FRA/ORD-79/14

TECHNIQUES FOR IMPROVING THE RAILROAD MAINTENANCE-OF-WAY EQUIPMENT EVALUATION PROCESS

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FINAL REPORT

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WASHINGTON, D.C 20590

01-Track & Structures

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16. Abstract

This report presents the results of a study of techniques for improving the railroad maintenance-of-way equipment evaluation process. The approach involved a review of existing methods, interviews with equipment manufacturers and railroads, discussions with industry representatives, and an equipment reliability study.

Conclusions include the standardization of published data, indexes for the determination of the effects of man-machine interface, the application of procedures for quality testing, and functional characteristics analysis methods.

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PREFACE

This report was prepared by De Leuw, Cather & Company (DCO) under Contract No. DOT-FR-8028 for the Federal Railroad Administration (FRA), Washington, D.C.

The objectives of the contract were to develop: (1) a plan to identify criteria for the evaluation and selection of maintenance-of-way (MOW) equipment, and (2) a master R & D plan depicting alternative proposals to develop such criteria. This report presents the results of the study of MOW equipment evaluation techniques. The master plan is contained in a separate internal FRA report.

The project was technically directed by Mr. Arnold Gross, the Contracting Officer's Technical Representative for FRA. The work was performed principally by Robert L. Shipley (DCO) and David R. Burns, Special Consultant, with significant contributions from Errol C. Bisutti, John E. Freedman and R. Ellen Gallagher of De Leuw, Cather.

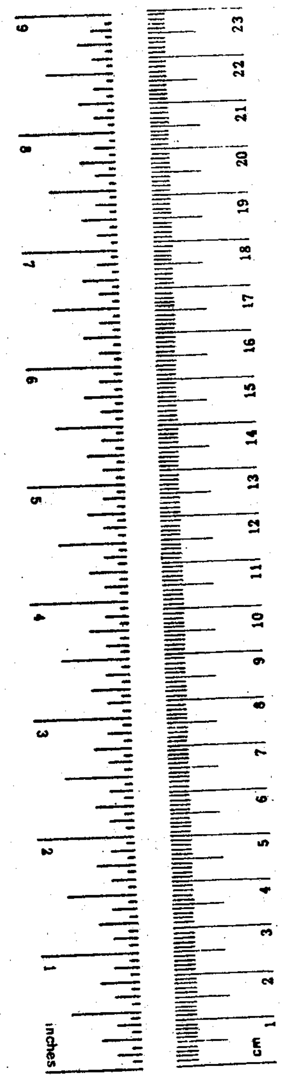
The cooperation and suggestions of Mr. Philip Olekszyk, Chief, Analysis and Evaluation Division, Office of Freight Systems, FRA is gratefully acknowledged.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

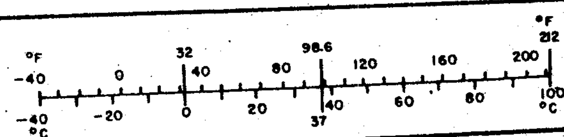
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. EXECUTIVE SUMMARY

In April 1978 the Federal Railroad Administration (FRA) issued a contract to De Leuw, Cather and Company (DCO) for the development of a "Master R & D Plan in the Field of Maintenance-of-Way Equipment Evaluation." The objectives of the contract were to develop: (1) a plan to identify the criteria for the evaluation and selection of maintenance-of-way (MOW) equipment, and (2) a master R & D plan depicting alternative proposals to develop such criteria.

Approximately $55-65 million was spent in 1978 on purchases of new on-track MOW machinery, with an additional $100-150 million spent for machinery maintenance. With indications of a trend toward more sophisticated machinery, these figures are likely to increase. Further, these machines play a central role in approximately $1 billion worth of maintenance annually. When a railroad makes a decision regarding the purchase of a piece of MOW equipment, it is usually faced with a choice of from four to seven different models of each significant machine. An improvement in current methods of equipment selection could create savings in decreased equipment maintenance costs, increased productivity, and improved production quality. These savings are not necessarily additive; however, they would amount to approximately $30 million per year.

In view of the foregoing, an action plan outlining the tasks to be performed during the project was developed. The major work elements included:

- A review of existing literature to determine what efforts, if any, have been previously made in the field of equipment evaluation;

- The development of standard machine definitions and machine categories;

- A review of present equipment evaluation methods;

- Correspondence and visits with the Railway Equipment Manufacturers Supply Association (REMSA) and individual equipment manufacturers to discuss the project, gain the industry's viewpoint, obtain manufacturers' equipment brochures, and review the manufacturers' production facilities;

- Correspondence and visits with American Railway Engineering Association technical committees and several individual railroads to discuss the project, gain the railroads' viewpoint, and learn of various railroad's equipment evaluation and monitoring techniques;

- Development of a plan for the evaluation of maintenance-of-way equipment.

As a result of these efforts it has been determined that implementation of the following procedures should improve the railroads' ability to select, and manufacturers to design, the best equipment for any given track maintenance situation:

1. Standardization of manufacturers' published data;
2. Indexes for the determination of relative values of maintainability, operability, repairability, and reliability of track machinery (MORR indexes);
3. Production quality evaluation and functional characteristics analysis.

A discussion of these recommendations follows.

Standardization of Manufacturers' Published Data

At present, all track machinery manufacturers determine the information to be included in their brochures and calculate the values of the data to be published in their brochures by various means. For example, a review of the manufacturers' brochures showed that five different methods of horsepower calculation were used, equipment weight was presented with and without fuel and/or accessories, and speed was stated without reference to track conditions. These methods result in a wide disparity of information and do not allow easy comparison of similar machines sold by different manufacturers. Accordingly, it appears that the establishment of standards for published data would be beneficial to the railroad industry. The standardization of published data is not a new or unique concept, having been used in the construction equipment industry for many years. Standardized construction equipment data is published by the Equipment Guide Book Company of Palo Alto, California and Morgan Grampian, Ltd. of London, England.

In the visits to the railroads and equipment manufacturers, a positive response was received from virtually all parties concerning the standardization of published data. Standardization would allow the railroads and manufacturers to generally determine the relative capabilities of track machines by simply reviewing the information contained in the manufacturers' brochures.

