the yard's future performance. To our knowledge, these uncertainties have not been definitively quantified.

The uncertainties in rolling resistance not only affect yard design but also yard operation in many ways. As one example: In many of the automated yards, the rolling resistance of a car on a bowl track is predicted by the measured resistances at the master and group retarders, and by a statistical correlation. Uncertainty in either or both of these input factors could cause error in the predicted bowl-track rolling resistance. An overprediction of 0.5 lb/ton would result in a coupling speed of 5.6 mph instead of the usual target value of 4 mph at a point 2000 ft from the last retarder. An overprediction of 1.0 lb/ton would mean a coupling speed of nearly 7 mph.

If we denote car rolling resistance in lb/ton by the symbol R, and the uncertainty of R by the symbol $\Delta R$, our following analysis will show that

$$\Delta R = \pm 0.5 \text{ lb/ton}$$

is sufficient for yard application. This value is arrived at by considering:

- The achievement of satisfactory coupling performance on the class tracks.
- The achievement of adequate performance in the switch area.
- The practical limit on the number of cars that can be measured in a yard.

Figure 1 shows the results of a simple error analysis. It considers the case that, given the predicted bowl track resistance, the tangent-point retarder is programmed to release the car at an appropriate speed so that it will couple at 4 mph with a parked car 2000 ft down the bowl track. The analysis then assumes an uncertainty in retarder release speed of ±0.1 mph, an uncertainty in distance-to-couple of ±50 ft, and an uncertainty in the predicted rolling resistance of ±0.5 lb/ton. As expected, these uncertainties will cause the car to couple at a speed different from the target value of 4 mph. The calculated range of expected coupling speed for cars of various rolling resistances is shown in Figure 1. Because the range lies approximately between 2 and 6 mph, it is generally considered acceptable. The implication, then, is that $\Delta R$ of ±0.5 lb/ton is adequate for achieving satisfactory coupling performance.

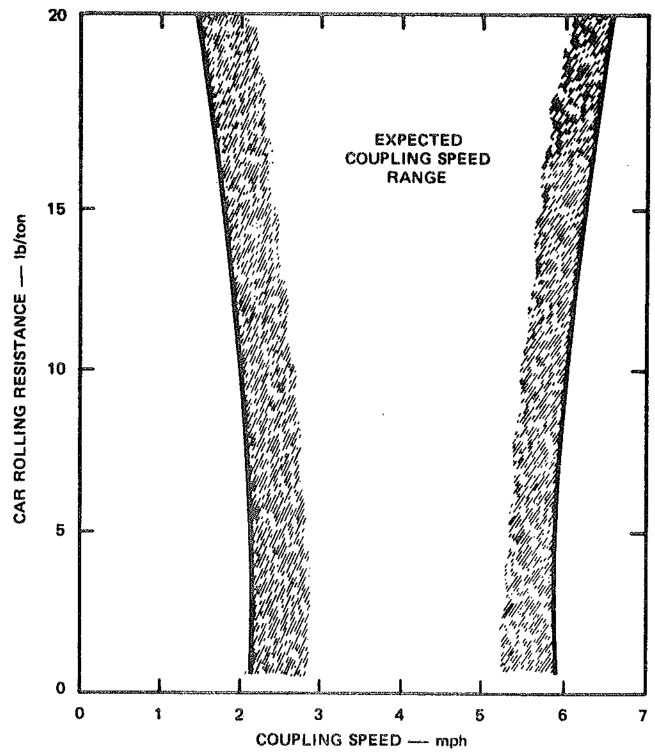


FIGURE 1 EXPECTED RANGE OF COUPLING SPEED WHEN UNCERTAINTIES IN ROLLING RESISTANCE, DISTANCE TO COUPLE, AND TANGENT POINT SPEED ARE ±0.5 lb/ton, ±50 ft, AND ±0.1 mph, RESPECTIVELY

Similar error analyses were performed to estimate the maximum possible effects on headway and on curve speed as a result of $\Delta R$ being ±0.5 lb/ton. The results show that the uncertainty in headway is only a couple of feet and the uncertainty in curve speed is less than 0.1 mph. Hence we conclude that a $\Delta R$ of ±0.5 lb/ton would adequately guarantee the proper execution of the switch area operation.

Now we come to the third criterion on which the $\Delta R$ of ±0.5 lb/ton is derived. This criterion has to do with the practical limit on the number of cars that can be measured in a yard. Perhaps the best way to explain the meaning of this criterion is by an example. Figure 2 shows a typical rolling-resistance histogram. The data base behind this diagram encompasses 1200 cars. Because the cars are grouped in rolling resistance of 2-lb/ton intervals, the distribution appears far from a smooth curve. Nevertheless, the general shape does conform to our expectation. In Figure 3, the same data base is replotted in 1-lb/ton intervals. The improved smoothness of the distribution is quite obvious. However, further improvement from plotting the data in even closer intervals is not possible. This can be seen in Figure 4, in which the data are plotted in 0.4-lb/ton intervals. The reason for the deterioration, as manifested by the uneven peaks and gaps in the high resistance values, is the size of the sample. For instance, the gap between 16.8 and 17.2 lb/ton might have been filled if 10,000 instead of 1200 cars were measured.

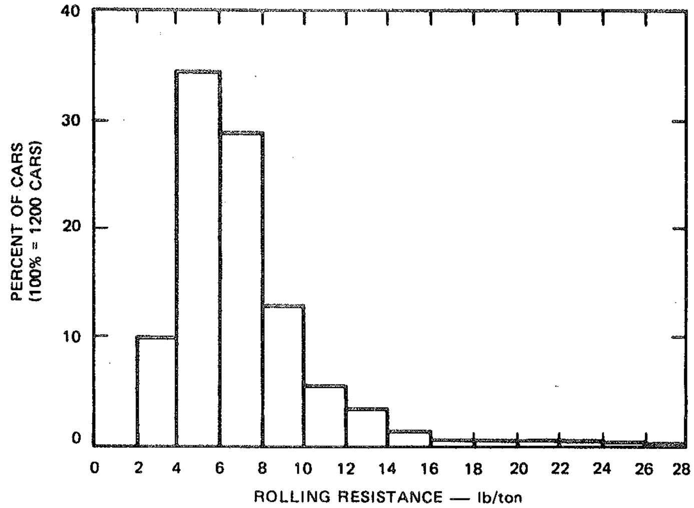


FIGURE 2 ROLLING RESISTANCE HISTOGRAM — 2-lb/ton INTERVALS

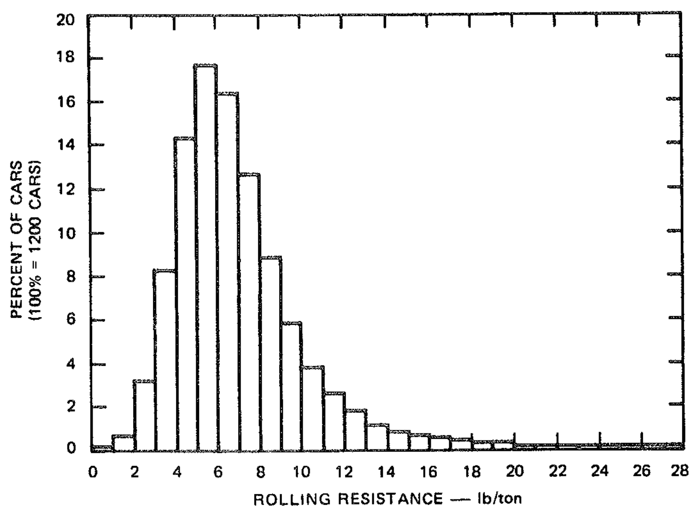


FIGURE 3 ROLLING RESISTANCE HISTOGRAM — 1-lb/ton INTERVALS

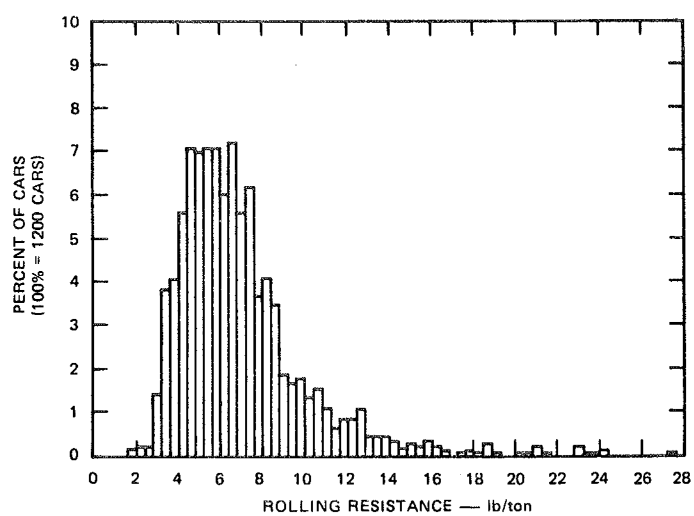


FIGURE 4 ROLLING RESISTANCE HISTOGRAM — 0.4-lb/ton INTERVALS

The mathematical interpretation of the above demonstration is that the extent to which a discrete probability distribution can represent a continuous probability distribution is ultimately limited by the number of samples rather than by the size of the discrete intervals. The implication is as follows: Unless one is prepared to take rolling-resistance data of more than several thousands of cars, plotting them in less than 1-lb/ton intervals will not improve the end results. If a 1-lb/ton-interval histogram is contemplated, a ±0.5 lb/ton accuracy is all that is necessary.

## SECTION 6—REQUIRED MEASUREMENT ACCURACIES—RESULTS OF COMPREHENSIVE ERROR ANALYSES

In a conscious effort to minimize the mathematical treatise in the main body of this paper, the statistical error analysis from which the required velocity measurement accuracies are derived is presented in the Appendix. The intent is to bring to the reader's attention, with minimum distraction, the significant results of this study. These results will be discussed in the following three subsections.

### 6.1 ERROR MAGNIFICATION

As mentioned in the opening paragraph of Section 5, we have identified car rolling resistance as a parameter that usually demands the highest accuracy in any of the three measurement schemes. In this subsection, we shall first demonstrate the extreme sensitivity of the calculated value of a car's rolling resistance to the measurement error. The reason for this sensitivity will then be identified.