Upon request, nearly all significant American manufacturers submitted brochures and data for review. Based upon this information and discussions with railroad personnel, the following structures were developed:

- Proposed Manufacturers' Published Data Matrix,
- Proposed Manufacturers' Published Data Definitions,
- Criteria for Determination of Equipment Production Rates.

These documents comprise a draft of the information proposed for inclusion in future manufacturers' brochures and the parameters to be followed in determining the data values.

All data values are proposed to be determined by the manufacturers and a third party retained to publish the data in one manual.

Indexes for the Determination of Relative Values of Maintainability, Operability, Repairability, and Reliability of Track Machinery (MORR Indexes)

The physical characteristics of track machines can be compared and evaluated using the proposed Standardized Manufacturers' Published Data. An equally important aspect of machinery evaluation is determining the factors affecting overall machine performance.

The Society of Automotive Engineers (SAE) has developed two indexes to assist engineers in determining the relative ease of maintaining and repairing equipment. Using these indexes, a dimensionless number can be developed for all types and models of equipment to express the difficulty of maintaining and repairing them. These indexes have been adapted for use on MOW equipment. Further, under this contract, the SAE maintainability and repairability index concept has been used to develop a method of determining relative reliability and operability.

Three of these indexes could be used by the railroads to determine the comparative ease of performing the man-machine functions of track machines and by the manufacturers to improve the design of the man-machine aspects of their products. The fourth index, reliability, could be used to compare the design reliability between machines, as well as to enable the manufacturer to improve his design.

The indexes proposed need a great deal of work to be more fully developed and to be substantiated by an independent agency under the guidance of either REMSA, AAR, AREA, or the FRA. After substantiation, these indexes could be included with the manufacturers' published data or used by railroads as an evaluation tool.

Production Quality Evaluation and Functional Characteristics Analysis

For certain machines, such as tampers, ballast cleaners and ballast compacters, an important part of the evaluation process is to know how well the machine performs its tasks. Similarly, the functional characteristics of certain machines, such as tampers, could cause them to be more efficient under some conditions than others. The MOW equipment reviewed in this contract has been divided into three categories: I - Equipment for which production quality is immaterial; II - Equipment for which production quality testing may be beneficial; and III - Equipment for which production quality testing is beneficial.

Accordingly, it has been recommended that tests for determining the production quality of machines for which production quality testing is beneficial be developed and that a functional characteristics analysis of those machines which are affected by varying operating environments be performed.

2. INTRODUCTION

In April 1978 the Federal Railroad Administration (FRA) issued a contract to De Leuw, Cather and Company (DCO) for the development of techniques for improving the railroad maintenance-of-way equipment evaluation process. The objectives of the contract were to develop: (1) a plan to identify criteria for the evaluation and selection of maintenance-of-way (MOW) equipment and (2) a master R & D plan depicting alternative proposals to develop such criteria.

In the past twenty years there has been a major development in the field of track maintenance machinery in the United States. What was once a piecemeal, almost totally manual effort has become a sophisticated mechanical operation.

Today, major track maintenance operations are somewhat similar to mass production lines in a factory, except that the material is stationary and the machinery moves. As labor costs increase , track maintenance is becoming more and more automated and is currently projected to continue increasing in complexity. This trend is very evident in Europe and Japan, where computer-controlled ballast cleaners, four-headed tampers, and automatic track renewal trains are in use.

As sophistication and cost of this equipment increases, the task of evaluating its performance and reliability becomes increasingly more important and correspondingly difficult to perform. Accordingly, the FRA determined that a study should be performed to establish methods and procedures to assist the railroads in evaluating the performance, cost, maintainability, and reliability of various items of maintenance-of-way equipment; to develop criteria that will allow all railroads (all classes, large and small) to determine which equipment is best for their particular situation; and to establish a system by which maintenance-of-way equipment manufacturers can determine how best to meet the needs of the railroad industry.

In view of the foregoing, an action plan outlining the tasks to be performed during the project was developed. The major work elements included:

- A review of existing literature to determine what efforts, if any, have been previously made in the field of equipment evaluation;
- The development of standard machine definitions and machine categories;
- A review of present equipment evaluation methods;
- Correspondence and visits with the Railway Equipment Manufacturers Supply Association (REMSA) and individual equipment manufacturers to discuss the project, gain the industry's viewpoint, obtain manufacturers' equipment brochures, and review the manufacturers' production facilities;
- Correspondence and visits with Americal Railway Engineering Association technical committees and several individual railroads to discuss the project, gain the railroads' viewpoint and learn of various railroads' equipment evaluation and monitoring techniques;
- Development of a plan for the evaluation of maintenance-of-way equipment.

Details of these and other tasks performed by the project are contained in Section 3, Project Discussion.

3. PROJECT DISCUSSION

3.1 DATA COLLECTION

The initial tasks of the project involved the organization of available information to form a framework for the project. These tasks were:

- A literature search;
- Development of standard MOW machine definitions;
- Development of MOW machine categories;
- A review of present equipment evaluation methods.

3.1.1 Literature Search

A literature search for articles, papers, and similar material was undertaken for information relevant to machinery evaluation. The search focused on railroad-related information, as well as exploring other fields to arrive at evaluation procedures.

The literature search was conducted using the following abstracts:

1. Highway Research Information Service (HRIS), from 1968 through 1977.
2. Engineering Index (EI), from 1966 through 1977 under all railroad headings.
3. Railroad Research Information Service (RRIS), from 1973 through March 30, 1978.

A list of all articles obtained and reviewed is shown in Appendix A.

The literature search resulted in the generation of information which was directly applicable to the project objectives. Of particular value were the maintainability and repairability indexes developed by the Society of Automotive Engineers (SAE) which are contained in the SAE Handbook. These indexes were developed by the SAE to assist engineers in determining the relative ease of maintaining and repairing mechanical equipment.

In the maintainability index, lubrication and maintenance items are assigned a point value on the basis of certain requirements such as where located, how easy to reach and how easy to perform. The sub-total of the individual items is multiplied by a frequency multiplier representative of the frequency of required service intervals. The point total of all items is the maintainability index of a machine. A maintainability index approaching zero is ideal. Similarly, in the repairability index, diagnosis and repair operations are assigned a point value on the basis of considerations such as the need for complex tools and equipment and the location and access of machine components. In either index, items which have a high point value should be carefully reviewed. In addition to pointing out areas where design changes should be attempted, items with high point values emphasize areas which are likely to be skipped by service and repairmen because of the difficulty involved in performing the task.

Although originally developed as a design tool, the indexes may be used to make comparative assessments of different machines and as such could be used in the maintenance-of-way equipment evaluation process.

A series of articles on track leveling and aligning systems was published in Railway Track and Structure[1, 2, 3] in the fall of 1976. This series of articles enables the reader to better understand how each manufacturer's system works. The articles are very detailed descriptions, ideally suited for making a sound evaluation of track leveling and aligning systems. However, these articles point out the fact that every machine has its own functional characteristics and, secondly, that selection decisions require an understanding of the differences of these characteristics. This subject is discussed further in Section 3.6.5.

In general, however, the articles from all the periodicals reviewed lack specific detail and did not contain information which was of an evaluative nature.

3.1.2 Development of Standard Machine Definitions

In order to eliminate any misunderstanding of the function and type of each piece of equipment, a definition for each specific type of equipment to be included in this study was developed. The development of the definitions resulted from a review of in-house manufacturers' literature, the Track Cyclopedia, and information obtained from project staff members knowledgeable in the field of MOW equipment. The standard machine definitions are in Appendix B.

3.1.3 Development of Machine Categories

Similarly, to eliminate any misunderstanding for the remainder of the study, machine categories were set up in a manner that would allow the development of evaluation methods for each category rather than for individual machines. The machine categories are defined in Paragraph 3.6.6, Table 3.

3.1.4 Review of Present Equipment Evaluation Methods

This review involved a three-fold effort. As a result of the literature search, technical reports were obtained of evaluation studies in other industries, in particular, production efficiency studies[34, 35, 36] conducted by the Federal Highway Administration and a Vibratory Roller Evaluation study[37] by the Louisiana Highway Research Department.

The primary objective of the Federal Highway Administration studies was to assist the highway industry in evaluating time utilization and operational efficiency of various types of construction and maintenance equipment and operations. The studies did not result in ratings of the different manufacturers' equipment performance, but rather produced a methodology for individual contractors to use in evaluating the performance of their operations. These studies have been conducted since the early 1920's. The Vibratory Roller Evaluation study was undertaken by the Louisiana Highway Research Department to evaluate the capabilities of vibratory rollers in meeting specifications for the compactness and smoothness of paved asphaltic concrete. This study produced a rating of the capabilities of each of the nine machines tested.

Since the Department of the Army is the single largest purchaser of construction equipment in the United States, the U.S. Army Mobility Research and Development Command was contacted to determine their methods of selecting construction equipment. It was found that the Army initially develops the requirements for an item of construction equipment to accomplish a specific task. A survey of the private sector is then conducted to determine how private industry accomplishes the task. A draft specification developed from the survey is sent to all known manufacturers of the required machine and a plant visit is made.

Information obtained from the survey and at the plant is then assembled into an evaluation summary. The summary does not rank each manufacturer's machine; however, the relative capabilities of the machines can be compared by the summary. After the Army issues a solicitation for the equipment, each proposal is technically evaluated and judged acceptable or not acceptable, based on whether the requirements of the soliciation have been met. The acceptable bids are then ranked according to price and delivery, with the contract award being made to the responsible bidder having the lowest cost.

An additional effort involved a visit to the German National Railways (Deutches Bundesbahn or DB) and British Rail (BR) to obtain information on their methods for evaluating and selecting track maintenance equipment, as well as the management information systems used to keep records of productivity, reliability, and costs of their MOW equipment fleet. A summary of the various meetings and information obtained is in the meeting reports in Appendix C.

3.2 RAILWAY EQUIPMENT MANUFACTURERS SUPPLY ASSOCIATION (REMSA) AD HOC COMMITTEE

On May 16, 1978, a meeting was held with an Ad Hoc Committee from the Railway Equipment Manufacturers Supply Association (REMSA). A list of the committee members is given in Appendix H. The purpose of this meeting was to inform the manufacturers about the program and generate input from them with regard to the direction of the program. The result of the meeting was that the REMSA representatives felt the program might be beneficial; however, there should be no ranking of machinery.

On January 29, 1979, another meeting was held to present the preliminary project conclusions for comments from the Committee. The responses of the committee members to the presentation tended to be negative towards the MOW evaluation program.

3.3 EQUIPMENT MANUFACTURERS' INFORMATION

Using information supplied by REMSA, a list of the majority of equipment manufacturers in the United States and Europe was developed for the purpose of requesting information about their MOW equipment. Letters were sent to manufacturers requesting published literature, number of units in service (listed by model), lease costs, and purchase price. Almost all major manufacturers in the United States responded. Of those responding, all sent published literature and several supplied the other requested information. A list of all equipment manufacturers from which information was requested is contained in Appendix D.

All equipment data pertinent to an evaluation, obtained from the manufacturers' published literature and of the type envisioned by this program, was tabulated by machine (Appendix E). The purpose of this tabulation was to determine if an evaluation by a railroad could be based solely on published information when selecting MOW equipment. After review, it was concluded that the information as presented was somewhat inconsistent and could not be used alone in making a valid equipment selection.

At present, each track machinery manufacturer determines the information to be included in their brochures and calculates the the values of the data to be published in their brochures by various means. These methods result in a wide disparity of information which does not allow easy comparison of similar machines sold by different manufacturers. Several examples of this disparity follow:

- Variance in the method of determining criteria data
  - five methods of determining horsepower,
  - weight of equipment either estimated or measured with a full or empty fuel tank, or with or without accessories,
  - travel speed stated without reference to track condition.
- Variance in presented data
  - Rail drill - amount of evaluating data varied from two to 18 entries.
- No consistent format. The presentation of the data varied from a narrative format to tabulation.