One of the standard methods of measuring a car's rolling resistance in a classification yard is to use three wheel detectors along a measurement section of length $x_2$ and grade G. The first wheel detector marks the start of the section, $x = 0$. The second wheel detector is usually placed somewhere in the midsection denoted by $x_1$. The third and last wheel detector is situated at the end of the section. We assume that $x_1$ and $x_2$ are known. As a car with constant rolling resistance travels through this section, we measure the time it takes to go from the first to the second wheel detector ($t_1$) and from the first to the third wheel detector ($t_2$). With this information, we calculate the rolling resistance by the equation:*

$$R = G - \frac{2}{g}\frac{1}{t_2 - t_1}\left(\frac{x_2}{t_2} - \frac{x_1}{t_1}\right) \qquad (2)$$

Consider the following typical values:

$G = 0.04$ (a 4 percent grade, typical of a master retarder measuring section)
$x_1 = 40$ ft
$x_2 = 80$ ft (length of measuring section)
$t_1 = 2.47$ sec
$t_2 = 4.59$ sec

Using Eq. (2), this car's rolling resistance can be readily calculated:

$$R = 7.6 \text{ lb/ton} \quad .$$

Now, it is known that a wheel detector does not locate a passing wheel precisely every time. Unfortunately, quantitative accuracy information of any of the commercial wheel detectors is unknown. We shall assume a plausible value of 0.1 ft. Using a value of 40.1 ft

*The derivation of this equation is straightforward and is therefore omitted.

for $x_1$ instead of 40 ft, the calculated rolling resistance becomes

$$R = 10.0 \text{ lb/ton} \quad ,$$

a difference of more than 30 percent from the original value!

What happened? A 0.2 percent error in the $x_1$ measurement has translated to a 30 percent error in R. The reason is error magnification as a result of subtracting two large quantities to obtain a small quantity. In the above example, two error magnifications are involved. The first one is associated with the term

$$\frac{x_2}{t_2} - \frac{x_1}{t_1} \quad .$$

In this expression, the difference between the two terms is more than a factor of ten smaller than each of the individual terms. Hence an error of 0.2 percent in either term becomes an error of more than 2 percent in the resulting difference. The second magnification is associated with the right-hand side of Eq. (2):

$$G - \left[\frac{2}{g}\frac{1}{t_2 - t_1}\left(\frac{x_2}{t_2} - \frac{x_1}{t_1}\right)\right] \quad .$$

Again, the difference between G and the bracketed term is about a factor of ten smaller than either of the two terms. So a greater than 2 percent error in the bracketed term is translated to a greater than 20 percent error in the difference. Unfortunately, this multiple-error-magnification situation has no easy remedy.

Let us now take this same car to a measuring section just ahead of the group retarder. The grade there is typically 1 percent. The typical values are

$$G = 0.01$$
$$x_1 = 40 \text{ ft}$$
$$x_2 = 80 \text{ ft}$$
$$t_1 = 3.73 \text{ sec}$$
$$t_2 = 7.225 \text{ sec}$$

The rolling resistance calculated from this set of numbers is

$$R = 7.6 \text{ lb/ton} \quad .$$

If the actual $x_1$ is 40.1 ft instead of 40 ft, the revised rolling resistance is

$$R = 8.6 \text{ lb/ton} \quad .$$

This time, the error in R is only 13 percent. Thus the second example demonstrates that for a lower grade, the R value is less sensitive to the measurement error.

The above examples vividly illustrate a fundamental reality that confronts anyone who attempts to measure car rolling resistance. Although we used a three-wheel detector measurement scheme as an illustration,* the demand for high measurement accuracy extends to acceleration as well as velocity measurements.

*The three-wheel detector measurement scheme can be considered the simplest of all time-sequence measurement schemes.

## 6.2 EXAMPLES OF ERROR ANALYSIS

For each of the yard performance-related parameters such as rolling resistance (nine such parameters have been identified), an error analysis had to be performed for each of the three methods of measurement. Of the 27 analyses, three will be summarized in this paper. Two simple analyses will be discussed in this section. The other, which involves an extensive use of statistical theories, will be presented in an appendix. These three examples were chosen because they illustrate the range of sophistication of the analyses. Their results also show the demand for high measurement accuracies.

Let us first discuss the required accuracy for time-sequence measurement to maintain adequate headway between cars in the switch area. Since the minimum separation between cars is generally accepted as 50 ft, or one average car length, an accuracy of 0.1 of that value is considered adequate. In the time-sequence measurement scheme, the distance along a track is measured in a way analogous to the end-over-end measurement of a long object with a short ruler. It is obvious that with this scheme, random errors will tend to cancel one another, but fixed error will be cumulative. If we assume the last switch is no farther than 1000 ft from the crest, a ±5-ft error at 1000 ft corresponds to an allowable error of ±0.5 percent. To achieve such an accuracy by the use of, say, a fifth wheel on the rail is neither too easy nor extremely difficult. Thus one might consider the probability of success to be medium.

Next let us consider the required accuracy of an acceleration measurement for deriving the coupling speed to within ±0.5 mph. The methodology of the error analysis in this case is entirely different from that of the above example. If we denote the distance along a track of grade G by x, then the acceleration, or deceleration, of a car is governed by the equation

$$\frac{d^2x}{dt^2} = (G - R)\, g \quad , \qquad (3)$$

where R denotes the car's rolling resistance, and g is the gravitational constant. It so happens that the R·g is also the quantity measured by an accelerometer and hence is related to the accuracy specification.

In order to obtain the car's velocity, we integrate the above equation. The result is

$$V(t) = \frac{dx}{dt} = (Gg - Rg)\, t + V_0 \quad , \qquad (4)$$

where $V_0$ denotes the velocity at the start of the integration, usually at a time when the car's location can be identified, such as when it exits a tangent-point retarder. We assume the grade and the value of g are known exactly. With the availability of inexpensive but highly accurate timing devices nowadays, we shall also assume that t is measured exactly. The remaining parameters that can affect the accuracy of V(t) in Eq. (4) are $V_0$ and R·g. If we denote the uncertainty of a quantity by a Δ, a statistical theory* dictates that the uncertainty of V(t) as a result of uncertainties in $V_0$ and R·g can be calculated according to

*Kline, S. J., and F. A. McClintock: "Describing Uncertainties in Single-Sample Experiments," Mech. Eng., p. 3, January 1953.

$$\Delta V(t) = \sqrt{\left(\frac{\partial V}{\partial Rg}\right)^2 (\Delta Rg)^2 + \left(\frac{\partial V}{\partial V_0}\right)^2 (\Delta V_0)^2}$$

$$= \sqrt{t^2(\Delta Rg)^2 + (\Delta V_0)^2} \quad (5)$$

To obtain a numerical value for $\Delta Rg$, the required accuracy for an accelerometer, we use the following values for the rest of the terms in the above equation:

$\Delta V(t)$ = ±0.5 mph (a reasonable target value for an expected coupling-speed range of 2 to 6 mph)

t = 180 sec (assumed maximum traveling time between tangent point and point of couple)

$\Delta V_0$ = ±0.1 mph (assumed accuracy of the release speed of tangent-point retarder)

$\Delta Rg$ can readily be calculated as $1.2 \times 10^{-4}$g. Considering the approximate nature of any error analysis, we round off the number and specify the required accuracy for the acceleration measurement, as far as coupling speed is concerned, to be $\pm 1.0 \times 10^{-4}$g. Accelerometers of such accuracy are commercially available. However, the survivability and the signal-to-noise ratio in a yard environment are unknown until a field trial. We therefore rate this probability of success to be medium.

Our last example of error analysis involves estimating required velocity measurement accuracy to ensure that the car rolling resistance calculated from such a measurement is accurate to within ±0.5 lb/ton. This analysis is much more involved than the two we just discussed. For this reason, it is presented in an appendix at the end of the paper.

### 6.3 REQUIRED MEASUREMENT ACCURACIES AND PROBABILITIES OF SUCCESS

The results of all error analyses, including the ones not discussed in detail, are presented in Table 2.

The first column of Table 2 lists the 9 yard performance parameters that are of interest. The second column identifies the desired accuracy for each of the nine parameters. The three methods of measurement are each assigned two columns. The first column of each method (Columns 3, 5, and 7) contains the measurement accuracy required to achieve the desired accuracy given in Column 2. The second column of each method (Columns 4, 6, and 8) gives a crude estimate of the probability of success in achieving the desired accuracy. This estimate is based both on consideration of the cost and stated accuracy of commercially available instruments, and on prospects of developing special-purpose instruments for the application. For example, an accelerometer with $10^{-4}$g accuracy can be purchased for approximately $1,000. The uncertainties about such an accelerometer's survivability and signal-to-noise ratio led us to assign a medium probability of success. As another example, we are not aware of any commercial velocity measurement instrument that claims a random error of less than ±0.01 fps within the yard speed range of 0 to 25 fps. Hence all applications that require such an accuracy are assigned a low probability of success in Table 2.

## SECTION 7--THREE POTENTIALLY PROMISING CONCEPTS

Let us now compare the three probability-of-success columns in Table 2. It is obvious that the velocity measurement has the lowest rank. We shall, therefore, eliminate all velocity measurement methods that were shown in Table 1. Both the acceleration and the time-sequence measurements have a fair chance of success. Of the many methods shown in Table 1 that use time-sequence measurement, we have to eliminate all three wheel-rotation counter schemes and the fifth-wheel-on-the-car-wheel concept because hunting of the railcar wheel destroys any hope of meeting the accuracy requirements. The wayside wheel-detector concept is not economical because hundreds of wheel detectors would be needed from the crest to the end of just one class track. We are thus left with three potentially promising concepts:

- Fifth wheel on rail
- Acceleration measurement
- IR correlation scheme.

## SECTION 8--RECOMMENDATIONS FOR FUTURE WORK

The identification of the three most promising measurement concepts represents the first step toward the development of a velocity data-acquisition package. It is a significant step because we can now focus the hardware development effort, which is inevitably much more costly, on a minimum number of schemes. The future work, as we see it, involves at least three more steps:

- Field verification and further concept elimination--this phase will involve hardware design (such as the fifth wheel), instrument selection (such as the accelerometer and the recording device), instrument calibration and interfacing, and exploratory field-data collection. The results from a number of field tests should allow us to further narrow the choices to one concept.
- Breadboarding the selected concept, followed by more extensive field testing.
- Production model design and fabrication.