A representative sample of manufacturers (Table 1) was surveyed to determine how they develop their published performance data; their quality control, production and design practices; and their opinions regarding evaluation techniques and testing. Of the 12 manufacturers who responded, 10 expressed a willingness to participate in the program. Six of the manufacturers were visited during the survey.

TABLE 1 - LIST OF REPRESENTATIVE MANUFACTURERS

MANUFACTURER	RESPONSE*	WHEN VISITED
Canron Railgroup	Willing	8/22/78
Fairmont Railway Motors, Inc.	Willing	Did not visit
Jackson Vibrators, Inc.	Unwilling	Did not visit
Kershaw Manufacturing Co. Inc.	Unwilling	Did not visit
Loram Maintenance of Way Inc.	Unwilling	Did not visit
Modern Track Machinery	Willing	9/21/78
Plasser American Corporation	Willing	8/11/78
Portec Inc., RMC Division	Willing	Did not visit
Racine Railroad Products Inc.	Willing	8/17/78
Railway Products Company/ Marmon Transmotive	Willing	8/25/78
Railway Track-Work Company	Unwilling	Did not visit
Rexnord Inc., Railway Equipment Division	Willing	8/18/78

* Willingness or unwillingness to be interviewed.

The questions asked and the manufacturers' general responses were as follows:

1. How is published performance data determined?

   Three of the manufacturers indicated that their published performance data was based on the results of several tests of the equipment on railroad tracks. One of the manufacturers used both track tests and theoretical analysis to determine published performance data. The other manufacturers developed their performance data analytically.

2. Do you evaluate competition? If so, how?

   Competitor's equipment was generally evaluated by observing the equipment in operation. Two manufacturers also performed economic analyses of competitor's equipment, and one manufacturer had purchased competitor's equipment for testing and evaluation.

3. What do you do to ensure that the quality of each machine is the same or better than the last?

   Four of the manufacturers cited testing the machines upon completion of construction to ensure quality control. One manufacturer also used in-process inspection check lists to assure that proper procedures have been followed and that machine parts are of proper dimensions and quality. Three manufacturers listed designer or customer (railroad) specifications as a basis for machine quality.

4. What production methods are used -- single, batch, production line?

   Four of the manufacturers generally used single production methods. Very small machines were batch assembled by two of these manufacturers. One manufacturer used batch production for most equipment. Another used a production line for small machines.

5. Could you validate published data in your plant? How?

   Five of the manufacturers could not validate published data in their plants except for minor information such as dimensions and one manufacturer said that the published data for small machines could be validated.

6. Willingness to publish data based on standard specification.

   Five manufacturers responded that they would be willing to publish data, assuming there was generalized agreement on using the standardized criteria. One manufacturer did not believe that it would be possible to establish standard criteria for those companies which produce unique equipment.

7. Design practices.

   Design changes were generally made by the manufacturers in response to problems encountered with existing equipment, requests by the railroads for new machines, and for marketing reasons.

8. What would you consider to be a valid comparative criterion for each of your products?

   Four manufacturers stated that demonstrations would be a valid method of comparing machines. One manufacturer said that equipment should be compared on the quality of design. Another felt that a valid comparison would be one based on a cost per increment-of-work basis, where every element of capital, maintenance, operating costs, and production was considered.

9. To what extent do you do R & D and long-range planning?

One supplier had an R & D division of 30 employees which develops new systems and equipment in response to perceived needs. Costs allocated to R & D by manufacturers ranged from about five percent of gross revenue to 12 percent. One company's research was directed to solving existing equipment problems only. Most manufacturers said they anticipate that machines will get larger and more complex in the future.

10. How are railroad machine requirements determined? Then, how is a responsive machine developed?

Most manufacturers responded that railroad requests and feedback were the basis for determining machine requirements for developing new machines and improving capabilities of existing machines.

11. Would combined railroad block purchases of the same machines be better than individual purchases of slightly different machines?

Only one manufacturer felt that block purchases of machines would be preferable to individual railroad purchases. The other manufacturers said that block purchases would not make an appreciable difference.

12. How are your spare part distribution functions accomplished?

Five of the manufacturers had all spare parts distributed from one central location. No information was obtained on the length of time involved in distributing spare parts.

13. Do you participate in the export market?

Three manufacturers said they were significantly involved in the export market. One supplier exported a few machines, and one did not participate in the export market.

14. General data--dollar volume, number of machines produced, plant locations, payroll, number of employees, etc.

Estimated dollar volumes of the manufacturers ranged from $3 million to $40 million in annual sales. Number of machines produced varied widely, from eight major machines per month for one manufacturer to 7,000 - 8,000 smaller machines produced annually for another manufacturer. Several manufacturers were subsidiaries of firms with plant locations in various countries. The number of U.S. employees for the firms interviewed ranged from 20 to several hundred.

15. What methods do you employ to sell your equipment to the railroads? How do you keep their business, e.g., direct sales, distributors?

Two manufacturers said that most sales were through distributors. One manufacturer cited both direct sales and distributors. Another said that most sales were by company salesmen. This manufacturer also had some specially equipped trucks, so that equipment could be sold directly from the trucks to small railroads. One manufacturer said that 90 percent of his sales were made by competitive bidding; the remainder by sales representatives.

16. How often are models changed?

Three manufacturers said that model changes were infrequent. One of these gave an average of at least five years between changes, and another said that some models had been produced for 20 years. One said that major changes occurred on an average of every two years, with complete new models from five to eight years. Another manufacturer said that models were changed when improvements were developed.

17. Any suggestions from the supplier with respect to the FRA MOW equipment evaluation methods program?

Comments and suggestions included the following:

- There was concern that FRA will dictate which machines to purchase.
- There was concern as to whether the information generated by the MOW project will be used.
- The major problem is poor operator training.
- Publishing the results of equipment performance derived at a test site would be of little use since climate, track, operator, skills and condition of equipment are different in various locations.
- Equipment is constantly changing, and a defect could be removed before a published report could be revised to reflect the fact.
- If standard criteria are to be established, AREA Committee 27 should set the standards.
- Index method of comparison is a good idea, if it is proven workable.

3.4 AMERICAN RAILWAY ENGINEERING ASSOCIATION (AREA) COMMITTEES

A presentation was made to AREA Committee 27, (members listed in Appendix H), Maintenance-of-Way Work Equipment, at a meeting held in Philadelphia, Pennsylvania, on June 27, 1978. The purpose of the presentation was to inform the Committee of the general goals of the program and to solicit their guidance, advice, and comments. The committee members tended to be either noncommittal or negative in their responses to the presentation. The main theme of the response was that they did not want the FRA to dictate to the railroads, and that Committee 27 was responsible for the type of effort that FRA was now paying a contractor to perform.

Another presentation was made to Committee 27 and Committee 22 (members listed in Appendix H), Economics of Railway Construction and Maintenance, on January 29, 1979 in Shreveport, Louisiana, to inform the Committees of the progress of the program and present tentative recommendations. Comments made by members of the Committees at this meeting were generally negative towards the value of the program.

3.5 RAILROAD INFORMATION

A group of twenty-one railroads was selected as a representative sample of the industry, considering factors such as speed and density of traffic, operating terrain and financial situations, for a telephone or personal interview to ascertain the following:

- Present equipment selection techniques
- Management information system suitable for:
  - data collection from long-term field testing
  - possible validation of test results
  - development of evaluation methodology
- Comments and suggestions for project direction.

Of the 21 railroads listed in Table 2, 13 responded favorably, granting interviews. Those railroads interviewed were asked the same basic questions. The varied responses elicited by the questionnaire have been combined into the list below, preserving each discrete answer with no indication of the frequency of each.

1. How is your annual MOW program developed?

   A. How are maintenance goals established?
   Maintenance goals are--
   - Established by having each division engineer determine his needs and submitting a list to headquarters, which then determines what maintenance work will be performed.
   - Set by the engineering department.
   - Based on a five-year plan for rail and tie replacement reflecting rail age and tie life.
   - Determined by riding the railroad and by track geometry cars when possible.

TABLE 2 - LIST OF RAILROADS CONTACTED

U.S. RAILROADS	RESPONSE*	HOW/WHEN INTERVIEWED
Bessemer & Lake Erie Railroad Company	Willing	Telephoned 7/21/78
Canadian National Railways	Willing	Telephoned 7/26/78
Grand Trunk Western Railroad Company	Willing	Telephoned 10/10/78
Missouri Pacific Railroad Company	Willing	Visited 8/7/78
Norfolk & Western Railway Company	Willing	Telephoned 10/9/78
Richmond, Fredericksburg, & Potomac Railroad Company	Willing	Telephoned 7/25/78
Southern Railway Company	Willing	Telephoned 7/28/78
Chessie System	Willing	Did not interview
Consolidated Rail Corporation	Willing	Visited 9/12/78
Soo Line Railroad Company	Willing	Telephoned 7/26/78
The Belt Railway Company of Chicago	Willing	Visited 9/26/78
National Railroad Passenger Corporation	Willing	Telephoned 8/4/78 & 10/6/78
St. Louis - San Francisco Railway	Willing	Telephoned 7/25/78
Union Pacific Railroad Company	Willing	Visited 10/9/78
The Atchison, Topeka & Santa Fe Railway Company	Unwilling	Did not interview
Illinois Central Gulf Railroad Company	Unwilling	Did not interview
Burlington Northern	None	Did not interview
The Denver & Rio Grande Western Railway Company	Unwilling	Did not interview
Duluth, Missabe & Iron Range Railway Company	Unwilling	Did not interview
Florida East Coast Railway Company	None	Did not interview
Southern Pacific Transportation	None	Did not interview

Table 2 (continued)

FOREIGN RAILROADS	RESPONSE*	HOW/WHEN INTERVIEWED
British Rail	Willing	Visited 6/5/78 - 6/9/78
German National Railways (Deutches Bundesbahn)	Willing	Visited 6/13/78 - 6/15/78

* Willingness or unwillingness to be interviewed.

- Determined on a year-to-year basis dependent upon economic analysis of budget data contained in the United States Railway Association Final System Plan (CONRAIL).

B. How do you match goals to available equipment?
   - Sufficient equipment is available to perform required maintenance.
   - Tie and surfacing machinery is assigned to the districts for allocation, while rail machinery is under the control of the system planning office headquarters.
   - Planning is based on the availability of equipment, which was purchased specifically to fulfill the current five-year plan.
   - Determination is made of the number of gangs and type of equipment required to carry out the plan. Specifications for any additional needed equipment are then prepared for bid.

C. Do you have an "overall" philosophy regarding MOW machine utilization? (e.g., use until worn out, replace after x years, purchase used machines when possible).
   - Generally, the replacement of older machines is based on judgment and funds available.
   - Machines are typically replaced when parts are no longer available.

D. Do you have MOW training classes, facilities, etc., R & D for MOW equipment?
   - Training classes are conducted for operators and mechanics, usually during the winter.
   - Each operator serves an apprenticeship.
   - Seminars are held to instruct groups of operators on new types of equipment.
   - The lack of formal training for new operators is a problem to many railroads.

2. When new machines are to be acquired--

A. How do you determine which manufacturer's machines should be purchased?

- Review bids from the manufacturers.
- Visit to observe the machine in operation or ask for a demonstration.
- Rely on previous experience with the manufacturer's product.
- Buy the same type of machinery as previously because of the advantages of familiarity with the machines, fewer training requirements, and a reduced parts inventory.
- Purchase the least expensive machine, unless selection of another machine can be justified.

B. Do you provide specifications to manufacturers? Content?

- Most of the railroads do provide specifications. Contents vary, but include such items as:
  - a list of the type of work that must be performed,
  - fuel tank size,
  - subassembly manufacturers,
  - type of engines.
- One railroad writes specifications around the machines which have given the best performance in the past.
- The level of detail of the specifications varied among the railroads.

C. What criteria are utilized in machine selection?

- Criteria most frequently utilized by the railroads in machine selection are:
  - cost,
  - performance capability,
  - experience with the manufacturer's product.