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TABLE 1--REQUIRED INSTRUMENT ACCURACIES AND PROBABILITIES OF SUCCESS

| Parameters To Be Obtained (1) | Desired Accuracy (2) | Method of Measurement | | | | | |
|---|---|---|---|---|---|---|---|
| | | Acceleration | | Velocity | | Time Sequence | |
| | | Required Instrument Accuracy (3) | Probability of Success (4) | Required Instrument Accuracy (5) | Probability of Success (6) | Required Instrument Accuracy (7) | Probability of Success (8) |
| Coupling speed | ±0.5 mph* | Fixed error $<\pm 1 \times 10^{-4}$g | Medium | Fixed error <±0.5 fps | High | Fixed error <±5% in distance register | High |
| Rolling resistance (crest to master retarder) | ±0.5 $\frac{lb^{\dagger}}{ton}$ | Fixed error $<\pm 2.5 \times 10^{-4}$g | Medium | Fixed error <±0.05 fps Random error <±0.005 fps | Low | Fixed error <±0.2% Random error <±0.02% | Low |
| Rolling resistance (switch area) | ±0.5 $\frac{lb}{ton}$ | Fixed error $<\pm 2.5 \times 10^{-4}$g | Medium | Fixed error <±0.1 fps Random error <±0.01 fps | Low | Fixed error <±0.5% Random error <±0.05% | Medium |
| Rolling resistance (class track) | ±0.5 $\frac{lb}{ton}$ | Fixed error $<\pm 2.5 \times 10^{-4}$g | Medium | Fixed error <±0.1 fps Random error <±0.01 fps | Low | Fixed error <±1% Random error <±0.1% | Medium |
| Curve resistance | ±0.5 $\frac{lb}{ton}$ | Fixed error $<\pm 2.5 \times 10^{-4}$g | Medium | Fixed error <±0.1 fps Random error <±0.01 fps | Low | Fixed error <±1% Random error <±0.1% | Medium |
| Switch resistance | ±0.01 ft of velocity head (V.H.)‡ | Fixed error $<\pm 1 \times 10^{-4}$g | Medium | Random error <±0.01 fps | Low | Random error <±0.05% | Low |
| Velocity head removed by retarder | ±0.05 ft of V.H.§ | Fixed error $<\pm 5 \times 10^{-4}$g | Medium | Fixed error <±0.1 fps | Low | Fixed error <±0.5% | Medium |
| Stall distance | ±50 ft§ | Fixed error $<\pm 1 \times 10^{-4}$g | Medium | Fixed error <±0.2 fps | Medium | Fixed error <±2% | High |
| Headway between cars | ±5 ft§ | Fixed error $<\pm 2.5 \times 10^{-4}$g | Medium | Fixed error <±0.05 fps | Low | Fixed error <±0.5% | Medium |

*A reasonable target for an expected range of 2 to 6 mph;

†result of analysis (cf. Section 5);

‡a reasonable requirement for an average switch loss of 0.06 ft V.H.;

§values chosen because they are reasonable

## Appendix

## VELOCITY MEASUREMENT ACCURACIES REQUIRED FOR ACCEPTABLE UNCERTAINTY IN CAR ROLLING RESISTANCE

In Section 5 we showed that the acceptable uncertainty in the car rolling resistance is

$$\Delta R = \pm 0.5 \text{ lb/ton} \quad . \tag{A-1}$$

In this Appendix we shall derive the required velocity measurement accuracies in order to achieve this limit of ±0.5 lb/ton.

Consider a car velocity measuring instrument that has fixed error $\varepsilon_f$, and random error $\varepsilon_r$. We shall assume $\varepsilon_f$ to be proportional to the measured velocity and $\varepsilon_r$ to be a random variable with a variance of $\sigma_v^2$. $\sigma_v$ is to be considered the population standard deviation of the random error. Our objective is to derive the requirements for $\varepsilon_f$ and $\sigma_v$.

It is reasonable to expect that the signal from the car-mounted instrument would be quite noisy. Assuming the signal is analog, we shall process the raw signal through a 1-Hz low-pass filter,* then digitize it at a sampling rate of 2 Hz.† We shall then plot the square of each velocity measurement against distance along the track. An example of such a set of data is shown in Figure A-1. Since instrument error is the subject of interest, we shall assume that the scatter of the data from their linear fit is caused by the random error of the instrument rather than by, say, uneven track. Following the popular convention in linear regression analysis, we have used capital letters to denote the variables in a least-squares fit to the data. The true values of the physical parameters are denoted with carats (e.g., $\hat{V}$, $\hat{b}_0$, $\hat{X}$). $S_v^2$, the variance of $v_i^2$ from the fitted line, is indicated in Figure A-1. Also shown in Figure A-1 is an offset straight line depicting the true $V^2$ versus X relationship if one had a perfect instrument. The amount of offset is the fixed error of the instrument.

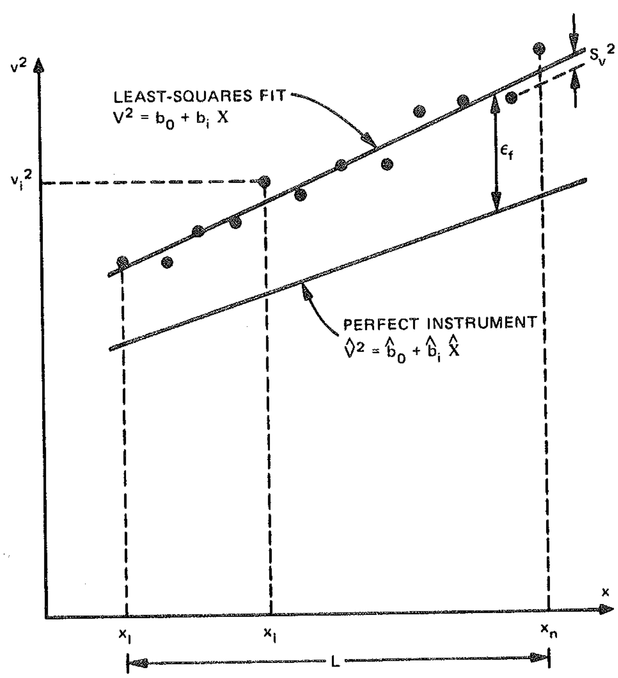


FIGURE A-1 INSTRUMENT ERRORS

The reason we choose to plot $v_i^2$ versus x instead of $v_i$ versus x is because

- The velocity-distance relationship of a car with constant rolling resistance traveling on a constant grade is theoretically a straight line in a $v^2$ versus x diagram, and
- The slope of this straight line can be used directly to calculate the car's rolling resistance by the following equation.

$$R = G - \frac{b_1}{2g} \quad , \tag{A-2}$$

where G is the grade and $b_1$ is the slope. Deviation of $b_1$ from the true slope $\hat{b}_1$ is due to both fixed and random errors.

Consider first the fixed error. In accordance with our assumption that $\varepsilon_f$ is proportional to the velocity being measured, we can write

$$\varepsilon_f \equiv V - \hat{V} = k\hat{V} \quad , \tag{A-3}$$

where k is the proportional constant. The fixed error at station $x_1$ is then

$$V_1 - \hat{V}_1 = k\hat{V}_1 \quad . \tag{A-4}$$

For a precision instrument, we expect k << 1. Equation (A-5) then follows readily from Eq. (A-4):

$$V_1^2 \approx (1 + 2k)\hat{V}_1^2 \quad . \tag{A-5}$$

A similar expression can be obtained for station $X_n$. By definition,

$$b_1 \equiv \frac{V_n^2 - V_1^2}{L} \quad ; \tag{A-6}$$

with a comparable expression for $\hat{b}_1$. It then follows that

$$b_1 - \hat{b}_1 = 2k\hat{b}_1 \approx 2kb_1 \approx 2 \frac{\varepsilon_f}{V(\bar{x}_i)} b_1 \quad , \tag{A-7}$$

where $V(\bar{x}_i)$ can be considered the car velocity at the midpoint of this measuring section. Denoting $b_1 - \hat{b}_1$ by $\Delta b_f$, the fixed error in slope, we have

$$\Delta b_f = 2 \frac{\varepsilon_f}{V(\bar{x}_i)} b_1 \quad . \tag{A-8}$$

*A free-rolling car in a hump yard is not expected to undergo subsecond velocity changes of any significance.

†Compatible with the Nyquist criterion.

Equation (A-8) describes how a fixed error in a velocity-measuring instrument is translated to a fixed error in the slope of a $v^2$ - x plot, and eventually, via Eq. (A-2), to a fixed error in the measured car rolling resistance.

Now, let us turn our attention to the random error. Referring to Figure A-1, the scatter of the data points around their least-squares fit is measured by a quantity $S_v2$, the square of which is defined as

$$S_v^2 2 \equiv \frac{\sum_{i=1}^{n} \left(v_i^2 - V_i^2\right)^2}{n - 2} \quad . \qquad \text{(A-9)}$$

According to the statistical theories,* the magnitude of this quantity directly affects the variance of the slope of the linear fit in the following way:

$$S_{b_1}^2 = \frac{S_v^2 2}{\sum_{i=1}^{n} (x_i - \bar{x}_i)^2} \quad , \qquad \text{(A-10)}$$

where

$$\bar{x}_i \equiv \frac{\sum_{i=1}^{n} x_i}{n} \quad . \qquad \text{(A-11)}$$

The variance of slope, in turn, determines the expected upper and lower bounds of the slope by the following equation:

$$\left.\begin{matrix}\text{U.B. of } b_1 \\ \text{L.B. of } b_1\end{matrix}\right\} = b_1 \pm t_{(1 - \alpha/2),(n - 2)} S_{b_1} \quad , \qquad \text{(A-12)}$$

where the t function is referred to as the student's t function. The numerical values of this function are tabulated in terms of degree of confidence (expressed as $1 - \alpha/2$) and degree of freedom (n - 2, where n is the number of data points). The tabulated values of the t function can be found in many statistics books.

The difference between the upper bound of $b_1$ and $b_1$, or that between the lower bound of $b_1$ and $b_1$, is of course the expected error in $b_1$ that we are seeking. Since this error has its origin in the random scatter of the data, we shall denote it by $\Delta b_r$, In other words,

$$\Delta b_r = t_{(1 - \alpha/2),(n - 2)} S_{b_1}$$

$$= t_{(1 - \alpha/2),(n - 2)} \sqrt{\frac{S_v^2 2}{\sum_{i=1}^{n} (x_i - \bar{x}_i)^2}} \quad . \qquad \text{(A-13)}$$

The second equality follows from Eq. (A-10).

*Ostle, B., and R. W. Mensing, Statistics in Research, 3d ed., pp. 169-173 (Iowa State University Press, 1975).

Before we go on combining $\Delta b_f$ and $\Delta b_r$, we need to relate $S_v^2 2$ to the instrument random-error specification $\sigma_v$. This will involve two steps. The first step makes use of the fact that over a rollability measuring section, typically 100 ft, the variation in the car's speed from one end to another is small compared with the average speed of the car. Hence

$$v_i + V_i \approx 2 V_i \approx 2V(\bar{x}_i) \quad , \qquad \text{(A-14)}$$

where $V(\bar{x}_i)$ is taken as the car's speed at midpoint of the measuring section. With this approximation, Eq. (A-9) can be rewritten as

$$S_v^2 2 = 4 V^2(\bar{x}_i) S_v^2 \quad , \qquad \text{(A-15)}$$

where

$$S_v^2 \equiv \frac{\sum_{i=1}^{n} (v_1 - V_i)^2}{n - 2} \quad . \qquad \text{(A-16)}$$

The second step is to relate $S_v$, which is a sample standard deviation, to $\sigma_v$, the population standard deviation. The relationship between the two is tied to the Chi-square ($\chi^2$) distribution. That is

$$\text{U.B. of } S_v = \sqrt{\frac{\chi^2_{\alpha/2}}{n - 1}} \sigma_v \quad , \qquad \text{(A-17)}$$

$$\text{L.B. of } S_v = \sqrt{\frac{\chi^2_{1 - \alpha/2}}{n - 1}} \sigma_v \quad . \qquad \text{(A-18)}$$

The $\chi^2$ distribution, similar to the t function, is tabulated in terms of degree of confidence and degree of freedom. To be conservative (that is, to specify a lower value for $\sigma_v$) we shall use Eq. (A-18).