- Other criteria mentioned included:
  - the ability of the manufacturer to meet the procurement schedule,
  - universal design configuration,
  - parts inventory on hand.

D. Do you have a systematic method to determine the weight each criterion should have, relative to another, for each new machine purchased?

- No, none.
- Yes, we depend on the judgment of selection personnel.

E. Do you test machines before purchase? How do you measure results? What is the test time required to determine MOW equipment performance?

- Yes, but with no systematic method for measuring test results.
- Yes, usually lasting from one week to 30 days.

F. Would it be helpful to the railroads if all MOW equipment suppliers had to test their machines over a standard track (located at the DOT Transportation Test Center or elsewhere)?

- Yes, it would be helpful, since testing would:
  - provide competition,
  - point out problem areas,
  - allow corrections to be made prior to purchase of equipment,
  - provide information on comparative capabilities.
- Yes, standardized data would be useful.
- No, no benefit to the testing.

(Some railroads were not asked this question.)

3. After a new machine is purchased --

A. What records are maintained regarding performance, dependability, parts replacement, etc.?

- About half of the railroads keep records on individual machines which give information on items such as:
  - maintenance costs,
  - down time,
  - production rate.
- Railroads that do not presently keep records on individual machines, except for shop records, have information available from daily gang production reports which show machine down time and operating problems; however, this data is generally not compiled.
- Several railroads have or are planning to initiate computerized systems for maintaining records on machinery.

B. How is the quality of the machine checked?

- Judgment of supervisors.
- There is no formalized acceptance testing.

C. What control do you exercise on operator quality?

- Each operator serves an apprenticeship on the machine he is trying to qualify for and is required to do homework during the apprenticeship.
- Training programs for operators during the winter.
- Very limited turnover of operators results in their being generally experienced.

D. What procedures do you have to provide feedback to the manufacturers?

- Supervisors can contact various manufacturers at their discretion or go through the manager of MOW equipment.

- Problems are referred to the manufacturers by phone and are coordinated through a designated person.
- There is no organized feedback to the manufacturers.

4. Would you consider coordinating MOW machine purchases with other railroads to achieve block production, better price, better performance, and better service with manufacturers?
   - None of the railroads felt that block purchases with other railroads would be advantageous.

5. How do you determine lease vs. purchase option?
   - All track machines are purchased. Autos and trucks are leased.
   - The finance department makes the lease vs. purchase decision.
   - The Chief Engineer makes the decision; usually, however, leasing is only done for larger machines needed for a limited period of time.

6. What effort do you expend in MOW logistics, physical distribution (inventory, storage, "supply train," movable stores, etc.)
   - Systemwide gangs are accompanied by parts trucks or parts and rail cars; the mechanics travel with large gangs and roam among the various small ones.
   - Large MOW gangs are used where possible, and mechanics, supplied with fully equipped trucks, travel with them.

7. Any suggestions from the railroad with respect to the FRA MOW equipment evaluation methods program?
   - Standardization of performance data and a field testing program at Pueblo is a good idea.

- Skill of operators and mechanics can have an affect on the evaluation of the machines. System complexity should be included in the evaluation criteria. There is a need to determine the quality of the surfacing performed by a tamper.
- FRA must convince railroads that the program will result in equipment that is improved, more reliable, more easily maintained or less expensive.
- Uniform published data would be of considerable use to small railroads.
- Evaluation of track machinery will enable particularly small railroads to be aware of all products on the market.
- There is a need to agree on standards for published data. This project may have possible negative effects on small manufacturers, since it could cause manufacturers to spend considerably more effort on equipment design.
- The project should be a useful tool for assisting in machine selection.
- There is a need for a good measuring stick to determine the most suitable machine for a job. The project should be useful in this regard.
- There is a need for common criteria for published data.
- Evaluation and standardization of published data will be an advantage.
- There is a definite need for an organization which can determine that a machine is of poor design or quality. One railroad's statement of that fact has little effect.

- Standardization of published performance data would be of considerable use, provided there are some "teeth" to ensure that the manufacturers use the correct figures.
- There is a strong need for this program. It is difficult to evaluate and select machines because of the limited information available and personal preferences for particular manufacturers or machines.

3.6 DEVELOPMENT OF AN EVALUATION PLAN

As a result of discussions with various railroads and manufacturers, it was determined that the following factors affect the railroads decision making process concerning the selection of track maintenance equipment:

- environment,
- operator skill level,
- mechanic skill level,
- number of similar machines owned,
- familiarity with product,
- available funds.

Based on the railroad experience of the contractor, it was concluded that the following additional factors are also relevant in the selection of MOW equipment:

- total track mileage,
- track condition,
- traffic density,
- speed/axle load relationship of traffic,
- location in reference to manufacturers.

As all the factors vary from railroad to railroad, it was concluded that an evaluation plan which would result in an absolute ranking of equipment was neither feasible or necessary. What was determined was that an evaluation plan should be constructed to allow each railroad to analyze the available machines in a structured manner and to determine on their own the preferred machine for each situation.

Accordingly, an analysis was made for performing the evaluation of MOW equipment by the use of published data, plant testing, and field testing. A discussion of the results of this analysis follows.

3.6.1 Analysis of Published Data

As discussed in Section 3.3, analysis of current manufacturers' literature compiled in Appendix E revealed that an evaluation based on this data would be technically difficult and subject to question. When evaluating equipment, the railroads typically do not rely on published information but usually request detailed specifications of individual machines. This technique was also found to be of questionable value because of the different methods used in determining the data requested.

During the visits with the railroads, it was generally agreed that standardization of the manufacturers' published data would be of considerable value in the selection process. In addition, the manufacturers generally stated that they would agree to conform to a standard for publishing data if the railroads requested this standardization.

In view of the foregoing, a matrix of proposed manufacturers' published data was developed containing corresponding definitions or criteria for determining this data (Figure 1).

Standardization of published data would allow the railroads and manufacturers to generally determine the relative capabilities of track machinery by simply reviewing the information contained in the manufacturers' brochures.

Initially, nearly all significant manufacturers' brochures and data were gathered and reviewed. The data was tabulated by equipment type and is contained in Appendix E.

Based upon this information and discussions with railroad personnel, the following documents were developed:

- Proposed Manufacturers' Published Data Matrix, Figure 1.

FIGURE 1 - MATRIX OF PROPOSED

	Length - Work	Length - Travel	Width - Work	Width - Travel	Height - Work	Height - Travel	Base	Clearance	Weight	No. of Operators	Hourly Oper. Cost	Performance	Hours/Full Tank	Noise Level	Type	Make	Model	H.P. @ RPM	Number Cylinders	Cooling	Drive *	Suspension System	Transmission	Fuel	Hydraulic	Oil	Travel - Speed	Working Speed	Working Curve	Travel Curve	Buffing Force	Change to Cleaning	Conveyor Direction	Swing Speed	Crip Method	Rail Weight Limit	Boom Length	Hydraulic Power
	DIMENSION							———						ENGINE						———			———															
Ballast Compactor	/	/	/	/	/	/	/		/		/	/	/	/	/	/	/	/		/	A	/	/	/	/	/	/											
Ballast Undercutter	/	/	/	/	/	/	/		/	/	/	/	/	/	/	/	/	/		/	A	/	/	/	/	/	/		/				/					/
Ballast Undercutter/Cleaner	/	/	/	/	/	/	/		/	/	/	/	/	/	/	/	/	/		/	A	/	/	/	/	/	/		/	/	/	/	/					/
Ballast Regulator	/	/	/	/	/	/	/		/	/	/		/	/	/	/	/	/		/	A	/	/	/	/	/	/											/
Ballast Shoulder Cleaner	/	/	/	/	/	/	/		/	/	/	/	/	/	/	/	/	/			A	/	/	/	/	/	/		/				/					/
Brush Cutter	/	/	/	/	/	/	/	/	/	/	/		/	/	/	/	/	/						/	/	/	/	/										
Cleaner Track Yard	/	/	/	/	/	/	/		/	/	/		/	/	/	/	/	/			A			/	/	/	/	/					/					/
Cranes On-Track Only	/	/	/	/	/	/	/	/	/		/		/	/	/	/	/	/			A	/	/	/	/	/	/							/				
Crib Ballast Remover	/	/	/	/	/	/	/		/		/	/	/	/	/	/	/	/			A	/	/	/	/	/	/											/
Rail Slotter	/		/		/				/						/	/	/	/	/	/				/														
Gauging Machine	/	/	/	/	/	/			/		/		/		/	/	/	/	/	/				/														
Motor Car, Small	/	/	/	/	/	/	/		/		/		/	/	/	/	/	/	/	/	A	/	/	/			/											
Motor Car, Large	/	/	/	/	/	/	/		/		/		/	/	/	/	/	/	/		A	/	/	/			/											
Rail Anchor Adjuster	/	/	/	/	/	/	/		/		/	/	/	/	/	/	/	/		/	A		/	/	/		/											/
Rail Anchor App., Man. Set	/	/	/	/	/	/	/		/		/	/	/	/	/	/	/	/			A		/	/	/	/	/										/	/
Rail Anchor App., Semi Auto	/	/	/	/	/	/	/		/		/	/	/	/	/	/	/	/			A		/	/	/	/	/										/	/
Rail Drill	/		/		/				/			/			/	/	/	/	/	/	B			/													/	
Rail Heater	/	/	/	/	/	/	/		/			/	/		/	/	/	/			A			/														
Rail Joint Straightener	/	/	/	/	/	/	/		/		/		/	/	/	/	/	/			A			/		/	/										/	/
Rail Lifter	/	/	/	/	/	/	/		/					/	/	/	/	/	/	/				/														
Rail Saw or Abrasive Cutter	/		/		/				/			/			/	/	/	/	/		B			/														
Spike Driver, Pneumatic	/	/	/	/	/	/	/		/	/	/	/	/	/	/	/	/	/			A			/	/	/	/											
Spike Driver, Automatic	/	/	/	/	/	/	/		/	/	/	/	/	/	/	/	/	/			A			/	/	/	/											/
Spike Puller	/	/	/	/	/	/	/		/		/	/	/	/	/	/	/	/	/					/	/													/
Tamper	/	/	/	/	/	/	/		/		/	/	/	/	/	/	/	/			A	/	/	/	/	/	/		/									/
Tamper, w/Jacks	/	/	/	/	/	/	/		/		/	/	/	/	/	/	/	/			A	/	/	/	/	/	/		/									/
Tamper, w/Jacks & Aligner	/	/	/	/	/	/	/		/		/	/	/	/	/	/	/	/			A	/	/	/	/	/	/		/									/
Tamper, Joint	/	/	/	/	/	/	/		/		/	/	/	/	/	/	/	/			A	/	/	/	/	/	/											/
Tamper, Multi-head	/	/	/	/	/	/	/		/		/	/	/	/	/	/	/	/			A	/	/	/	/	/	/		/									/
Tamper, Switch	/	/	/	/	/	/	/		/		/	/	/	/	/	/	/	/			A	/	/	/	/	/	/		/									/
Tamper, Switch w/Aligner	/	/	/	/	/	/	/		/		/	/	/	/	/	/	/	/			A	/	/	/	/	/	/		/									/
Tie Adzer	/	/	/	/	/	/	/		/		/	/	/	/	/	/	/	/	/	/				/				/										
Tie Boring Machine	/	/	/	/	/	/	/		/						/	/	/	/	/	/	B			/														
Rail Threader	/	/	/	/	/	/	/	/	/	/	/		/	/	/	/	/	/	/	/				/	/	/		/										
Tie Cribber	/	/	/	/	/	/	/		/		/	/	/	/	/	/	/	/						/														/
Tie Destroyer	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/					/	/	/	/	/	/										/
Tie Handler	/	/	/	/	/	/	/	/	/		/		/	/	/	/	/	/			A		/	/	/	/	/							/			/	/
Tie Injector/Inserter	/	/	/	/	/	/	/	/	/		/	/	/	/	/	/	/	/					/	/	/	/	/										/	/
Tie Plug Setter Driver	/	/	/	/	/	/	/		/		/		/	/	/	/	/	/	/	/				/														
Tie Remover	/	/	/	/	/	/	/	/	/		/	/	/	/	/	/	/	/						/	/	/	/											/
Tie End Remover	/	/	/	/	/	/	/		/		/	/	/	/	/	/	/	/	/	/				/														/
Tie Saw or Shear	/	/	/	/	/	/	/		/		/	/	/	/	/	/	/	/	/	/				/			/											/
Tie Bed Scarifier/Inserter	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/					/	/	/	/	/											
Tie Spacer	/	/	/	/	/	/	/		/		/	/	/	/	/	/	/	/	/	/	A			/	/		/								/			/
Tie Sprayer	/	/	/	/	/	/	/		/		/		/	/	/	/	/	/	/	/				/														
Track Fastening Wrench	/	/	/	/	/	/	/		/		/		/	/	/	/	/	/	/	/	B			/	/													
Track Liner	/	/	/	/	/	/	/		/		/		/	/	/	/	/	/			A		/	/	/	/	/											/
Track Wrench	/	/	/	/	/	/	/		/		/		/	/	/	/	/	/	/	/	B			/	/													/
Track Vibrator	/	/	/	/	/	/	/		/		/		/	/	/	/	/	/	/	/	A			/			/	/										
Rail Grinder	/	/	/	/	/	/	/	/	/	/	/		/	/	/	/	/	/	/	/	A	/	/	/	/	/	/	/	/		/							
Rail Puller	/		/						/	/					/	/	/	/		/			/	/	/												/	/