Substituting Eqs. (A-18) and (A-15) into (A-13), we obtain

$$\Delta b_r = 2\sigma_v V(\bar{x}_i) t_{(1-\alpha/2),(n-2)} \sqrt{\frac{\chi^2_{1-\alpha/2}}{(n-1) \sum_{i=1}^{n} (x_i - \bar{x}_i)^2}} \quad . \qquad \text{(A-19)}$$

The standard way of combining $\Delta b_f$ and $\Delta b_r$ is by root-sum-square:

$$\Delta b = \sqrt{\Delta b_f^2 + \Delta b_r^2} \quad . \qquad \text{(A-20)}$$

To summarize, Eq. (A-20) together with Eqs. (A-8) and (A-19) describe how fixed and random errors in a velocity-measuring instrument are translated to an error in the slope of a $v^2$ - X plot, and eventually, via Eq. (A-2), to an error in the measured car rolling resistance. In the present application, we shall use this relationship in reverse. That is, we shall calculate the required $\varepsilon_f$ and $\sigma_v$ to limit the uncertainty in car rolling resistance to within ±0.5 lb/ton.

For such a calculation, we need to make an assumption about the relative magnitude of $\varepsilon_f$ and $\sigma_v$. From a separate analysis, we determined that with an instrument such as a Doppler radar, the random error over a 100-ft measuring section is expected to be about ten times smaller than the fixed error. This fact will be used to facilitate the calculations. It is to be noted that the resulting error requirements are not very sensitive to this ratio of $\varepsilon_f$ to $\sigma_v$. Considering the approximate nature of the error analysis, the numerical results to be obtained below would be applicable even if this ratio were 3 instead of 10.

We shall now calculate the quantitative results for three different segments of the track.

BETWEEN CREST AND MASTER RETARDER

The following typical values are assumed:

- Grade, G = 4%
- Length of measuring section, $x_n - x_1 = 100$ ft
- Mean car speed, $V(\bar{x}_i) = 25$ ft/sec.

With a sampling rate of 2 Hz, the following values can either be calculated or obtained from statistical tables:

$n = 9$

$$\sum_{i=1}^{9} (x_i - \bar{x}_i)^2 = 9375 \text{ ft}^2$$

$t = 2.37$

$\chi^2 = 17.5$

The values for t and $\chi^2$ are associated with a confidence level of 95 percent.

Table A-1 can be prepared by using Eqs. (A-8), (A-19), and (A-20).

TABLE A-1--ALLOWED VELOCITY ERRORS BETWEEN CREST AND MASTER RETARDER

| Car Rolling Resistance | Slope in Fig. A-1 | Allowed Uncertainties in Slope | Allowed Velocity Errors | |
|---|---|---|---|---|
| R (lb/ton) | $b_1$ (ft/sec$^2$) | $\Delta b_1$ To Limit $\Delta R$ to ±0.5 lb/ton | $\varepsilon_f$ (ft/sec) | $\sigma_r$ (ft/sec) |
| 2 | 2.51 | $5 \times 10^{-4}$g | 0.060 | 0.0060 |
| 6 | 2.38 | $5 \times 10^{-4}$g | 0.061 | 0.0061 |
| 12 | 2.19 | $5 \times 10^{-4}$g | 0.064 | 0.0064 |
| 18 | 2.00 | $5 \times 10^{-4}$g | 0.067 | 0.0067 |

IN THE SWITCH AREA

The following typical values are assumed:

- Grade, G = 1%
- Length of measuring section, $x_n - x_1 = 100$ ft
- Mean car speed, $V(\bar{x}_i) = 15$ ft/sec.

With a sampling rate of 2 Hz, the following values can either be calculated or obtained from statistical tables (95 percent confidence level):

$n = 14$

$$\sum_{i=1}^{14} (x_i - \bar{x}_i)^2 = 12272 \text{ ft}^2$$

$t = 2.18$

$\chi^2 = 24.7$

Table A-2 is then similarly prepared.

TABLE A-2--ALLOWED VELOCITY ERRORS IN THE SWITCH AREA

| Car Rolling Resistance | Slope in Fig. A-1 | Allowed Uncertainties in Slope | Allowed Velocity Errors | |
|---|---|---|---|---|
| R (lb/ton) | $b_1$ (ft/sec$^2$) | $\Delta b_1$ To limit $\Delta R$ to ±0.5 lb/ton | $\varepsilon_f$ (ft/sec) | $\sigma_v$ (ft/sec) |
| 2 | 0.580 | $5 \times 10^{-4}$g | 0.14 | 0.014 |
| 6 | 0.451 | $5 \times 10^{-4}$g | 0.16 | 0.016 |
| 12 | 0.258 | $5 \times 10^{-4}$g | 0.18 | 0.018 |
| 18 | 0.064 | $5 \times 10^{-4}$g | 0.20 | 0.020 |

ON THE CLASS TRACK

The following typical values are assumed:

- Grade, G = 0.1%
- Length of measuring section, $x_n = x_1 = 100$ ft
- Mean car speed, $(V(\bar{x}_i) = 6$ ft/sec.

With a sampling rate of 2 Hz, the following values can either be calculated or obtained from statistical tables (95 percent confidence level):

$n = 35$

$$\sum_{i=1}^{35} (x_i - \bar{x}_i)^2 = 30845 \text{ ft}^2$$

$\chi^2 = 52.0$

Table A-3 is then similarly prepared.

TABLE A-3--ALLOWED VELOCITY ERRORS ON THE CLASS TRACK

| Car Rolling Resistance | Slope in Fig. A-1 | Allowed Uncertainties in Slope | Allowed Velocity Errors | |
|---|---|---|---|---|
| R (lb/ton) | $b_1$ (ft/sec$^2$) | $\Delta b_1$ To Limit $\Delta R$ to ±0.5 lb/ton | $\varepsilon_f$ (ft/sec) | $\sigma_v$ (ft/sec) |
| 2 | 0 | $5 \times 10^{-4}$g | 0.96 | 0.096 |
| 6 | -0.129 | $5 \times 10^{-4}$g | 0.35 | 0.035 |
| 12 | -0.322 | $5 \times 10^{-4}$g | 0.15 | 0.015 |
| 18 | -0.515 | $5 \times 10^{-4}$g | 0.09 | 0.009 |

CONCLUSION

Within the stated assumptions, the above analysis gives the required accuracies for any car velocity measuring instrument for achievement of ±0.5 lb/ton accuracy in rolling resistance:

| Track Segment | Allowed Fixed Error (ft/sec) | Allowed Random Error (ft/sec) |
|---|---|---|
| Between crest and master retarder | ±0.05 | ±0.005 |
| In the switch area | ±0.1 | ±0.01 |
| On the class track | ±0.1 | ±0.01 |

# INNOVATIVE CONCEPTS FOR NEXT-GENERATION YARDS

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## 1.0 Introduction

The past 20 years have witnessed dramatic changes in the technology and operation of classification yards, particularly with the introduction of large-scale computerization. The technology which will influence the yards of the next 20 years may or may not exist now, but in either case it is difficult to conceive of any yard innovations which will have as powerful an impact during this period as automation has had in the past 20 years.

This paper reports on the first phase of a study to investigate the most promising innovations in yard technology which can be implemented by the end of the twentieth century. Such technology forecasting on a 20-year horizon is risky, particularly in a period of rapid change. The success or failure of any individual innovation will depend on its economics (both costs and benefits relative to current systems), and economic factors have been particularly elusive to predict. Certainly 10-year-old estimates of current prices of petroleum products and electronic components, to name two examples, were extremely wide of the mark. Rapid economic or technological changes within the next few years could quickly invalidate the best current predictions about the yard technology of 20 years hence.

The most dramatic changes to yards may well be economic, as the current generation of innovative technology becomes available at lower prices and thereby becomes cost-effective for a larger number of yards. Prices of electronic equipment and of data processing have been declining substantially and are expected to continue to decline, while at the same time the monetary value of the benefits which can be gained from improved yard operations (savings in fuel, labor and car service times) have been increasing. This combination of effects is likely to make some innovations which now seem marginally worthwhile become highly advantageous before long.

The scope of this study is defined to include only yard technology, and not the effects of changes to railroad-wide information systems or to the fleet of cars. Innovations in those areas may lead to many more radical changes in yard design and operation than any of the innovations which are implemented only in individual yards. For example, some of the innovative concepts for braking and coupling systems described in Ref. 1 could revolutionize classification yards once they are implemented on a substantial portion of the car fleet. Similarly, improved information handling railroad-wide could greatly facilitate yard operations and lead to substantial redistribution of the sorting work performed by yards. The benefits of information-system innovations such as centralized car and crew scheduling must be evaluated at the system level, and not at the level of the individual yard.

The remainder of this paper describes the framework which has been established for evaluating innovations in yard technology. Section 2 defines those aspects of yard operation which one would try to improve by applying innovative concepts. Once these "problems" are defined, the solutions can be sought from among the available technologies, rather than having the solutions seek problems they can solve. Section 3 reviews the innovative concepts which have been identified for later evaluation. The yard operating scenarios for which these innovations will be evaluated and the performance measures for that evaluation are discussed in Section 4. The evaluation and selection of the most promising concepts will be reported at a later date.

## 2.0 Yard Improvement Goals

Table 2.1 presents a list of generic goals for improving the operation of classification yards by increasing yard reliability, efficiency, and safety and reducing costs. These were derived from a systematic examination of all aspects of yard operation. Many of these goals are obvious, but they can be used as a trigger for deriving new innovations and for evaluating potentially useful existing innovations.

The first set of goals, covering the yard in general, concerns issues which are not specifically related to train arrival, classification, or make-up. They include safety, environment, energy consumption, inspection, service, and communications, as well as car handling issues such as interference and changes in traffic patterns. A wide variety of innovations could conceivably satisfy these goals.

Table 2.1 Yard Improvement Goals

The Yard in General

- Maximize safety to employees
- Minimize effect of environmental conditions on yard operations
- Minimize effect of yard operations on the environment (noise, air and water pollution)
- Maximize efficiency of communication both among employees and between employees and information
- Minimize interference among train arrival, classification, and departure activity
- Balance capacities of car arrival, classification, and departure systems
- Maximize ability to handle changes in traffic patterns, train schedules, and blocking strategies (flexibility)
- Maximize ease of servicing locomotives, cabooses, and bad order cars
- Maximize ease of car inspection
- Minimize energy use (especially petroleum)
- Minimize operating and capital costs

Train and Car Arrival

- Maximize accuracy of train arrival time estimate
- Maximize accuracy of advance train consist information
- Maximize speed and reliability of recording waybill information for arriving cars
- Minimize time required to set arriving cars
- Maximize capacity of receiving yard

Classification

- Maximize effectiveness of receiving policy
- Maximize effectiveness of blocking strategy and classification policy
- Maximize speed and reliability in moving cars to desired locations
- Minimize interference among cars being moved
- Minimize time required to undo problems and mistakes
- Maximize capacity (cars sorted per day)

Make-up and Departure

- Maximize effectiveness of make-up and departure policy
- Minimize time required to make-up train
- Minize interference among activity for make-up of several trains
- Minimize time required for connecting air brakes, locomotives, caboose, and other departure preparation

Table 3.1 Yard Innovations — Yard Information Systems

- Intrayard inventory
- Information presentation tailored to specific operating decisions
- Simulation of the near future
- Computer generated forms and work menus
- Computerized operating decisions
- Crew management system

Table 3.2 Yard Innovations — Automation

- Automatic car positioner at hump
- Negative grade hump lead
- Automatic pin puller
- Hand-held or cab-mounted switch control
- Remote control hump/switch engines
- Automatic air-hose connector
- Automatic vehicle location system

Table 3.3 Yard Innovations — Car Identification

- REIS - microwave pulse generator
- Radio Transponder (GM)
- SICARID - microwave passive transponder
- Automated entry of waybill info
- Hand held wireless computer terminal

Table 3.4 Yard Innovations — Operating Strategies

- Dynamic Classification Track Allocation
- Multistage Switching

Table 3.5 Yard Innovations — Layout

- Herringbone
- Two stage Hump
  - -Minihump
- Trim/key Departure Yard
- Switchback Hump

Table 3.6 Yard Innovations — Energy and Environmental Considerations

- Retarder Noise Reduction
- Journal Bearing Heaters
- Hot Water Pipe Heater for Snow Removal
- Energy Efficient Switch Engines
  - Yard Electrification
  - Regenerative Braking
  - Flywheel Energy Storage

### 3.2.5 Energy and Environmental Considerations

Retarder noise is the most studied and talked about topic regarding rail yard environmental impact. Proposed solutions of the past include noise deflectors, sheds and lubricants. Another method of reducing retarder noise is the use of new materials in the jaws (friction surfaces) of clasp retarders. Elastomeric materials and some innovative metal alloys have been suggested for both reducing retarder noise and improving the degree of speed control exercised by clasp retarders.

Switch engines are the largest consumers of energy in yard operations. New technologies or new uses of existing technologies could reduce switch engine fuel consumption. An entire yard could be electrified, so that all switch engines would be electric and receive power from a catenary. No complete discussion or study has yet been found that compares the operational benefits with the capital costs of electrification.

Yard switching operations involve so much start-and-stop maneuvering that the potential benefits of regenerative braking could be very considerable. The energy which is normally dissipated in braking is a significant fraction of the energy consumed. This energy could be stored in an onboard flywheel or, in an electrified system, returned to the electric distribution network by using the switch engine's motors as generators.

## 4.0 Operating Scenarios and Performance Measures

A convenient and useful way to evaluate yard innovations and their potential applicability for use in the future is to apply them to a set of scenarios covering all commonly found situations and evaluating their impacts on performance. The set of scenarios would ideally represent all common yard types so that innovations could be compared with a full range of operating situations. Performance measures should be those which best represent the operating effectiveness of an existing or proposed yard as a whole. The following sections derive appropriate scenarios and performance measures.

### 4.1 Operating Scenarios

The U.S. railroad system includes an immense variety of yards, making it difficult to derive a set of categories which covers them all completely. One way of categorizing yards is by capacity, distinguishing among high (i.e., greater than 2000 cars/day), medium (1000 to 2000 cars/day), or low (less than 1000 cars/day). This is simplistic and not entirely adequate because the role of the yard in the rail system and the type of sorting work required are not reflected. A categorizing system incorporating both capacity and the role of the yard in the rail system is desired.

Four basic categories are proposed here as yard scenarios. Cases I and II are high-capacity yards which play a key role in the entire rail system and can be considered "hub" yards. A hub would serve two or more intersecting high volume main lines which handle major traffic flows in the system. Case I is a high-capacity hub yard in a remote location, while Case II is a hub yard at a major urban/industrial center. The distinction between the two types of hubs is necessary because a remote yard is likely to classify through traffic with little, if any, local traffic, while an urban yard will have much local traffic.

Case III is a medium capacity collector/feeder yard. Such a yard would serve lower volume lines or a medium-sized industrial area. Examples of the former might be the junction of branch lines with a main line or the intersection of several lower volume main lines. The distinction between the two is not made here the way it is in the large hub case because local service to customers along lower volume lines is similar to local service to an industrial area. The amount of local service would be relatively high but a significant amount of handling would still be through traffic.

Case IV covers the low volume end of the spectrum and is referred to here as a lowcapacity yard. A low-capacity yard would serve light traffic lines or a few industrial customers. The geographic area covered would be small and very little through traffic would be handled.

Table 4.1 presents these four scenarios, described by functional characteristics and yard type (hump or flatyard). It should be noted that "capacity" refers to the initial capacity prior to implementation of the innovative concepts to be evaluated. Some of the characteristics, such

Table 4.1 Four Requirement Scenarios and Their Characteristics

| CHARACTERISTICS | CASE I HIGH CAPACITY HUB YARD (REMOTE) | CASE II HIGH CAPACITY HUB YARD (URBAN) | CASE III MED. CAPACITY COLLECTOR/FEEDER YARD | CASE IV LOW CAPACITY YARD |
|---|---|---|---|---|
| YARD TYPE | HUMP | HUMP | HUMP/FLAT | HUMP/FLAT |
| DAILY INBOUND TRAFFIC | HIGH | HIGH | MEDIUM | LOW |
| DAILY INBOUND VARIABILITY | LOW | LOW | LOW | HIGH |
| 24-HOUR ARRIVAL PATTERN | SMOOTH | SMOOTH | BUNCHED | BUNCHED |
| PERCENT SPECIAL CARS | HIGH | HIGH | LOW | LOW |
| NUMBER OF BLOCKS FORMED | HIGH | HIGH | MEDIUM | LOW |
| PERCENT SMALL BLOCKS | LOW | HIGH | HIGH | HIGH |
| BLOCK SIZE VARIABILITY | HIGH | HIGH | LOW | LOW |
| NUMBER OF DAILY TRAIN DEPARTURES | HIGH | HIGH | MEDIUM | LOW |
| 24-HOUR DEPARTURE PATTERN | SMOOTH | BUNCHED | BUNCHED | SMOOTH |
| NUMBER OF TRAINS WITH 5 OR MORE BLOCKS | LOW | HIGH | HIGH | LOW |
| TRAIN MAKE-UP FLEXIBILITY | FLEXIBLE | INFLEXIBLE | INFLEXIBLE | FLEXIBLE |
| LAND | UNCON-STRAINED | CON-STRAINED | UNCON-STRAINED | CON-STRAINED |
| CLIMATE | NO COLD WEATHER | COLD WEATHER | NO COLD WEATHER | COLD WEATHER |
| NOISE | UNREGU-LATED | REGU-LATED | UNREGU-LATED | REGU-LATED |

as Daily Inbound Traffic, are directly related to the attributes of the particular scenario, while others, such as climate, are not and are given arbitrary values. The following paragraphs describe each scenario and its relevant characteristics in more detail.

Cases I and II are high capacity yards, which automatically implies a hump yard arrangement and high values for Daily Inbound Traffic, Number of Blocks Formed and Number of Daily Train Departures. Percent Special Cars is high because most repair work occurs at larger yards and because high priority trains are more likely to originate/terminate at larger yards.

Differences between Case I and II characteristics stem from differences in location and traffic character. Percent Small Blocks and Number of Trains with 5 or More Blocks are low for Case I due to little local traffic, and are high for Case II because of much local traffic. An urban location is more likely to have land constraints and noise regulations, as indicated in the table.

Characteristics for Cases III and IV have been chosen in a similar manner, yet some clarifications are necessary. Number of Trains with 5 or More Blocks is high for Case III due to a high percentage of local traffic, but is low for Case IV since the number of industrial customers is low. Daily Inbound Variability is high for a small yard because the traffic level is very susceptible to fluctuating traffic patterns of its few industrial customers. Yard type can be either hump or flat for both cases.

An attempt has been made to select scenarios so that most common yard types and situations are represented. It is not possible to represent all situations, however, because all yards are different and selecting a large set of scenarios would be too cumbersome for the study at hand. This set of four scenarios can best be used as a framework for further study, in that categorizing any existing yard would probably involve choosing the closest case and changing a few of the characteristic values to create a subcase. For example, a high-capacity hub yard may have little local traffic yet be land-constrained in a small urban area. It would be considered a Case I yard with a constrained land characteristic. Subcases can be created and used as the nees arises by changing individual characteristics within a scenario.

## 4.2 Measures of Performance

Before a complete analysis and evaluation of yard innovations is possible, it is necessary to define a set of performance measures. These measures should be those which best evaluate the operating effectiveness of an existing or proposed yard as a whole, and will be used to determine the effects of innovative yard concepts. The measures chosen can be divided into six groups: (1) Operating Capability, (2) Level of Service, (3) Cost, (4) Personnel Safety, (5) Error Incidence, and (6) Environment. These will be discussed in the following sections, along with an explanation of their limitations and common measures not included.

### 4.2.1 Operating Capability

A measure of operating potential, or capability, is needed to assess the amount of work a given yard could conceivably perform. Three types of operating capability are defined here. The first is throughput capacity, a raw measure of the practical maximum number of cars the yard can handle per day. Throughput capacity is somewhat judgemental, so a practical throughput capacity is typically defined as the traffic volume which can be handled without suffering a serious (or substantial) degradation in service.

The second yard operating capability is the number of blocks, or classifications, a yard is able to make. This number is needed because it measures the amount of sorting work the yard can do. Some innovations may increase the number of classifications possible without significantly increasing throughput capacity, for example. The number of classifications will depend strongly on the operation of the yard as well as the yard design itself.

A third yard operating capability is its flexibility in adapting to traffic changes and anomalies. A yard having a layout or operation based on specific types of traffic or traffic levels will be more sensitive to changes. Innovations which simplify equipment needs or reduce labor will reduce sensitivity to breakdowns or work stoppages.

### 4.2.2 Car Handling

Car-handling performance measures are those which help assess how efficiently and effectively cars are being handled by a yard. Dwell time is by far the most common yard performance measure. Other terms commonly used include detention time and delay time. Dwell time is here defined as the elapsed time between a car's arrival at and its departure from a classification yard. The emphasis here is on the <u>distribution</u> of dwell times, rather than average dwell time alone, because it is simultaneously desirable to reduce average dwell time, the variability of dwell times (as expressed by standard deviation), and the maximum dwell time. The three measures of dwell time to be used are the mean, standard deviation, and maximum.

Another common measure of these problems is the probability of missed connections, which is the average percentage of the cars handled per day which miss their scheduled connection. Missed connections can be caused by a variety of problems both internal and external to the yard.

A reduction in classification errors could greatly improve yard performance, and therefore

4. "Railroad Classification Yard Technology: An Introductory Analysis of Functions and Operations," Report No. FRA/ORD-75-55, Federal Railroad Administration, May 1975.

5. Railroad Research Bulletin, Report No. FRA/ORD-80/38, Vol. 7, No. 1, Federal Railroad Administration, Spring 1980.

6. "Assessment of Classification Yard Speed Control Systems," Report No. FRA/ORD-80/90, Federal Railroad Administration, December 1980.

7. Gallacher, B.G., Engineer of Design (retired., Southern Pacific Transportation Co., personal communication, December 1980.

8. Jaquette, S., Staff Engineer, Systems Control, Inc., personal communication, November 1980.

9. Jakobsberg, W., "Applications of Automatic Vehicle Location Systems to Railroad Operations," ASME No. 73-RT-6, presented at IEEE-ASME Joint Railroad Conference, St. Louis, Mo., April 1973.

10. "Automatic Car Identification: Nonoptical Systems in or Near Testing," Railway Age, August 11, 1980.

11. "On the Trail of Perpetual Data Acquisition," Material Handling Engineering, p. 31, September 1979.

12. "Wireless Data Input with Infrared Light," Siemens Review, February 1980.

13. Hoppe, C.W., "Do We Need Yards?" Railway Management Review-Quarterly, No. 3, p. A1, 1972.

14. Kusano, K., "The Opening of the Modernized Marshalling Yard, Kitakami," Japanese Railway Engineering, Vol. 19, No. 3, 1979.

15. Christianson, H.B., "Should Future Yards Classify Freight in Two Stages?" Railway Management Review-Quarterly, No. 3, p. A20, 1972.

16. Progressive Railroading, July 1976, entire issue.

17. Seshagiri, M., "Switchback Hump - A New Marshalling Tool," Rail International, p. 219, April 1976.

# ABSTRACTS OF RELATED RESEARCH REPORTS

# CURRENT RESEARCH REPORTS

**Technical Report Documentation Page**

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| FRA/ORD 81/20.1 | | |

**4. Title and Subtitle**
RAILROAD CLASSIFICATION YARD TECHNOLOGY MANUAL--
VOLUME I: YARD DESIGN METHODS

**5. Report Date**
February, 1981

**6. Performing Organization Code**

**7. Author(s)** P. J. Wong, M. Sakasita, W. A. Stock, C. V. Elliott, and M. A. Hackworth

**8. Performing Organization Report No.**
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**9. Performing Organization Name and Address**
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Department of Transportation
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**13. Type of Report and Period Covered**
Final Report

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**15. Supplementary Notes**

**16. Abstract**

This volume (Volume I) documents the procedures and methods associated with the design of railroad classification yards. Subjects include: site location, economic analysis, yard capacity analysis, design of flat yards, overall configuration of hump yards, hump yard track and switch layout, hump profile design, and hump trim-end design.

Volume II is concerned with the design and specification of the yard computer systems, i.e., yard inventory and process control computer systems.

**17. Key Words**
Railroad yard: Design, operations, performance, evaluation, hardware, computers, modeling, cost

**18. Distribution Statement**
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| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
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**4. Title and Subtitle**
RAILROAD CLASSIFICATION YARD DESIGN METHODOLOGY STUDY
East Deerfield Yard Rehabilitation: A Case Study

**5. Report Date** February, 1980

**6. Performing Organization Code**


**7. Author(s)** M. Sakasita, M. A. Hackworth, P. J. Wong


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**13. Type of Report and Period Covered** Interim Report

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Prepared in cooperation with V. V. Mudholkar and D. B. Koretz of Boston and Maine Corporation.


**16. Abstract**

This interim report documents the application of a railroad classification yard design methodology to Boston and Maine's East Deerfield Yard Rehabilitation. This case study effort represents Phase 2 of a larger effort to develop a yard design methodology, and to document the methodology in the form of a yard design manual.

The application of the yard design methodology to CONRAIL's Elkhart Yard is described in a separate interim report.



**17. Key Words**
Railroad yard--Design, operations, performance, evaluation, hardware, computers, modeling, cost


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4. Title and Subtitle
RAILROAD CLASSIFICATION YARD DESIGN METHODOLOGY STUDY
Elkhart Yard Rehabilitation: A Case Study

5. Report Date
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7. Author(s) C. V. Elliott, M. Sakasita, W. A. Stock, P. J. Wong

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16. Abstract

This interim report documents the application of a railroad classification yard design methodology to CONRAIL's Elkhart Yard Rehabilitation. This case study effort represents Phase 2 of a larger effort to develop a yard design methodology, and to document the methodology in the form of a yard design manual.

The application of the yard design methodology to Boston and Maine's East Deerfield Yard is described in a separate interim report.

17. Key Words
Railroad yard--Design, operations, performance, evaluation, hardware, computers, modeling, cost

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| 1. Report No. FRA/ORD-80/90 | 2. Government Accession No. PB 81-161556 | 3. Recipient's Catalog No. |
| 4. Title and Subtitle RAILROAD CLASSIFICATION YARD TECHNOLOGY--ASSESSMENT OF CAR SPEED CONTROL SYSTEMS | | 5. Report Date December 1980 |
| | | 6. Performing Organization Code |
| 7. Author(s) R. L. Kiang, D. W. Ploeger, W. A. Stock, J. Eckerle, and P. J. Wong | | 8. Performing Organization Report No. SRI Project 7663 |
| 9. Performing Organization Name and Address SRI International 333 Ravenswood Avenue Menlo Park, California 94025 | | 10. Work Unit No. (TRAIS) |
| | | 11. Contract or Grant No. DOT-FR-8084 |
| 12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Railroad Administration Office of Research and Development 400 Seventh Street, S.W., Washington D.C. 20590 | | 13. Type of Report and Period Covered Final Report July 1978-June 1980 |
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15. Supplementary Notes

A presentation of this final report is scheduled for May 6-7, 1981, at the Classification Yard Technology Workshop to be held in St. Louis, Missouri, and sponsored by the Federal Railroad Administration (Code RRD-23) and the American Railway Engineering Association.

16. Abstract

The scope of this study has encompassed an evaluation of fourteen yard speed control devices, an identification of four generic speed control systems, a qualitative assessment of the four systems, and finally a quantitative analysis of three hypothetic yards each employing a system that is considered promising. These three systems are (1) the advanced clasp retarder system, (2) the quasi-continuous control system, and (3) a hybrid system incorporating quasi-continuous control. No ranking of these three systems is possible because each has its advantages and disadvantages; and one system may be more suitable than the others under a particular circumstance.

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| 17. Key Words hump yard, retarder, automatic speed control system, clasp retarder, quasi-continuous control | 18. Distribution Statement Available through National Technical Information Services (NTIS) |

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| 1. Report No. FRA/ORD-81/18 | 2. Government Accession No. | 3. Recipient's Catalog No. |
| 4. Title and Subtitle Railroad Classification Yard Technology: Noise Control | | 5. Report Date March 1981 |
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| 7. Author(s) E. Stusnick, M. Montroll, V. Kohli | | 8. Performing Organization Report No. |
| 9. Performing Organization Name and Address Wyle Laboratories * Wyle Research/Suite 404 2361 Jefferson Davis Highway Arlington, Virginia 22202 | | 10. Work Unit No. (TRAIS) RR 016/R0308 |
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| 12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Railroad Administration Office of Research and Development Washington, DC 20590 | | 13. Type of Report and Period Covered Final Report July 1980 - March 1981 |
| | | 14. Sponsoring Agency Code RRD-12 |

15. Supplementary Notes

* UNDER CONTRACT TO: U.S. Department of Transportation
Transportation Systems Center
Kendall Square, Cambridge MA 02142

16. Abstract

This report provides the railroad yard designer with a basic understanding of the principles involved in controlling noise, either in the design of new yards or in revisions to existing yards. The material presented allows the designer to better understand information contained in more advanced noise control writings should he undertake detailed noise control designs or elect to interact with acoustic experts in the development of such designs. The report contains discussions of sound fundamentals, measurement and analysis instrumentation, measurement procedures, current regulations, railroad noise sources and noise control methods.

NOTE:

A presentation of this final report is scheduled for May 6-7, 1981, at the Classification Yard Technology Workshop to be held in St. Louis, Missouri, and sponsored by the Federal Railroad Administration (Code RRD-23) and the American Railway Engineering Association.

| | |
|---|---|
| 17. Key Words NOISE, SOUND, RAILROAD NOISE, NOISE MEASUREMENT, NOISE PROPAGATION, SOUND MEASUREMENT ,YARDS | 18. Distribution Statement Available through National Technical Information Services (NTIS) Springfield, VA. 22161 |

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| 1. Report No. FRA/ORD-81/01 | 2. Government Accession No. | 3. Recipient's Catalog No. |
| 4. Title and Subtitle RAILROAD CLASSIFICATION YARD TECHNOLOGY Evaluation of Approaches to Car Presence Detection | | 5. Report Date March, 1981 |
| | | 6. Performing Organization Code |
| | | 8. Performing Organization Report No. |
| 7. Author(s) D. S. Wilson, N. J. Petersen | | |
| 9. Performing Organization Name and Address Shaker Research Corporation Northway 10 Executive Park Ballston Lake, N. Y. 12019 | | 10. Work Unit No. (TRAIS) |
| | | 11. Contract or Grant No. DOT/FR-8199 |
| 12. Sponsoring Agency Name and Address Federal Railroad Administration Office of Research and Development 400 Seventh Street, S.W. Washington, D.C. 20590 | | 13. Type of Report and Period Covered FINAL REPORT Oct. 1978 to Mar. 1981 |
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15. Supplementary Notes
A presentation of this final report is scheduled for May 6-7, 1981, at the Classification Yard Technology Workshop to be held in St. Louis, Missouri, and sponsored by the Federal Railroad Administration (Code RRD-23) and the American Railway Engineering Association.

16. Abstract
The techniques utilized to detect the presence of railroad cars in Railroad Classification Yards are discussed. The report addresses application requirements, performance characteristics, life characteristics and failure modes for commonly used detector types. A study is presented on alternate techniques for detecting railroad cars, including field and laboratory evaluations. A Specification Guide defining the requirements for presence detectors, for use by the railroad industry, is appended to the report.

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|---|---|
| 17. Key Words RAILROAD YARD PERFORMANCE WHEEL DETECTORS AXLE COUNTERS PRESENCE DETECTORS | 18. Distribution Statement Document is available to the public through the National Technical Information Service, Springfield, VA 22161 |

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| FRA/ORD-80/12 | PB 80-176621 | |

| 4. Title and Subtitle | 5. Report Date |
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| EMC CONSIDERATIONS IN CLASSIFICATION YARD DESIGN | January 1980 |
| | 6. Performing Organization Code |
| 7. Author(s) | 8. Performing Organization Report No. |
| Daniel J. O'Neill of IIT Research Institute | ECAC-PR-79-035 |
| 9. Performing Organization Name and Address | 10. Work Unit No. (TRAIS) |
| DoD Electromagnetic Compatibility Analysis Center<br>North Severn<br>Annapolis, MD 21402 | 11. Contract or Grant No.<br>AR-74311 Work Statement |
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| U.S. Department of Transportation<br>Federal Railroad Administration (RRD-12)<br>400 7th Street, SW<br>Washington, DC 20590 | Final Report |
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15. Supplementary Notes

16. Abstract

The automated freight classification yard is composed of many electrical and electronic devices working in a complex interrelationship, with the goal of safe and efficient transportation of goods. Since many of these devices potentially emit and/or are susceptible to electromagnetic energy, thus degrading equipment reliability and overall safety, electromagnetic compatibility considerations are of great concern in the design of new yards or the upgrade of presently existing yards. Important railroad electromagnetic compatibility considerations are discussed in a tutorial manner. In addition, measurement techniques used to obtain source and susceptibility data, and techniques to successfully mitigate electromagnetic interference are presented.

| 17. Key Words | 18. Distribution Statement |
|---|---|
| ELECTROMAGNETIC COMPATIBILITY<br>AUTOMATED FREIGHT RAILROAD CLASSIFICATION YARDS<br>FEDERAL RAILROAD ADMINISTRATION, OFFICE OF RESEARCH AND DEVELOPMENT | Document is available to the public through the National Technical Information Service, Springfield, VA 22161 |

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| FRA/ORD-80/57 | | |

| 4. Title and Subtitle | 5. Report Date |
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| Railroad Electromagnetic Compatibility in Classification Yards (Video Tape) | May 1980 |
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| 7. Author(s) | 8. Performing Organization Report No. |
| Thomas L. Freeman of IIT Research Institute | |
| 9. Performing Organization Name and Address | 10. Work Unit No. (TRAIS) |
| DOD Electromagnetic Compatibility Analysis Center<br>North Severn<br>Annapolis, MD 21402 | 11. Contract or Grant No.<br>AR 74311 Work Statement |
| 12. Sponsoring Agency Name and Address | 13. Type of Report and Period Covered |
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| | 14. Sponsoring Agency Code<br>FRA/ORD-12 |

15. Supplementary Notes

3/4" Video Cassette

16. Abstract


Illustrated explanations of electromagnetic compatibility (EMC) and electromagnetic interference (EMI) in relation to the railroad classification yard are presented. The investigation by the Electromagnetic Compatibility Analysis Center (ECAC) of EMI/EMC considerations in classification yards is introduced. An ECAC measurement trip to the Conrail yard at Conway, PA is used to explain the measurement goals and methodology.

The measurement techniques demonstrated are clear to understand and relatively routinely performed. They have general applicability for use by railroad communication and signal (C&S) personnel in similar situations. The equipment used for the measurements is often available at the C&S shops or is available from numerous instrument rental companies.


| 17. Key Words | 18. Distribution Statement |
|---|---|
| Electromagnetic Compatibility,<br>Classification Yards,<br>Communication, Signals | Video tape is available on loan basis (2 weeks). Forward request on your organization letter head to sponsoring agency (Block 12): Specify primary and secondary dates desired and size audience. |

| 19. Security Classif. (of this report) | 20. Security Classif. (of this page) | 21. XXXXXXXX | 22. Price |
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# ADDITIONAL REPORTS

Technical Report Documentation Page

| | | |
|---|---|---|
| 1. Report No.<br>FRA/ORD-78/15.III | 2. Government Accession No. | 3. Recipient's Catalog No. |
| 4. Title and Subtitle<br>Optical Automatic Car Identification (OACI)<br>Optical Properties of Labels | | 5. Report Date<br>March 1979<br>6. Performing Organization Code |
| 7. Author(s)<br>Hector C. Ingrao | | 8. Performing Organization Report No.<br>CSC-77-102 |
| 9. Performing Organization Name and Address<br>Cambridge Systems Corporation<br>545 Technology Square<br>Cambridge, MA 02139 | | 10. Work Unit No. (TRAIS)<br>11. Contract or Grant No.<br>DOT-FR-74292<br>13. Type of Report and Period Covered<br>Final Report<br>January - June 1977 |
| 12. Sponsoring Agency Name and Address<br>U.S. Department of Transportation<br>Federal Railroad Administration<br>Office of Research and Development<br>Washington, D.C. 20590 | | 14. Sponsoring Agency Code<br>DOT/FRA/ORD/OFS/RRD-10 |

15. Supplementary Notes

This is one of four reports which provides the final reports for the FRA/OACI Improvement Effort. Consistent with the four interim reports (Report No. FRA/ORD-77/38), the other final reports are: Advanced System Specification (78/15.I); Readability and Scanner Performance (78/15.II); System Alternatives Evaluation Model (78/15.IV).

16. Abstract

The results of a study on the optical properties of OACI labels (modules) and the review of the physical and chemical properties leading to a better understanding of the tests conducted by the CNR on IST, Standard, and overlayed labels are presented. Label operational lifetime is defined using as criteria a reduction to 5% of the original label retroreflectance during that period. Based on the IST tests conducted by CNR, the estimated operational life of those labels in that environment will be on the order of 12 years, provided that no failure in substrate or mechanical action on the label occurs. This life estimate is compatible with test data from OACI modules and raw material used in the manufacturing of modules by 3M and DuPont Companies. Solar radiation is identified as the major cause of non-reversible mechanisms determinant of OACI label operational life. Other operational and environmental factors with reversible and non-reversible components are identified. Some OACI label alternatives are suggested. Experiments and evaluations of OACI labels by the AAR and railroads are indicated.

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| 17. Key Words<br>Automatic Car Identification<br>Railroad Information Systems<br>Classification Yard Technology | 18. Distribution Statement<br>Document is available to the public through the National Technical Information Service, Springfield, VA 22161 |

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Technical Report Documentation Page

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| 1. Report No.<br>FRA/ORD-78/15.I | 2. Government Accession No. | 3. Recipient's Catalog No. |
| 4. Title and Subtitle<br>OPTICAL AUTOMATIC CAR IDENTIFICATION (OACI)<br>Volume I - Advanced System Specification | | 5. Report Date<br>DECEMBER 1978 |
| | | 6. Performing Organization Code<br>DTS-733 |
| 7. Author(s)<br>Lennart E. Long | | 8. Performing Organization Report No.<br>DOT-TSC-FRA-78-22,I |
| 9. Performing Organization Name and Address<br>U.S. Department of Transportation<br>Research and Special Programs Administration<br>Transportation Systems Center<br>Cambridge MA 02142 | | 10. Work Unit No. (TRAIS)<br>RR816/R9307 |
| | | 11. Contract or Grant No. |
| 12. Sponsoring Agency Name and Address<br>U.S. Department of Transportation<br>Federal Railroad Administration<br>Office of Research and Development<br>Washington DC 20590 | | 13. Type of Report and Period Covered<br>Final Report<br>October 1977-July 1978 |
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15. Supplementary Notes

This is one of four volumes which provide the final reports for the FRA OACI Improvement Effort. The other final reports cover the subjects of: Systems Alternatives Evaluation Model 78/15,IV (May 1978): Readability and Scanner Performance 78/15,II (March 1978); Optical Properties of Labels 78/15, III (to be published).

16. Abstract

A performance specification is provided in this report for an Optical Automatic Car Identification (OACI) scanner system which features 6% improved readability over existing industry scanner systems. It also includes the analysis and rationale which support this specification. This improved system is a result of design and test of selected modifications to existing equipment. It is projected that a cost reduction of fifty percent and a reliability improvement by a factor of three, along with a savings of seventeen hundred dollars per year due to maintainability considerations, could be realized using the new system. Sections of this report contain descriptions of test data showing the improvement in readability for degraded labels and difficult ambient conditions. Also included in this specification are guidelines for a compact, self calibrating scanner requiring no air conditioning. At the conclusion of the hardware and testing phase of the program, the modified scanner configuration was tested and demonstrated in the areas of optics, electronics, data processing, and packaging. Test results are included in this report.

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| 17. Key Words<br>Automatic Car Identification:<br>Railroad Information Systems:<br>Classification<br>Yard Technology | 18. Distribution Statement<br>DOCUMENT IS AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161 |

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| PROCEEDINGS OF THE OCTOBER 1979 WORKSHOP FOR CLASSIFICATION YARD TECHNOLOGY "A STATUS REPORT ON YARD RESEARCH" | 5. Report Date: December 1980<br>6. Performing Organization Code: PC-B |
| 7. Author(s): Ellen S. Witt, Norka Shedlock, Editors | 8. Performing Organization Report No.: PC-DOT-01 |
| 9. Performing Organization Name and Address: PACIFIC CONSULTANTS, 47 Winter Street, 4th Floor, Boston, MA 02108 | 10. Work Unit No. (TRAIS)<br>11. Contract or Grant No.: DOT-FRA 9126 |
| 12. Sponsoring Agency Name and Address: U. S. Department of Transportation, Federal Railroad Administration, Office of Research and Development, Washington, D. C. 20590 | 13. Type of Report and Period Covered: Proceedings for the workshop held in Chicago, Illinois October 30 & 31, 1979<br>14. Sponsoring Agency Code: RRD-23 |

15. Supplementary Notes

Second Classification Yard Technology Workshop will be sponsored by the Federal Railroad Administration and the American Railway Engineering Association. This workshop is scheduled for May 6-7, 1981, in St. Louis, Missouri. For more information, contact Ms. Ellen Witt of Pacific Consultants (617) 426-3967.


The Classification Yard Technology Workshop was sponsored by the Federal Railroad Administration (FRA) to present the results of current yard research under the Railroad Operational Improvements Program. The major program objectives are the development of technologies, quantification of areas for improvement, evaluation of components and systems, and improvement of effectiveness of railroad communication and control systems.

These proceedings include the technical papers, responses to the workshop questionnaire, and comments of conference participants and panel members of the following areas of research: Yard Design Methods, New Concepts in Car Speed Control, Improvements for Car Presence Detection, Measurements of Rolling Resistance, Electromagnetic Compatibility, and Yard Computer Systems.


| 17. Key Words | 18. Distribution Statement |
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| Classification Yards, Rehabilitation, Modification, Alternatives, Case Study, Speed Control System, Retarder, Presence Detectors, Rollability, Electromagnetic Compatibility (EMC), Process Control (PC) | DOCUMENT IS AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161 |

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| OPTICAL AUTOMATIC CAR IDENTIFICATION<br>Volume IV - System Alternatives Evaluation Model | May 1978 |
| | 6. Performing Organization Code |
| 7. Author(s) Anthony Kooharian | 8. Performing Organization Report No. |
| 9. Performing Organization Name and Address<br>Consultant<br>3800 N. Fairfax Dr.<br>Arlington, VA 22203 | 10. Work Unit No. (TRAIS) |
| | 11. Contract or Grant No.<br>DOT-FR-74296 |
| 12. Sponsoring Agency Name and Address<br>U.S. Department of Transportation<br>Federal Railroad Administration<br>Office of Research and Development<br>Washington, D.C. 20590 | 13. Type of Report and Period Covered<br>February 1977 - January 1978 |
| | 14. Sponsoring Agency Code<br>DOT/FRA/OR&D/OFS/RRD-10 |

15. Supplementary Notes

This is one of four reports which provides the final reports for the FRA OACI Improvement Effort. Consistent with the four interim reports (Report No. FRA/ORD-77/38), the other final reports cover the subjects of: Scanner System Performance and Cost Improvements 78/15.I (to be published); Readability and Scanner Performance 78/15.II (March1978); Optical Properties of Labels 78/15.III (to be published).

16. Abstract

The report presents the development of an analytical model together with descriptions and illustration of how it can be applied in analyzing the comparative benefits and costs of using ACI to improve typical railroad operation and control management information systems (MIS). Summaries are made of background studies of how ACI has been employed by different railroads. The system implementations at these organizations were found to vary significantly. The basic measure of the overall MIS operational effectiveness is defined. Also the report identifies and discusses basic kinds of errors which can occur relating to car handling and clerical reporting. The ACI system is described and analytical (probabilistic) representations are made for characterizing the imperfect status and performance accuracies. The report provides a qualitative discussion of the considerations underlying systematic integration of pre-car movement information produced by yard level operations with actual car movement reports produced by ACI to generate updated advance consist reports with enhanced accuracy. Four appendices covering the analytical development, procedures for applying (manual or computer) the model, and illustrations of model applications, are considered an integral part of model development.

| 17. Key Words | 18. Distribution Statement |
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| FRA/ORD-78/15.II | | |

| 4. Title and Subtitle | 5. Report Date |
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| OPTICAL AUTOMATIC CAR IDENTIFICATION (OACI)<br>Readability and Scanner Performance | March 1978 |
| | 6. Performing Organization Code |
| 7. Author's | 8. Performing Organization Report No. |
| Hector C. Ingrao and William I. Thompson III | CSC-77-101 |
| 9. Performing Organization Name and Address | 10. Work Unit No. (TRAIS) |
| Cambridge Systems Corporation<br>545 Technology Square<br>Cambridge, MA 02139 | 11. Contract or Grant No.<br>DOT-FR-74292 |
| 12. Sponsoring Agency Name and Address | 13. Type of Report and Period Covered |
| U.S. Department of Transportation<br>Federal Railroad Administration<br>Office of Research and Development<br>Washington, DC 20590 | February - June 1977 |
| | 14. Sponsoring Agency Code<br>DOT/FRA/OR&D/OFS/RRD-10 |

15. Supplementary Notes

This is one of four reports which provides the final reports for the FRA OACI Improvement Effort. Consistent with the four interim reports (Report No. FRA/ORD-77/38), the other final reports (to be published) will cover the subjects of: Scanner System Performance and Cost Improvements (78/15.I); Optical Properties of Labels (78/15.III); System Alternatives Evaluation Model (78/15.IV).

16. Abstract

The results of the Optical Automatic Car Identification (OACI) study on readability and scanner performance conducted on the Chicago Railroad Terminal Information System (CRTIS) data which includes operation from February 1 to June 15, 1977 are presented. The main purpose of this study was to determine the scanner non-read and error-read contributions to overall OACI readability measurements, the use of the calibration train concept as a method of OACI network analysis, and possible network automatic checkout. The study attempts to separate the non-read and error-read components due to the scanner performance from other label factors which affect the readability measurements. The scanner performance contribution to non-read and error-reads was estimated on the basis of scanner readability differences observed by means of calibration trains. The calibration train concept is suggested as an effective tool to evaluate OACI scanner network performance. The present study complements the one conducted in 1975 by the Federal Railroad Administration (Final Report No. FRA/ORD-76/249, May 1976). Conclusions are presented.

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| 4. Title and Subtitle | 5. Report Date |
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| FLYWHEEL ENERGY STORAGE SWITCHER<br>Volume II--Field Data | April 1979 |
| | 6. Performing Organization Code |
| 7. Author(s)<br>R. McConnell | 8. Performing Organization Report No.<br>79-15651-2 |
| 9. Performing Organization Name and Address<br>AiResearch Manufacturing Company of California<br>2525 West 190th Street<br>Torrance, Ca. 90509 | 10. Work Unit No. (TRAIS) |
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15. Supplementary Notes

16. Abstract


This is Volume II of the two-volume report, Flywheel Energy Storage Switcher Final Report. The report comprises

Volume I - Summary and Detailed Description of Analysis

Volume II - Field Data

Volume II contains supporting information and detailed data developed during switchyard and locomotive test phases.


| 17. Key Words | 18. Distribution Statement |
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| 4. Title and Subtitle FLYWHEEL ENERGY STORAGE SWITCHER Volume I--Study Summary and Detailed Description of Analysis | | 5. Report Date April 1979 |
| | | 6. Performing Organization Code |
| 7. Author(s) L.M. Cook, W.T. Curran, R. McConnell, A.K. Smith | | 8. Performing Organization Report No. 79-15651-1 |
| 9. Performing Organization Name and Address AiResearch Manufacturing Company of California 2525 W. 190th Street Torrance, California 90509 | | 10. Work Unit No. (TRAIS) |
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15. Supplementary Notes

Volume II (Report No. FRA/ORD-79/20.2), 363 pages, contains appendixes that comprise field data developed during switchyard and locomotive test phases.

16. Abstract


An indepth study of the application of flywheel energy storage to the railroad switchyard locomotive was conducted to determine the practicality and viability of such a system. The system, as originally conceived, required the use of separately excited traction motors, and a major task of the study was to test separately excited version of the Electro-Motive Division's D77 traction motor.

The attractiveness of the system is very dependent on the operational scenario of the switching locomotive. Therefore, the study examined the operation of locomotives at three flatyards: Dillard (Southern Railway System), Baldwin (Seaboard Coast Line), and Whitefish (Burlington Northern). Also, a large amount of data concerning the operating environment of switching locomotives was collected.

It was concluded early in the study that a boxcar was required to carry the energy storage unit because no room existed on the locomotive. This, combined with the increased auxiliary load, results in the same energy consumption with or without the FESS system, for a typical flatyard operation in spite of the energy recuperated and reused. Brake maintenance savings, although significant, are not sufficient to give an attractive return on investment.


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|---|---|
| 17. Key Words Transportation, Railroads, Energy Storage, Flywheels, Regenerative braking, Energy conservation, Flatyards | 18. Distribution Statement |

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RAILROAD ELECTROMAGNETIC COMPATIBILITY VOLUME II ASSESSMENT FOR CLASSIFICATION YARDS AND ELECTRIFICATION

**5. Report Date**
September 1978

**6. Performing Organization Code**

**7. Author(s)**
Paul E. Speh and Scott Griffin, of IIT Research Institute

**8. Performing Organization Report No.**
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**9. Performing Organization Name and Address**
DoD Electromagnetic Compatibility Analysis Center
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**15. Supplementary Notes**
This is one of a series of reports that provides results of the FRA Office of Freight Systems R&D efforts in investigating railroad electromagnetic compatibility. Volume I of this series is entitled *Railroad Electromagnetic Compatibility - Electrification Bibliography*, Report No. FRA/ORD-77/77.I.

**16. Abstract**

The automated freight classification yard electromagnetic environment is composed of electrical and electronic devices that are each potential sources and/or victims of electrical interference. The electromagnetic radiation of the environment and selected railroad yard devices such as doppler radars and switch machines was measured at three railroad classification yards. The susceptibilities of selected yard devices were measured to determine operational sensitivity to the yard electromagnetic radiations. In addition to yards, since railroad electrification has important implications, radiations from an electrified railroad operating at 50 kilovolt 60 Hertz were also measured to formulate a measurement methodology and to determine the potential interference effects on railroad operations.

**17. Key Words**
ELECTROMAGNETIC COMPATIBILITY
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CLASSIFICATION YARDS
INTERFERENCE
MEASUREMENTS
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| RAILROAD CLASSIFICATION YARD TECHNOLOGY<br>A Survey and Assessment | January 1977 |
| | 6. Performing Organization Code |
| 7. Author(s) S. J. Petracek, A. E. Moon, R. L. Kiang<br>M. W. Siddiqee | 8. Performing Organization Report No.<br>DOT-TSC-FRA-76-35<br>SRI Project 3983 |
| 9. Performing Organization Name and Address<br>Stanford Research Institute<br>333 Ravenswood Avenue<br>Menlo Park CA 94025 | 10. Work Unit No. (TRAIS)<br>RR716/R7308<br>11. Contract or Grant No.<br>DOT-TSC-968 |
| 12. Sponsoring Agency Name and Address<br>U.S. Department of Transportation<br>Federal Railroad Adminstration<br>Research and Development<br>Washington DC 20590 | 13. Type of Report and Period Covered<br>Final Report<br>Jan. 1975 - July 1976<br>14. Sponsoring Agency Code |

15. Supplementary Notes

16. Abstract

This report documents a survey and assessment of the current state of the art in rail freight-car classification yard technology. The major objective was the identification of research and development necessary for technological improvements in railroad classification yards. This involved a projection of future classification yard needs and a comparison of these requirements of existing technology. Separate tasks included a description of the hardware, costs, performance characteristics, and operational practices of existing yards; formulation of general yard-network interaction concepts; collection of in-depth background information concerning the yard population in the United States (categorized by type, technology, and function); estimation of the demands likely to be placed on the nation's network of freight-car terminals during the foreseeable future; and an assessment and prioritization of those areas of terminal operations that warrant further research or development.

| 17. Key Words | 18. Distribution Statement |
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| 4. Title and Subtitle | 5. Report Date |
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| RAILROAD CLASSIFICATION YARD TECHNOLOGY: An Introductory Analysis of Functions and Operations | May 1975 |
| | 6. Performing Organization Code |
| 7. Author(s) Kenneth F. Troup, III Editor | 8. Performing Organization Report No. DOT-TSC-FRA-75-19 |
| 9. Performing Organization Name and Address U.S. Department of Transportation Transportation Systems Center Kendall Square Cambridge MA 02142 | 10. Work Unit No. RR516/R6302 |
| | 11. Contract or Grant No. |
| 12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Railroad Administration Office of Research and Development Washington DC 20590 | 13. Type of Report and Period Covered Final Report January 1974-January 1975 |
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15. Supplementary Notes

16. Abstract

A review of the basic operating characteristics and functions of railroad classification yards is presented. Introductory descriptions of terms, concepts, and problems of railroad operations involving classification yards are included in an attempt to provide a "primer" on railroad yards. The report describes certain railroad operating practices and identifies problems that inhibit the efficient operation of railroad yards and the rail system of which they are a part. An extensive bibliography has been provided.

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