*See Proposed Manufacturers' Published Data Definitions (See Appendix F)

Legend:

/ Data Required

☐ Data not required

MANUFACTURERS' PUBLISHED DATA

GENERAL DATA

Minimum Cut Depth	Maximum Cut Depth,	Reach *	Maximum Spoil Size	Crib Depth	Broom Diameter	Broom Velocity	Vibration Frequency	Amplitude	Blade Energy	Cribbing Force	Carry Capacity *	Nipper Force	Boxing Pressure	Extraction Force	Insertion Force	Hyd. Pump Capacity	Tractive Effort	Hoist Line Speed	Hoist Line Power	Lift Capacity *	Dynamic Force	Static Force	Optional Extras	3-D Machine Profile	Turntable	Insulated	Set-off	Material Tolerance	Lift Envelope	Max. Toe Line	Feed	Gear Reduction	Fuel Type	Blow Force	Blows/Minute	Lift Weight	No. of Tools	Max. Shift	Spindle Speed	No. of Stones	Pull Range	Pull Force
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- Proposed Manufacturers' Published Data Definitions (Appendix F).
- Criteria for Determination of Equipment Production Rates and Performance Levels (Appendix G).

These documents comprise a recommended format for the information proposed to be included in future manufacturers' brochures and the parameters to be followed in determining the data values.

All data values would be determined by the manufacturers. In addition to the manufacturers' brochures, a third party could be retained to publish all manufacturers' data in one document. This type of information is presently furnished for construction equipment by the Equipment Guide Book Company of Palo Alto, California, and Morgan Grampian Limited of London, England.

The data values would require periodic substantiation. This could be accomplished by an independent agency under the guidance of either REMSA, AAR, or the AREA.

3.6.2 Determination of the Feasibility of Plant Testing

As a result of the interviews with manufacturers, which in many cases involved plant visits, it was determined that plant testing at the manufacturers' facilities would not be feasible because of a general lack of testing equipment, test tracks, and the space to install necessary facilities.

However, the AAR laboratory in Chicago and the U.S. Transportation Test Center at Pueblo have extensive test facilities. It could be possible for a manufacturer lacking suitable facilities for determining the data to be published to make use of these facilities.

Also, if a railroad wished to determine such information as structural, hydraulic, and electronic integrity of a machine or series of machines, these facilities could be suitable.

3.6.3 Determination of the Feasibility of Field Testing

Key considerations in the evaluation of track machines are the cost per unit of production, production rate and production quality. It is logically assumed that a good method for determining these parameters would be by field testing.

In the trips to British Rail (BR) and Deutches Bundesbahn (DB), considerable time was spent reviewing their field test procedures. Detailed trip reports are contained in Appendix C.

The R & D division of British Rail has performed comparative evaluations of tampers, production tampers, and consolidators. These evaluations are performed to determine which machines are best and to find out what improvements are required, if any.

British Rail uses multiple sites to evaluate equipment. The number of sites ranges from four to nine per machine, with the sites paired so that each machine will be working under similar conditions. British Rail has determined that four sites are too few and is hoping to have as many as 20 test sites per machine in the future. The test sites are typically a minimum length of one-half mile. This length is the distance equal to ten times the longest wavelength (80 meters) measured by the BR track geometry cars.

The measurement of track geometry is one of BR's prime methods for determining the comparative value of tampers, liners, and consolidators. In the particular comparative evaluation discussed with the contractor, geometry measurements were taken over a three-year period to determine deterioration with time after track maintenance has been performed.

British Rail has found that some machines provide more precise track geometry initially, but deterioration with time is greater than other machines having lower initial precision. Accordingly, the measurement of track deterioration over the long term (1-2 years) is important to British Rail.

Test for tampers usually requires 1½ to 2 man years of effort over a three-year period. Additional tests beside the measurement of geometry include:

- the measurement of unloaded and loaded lateral strength of track,
- settlement,
- pressure distribution under tie,
- bending in ties,
- effect of machine on ballast,
- effect of machine on subballast,
- damage to structure from vibration and loads,
- effect of machine on lateral resistance, and
- noise and vibration of equipment.

Most of the above tasks are performed on tampers and consolidators.

British Rail tests approximately one machine per year and has been testing for seven years.

Parameters affecting the quality of work performed by tampers include the rate of production (speed) and the technique of the operator. The equipment being evaluated is usually borrowed or rented for the period of testing. In some cases, however, equipment has been purchased. The tests are usually performed under confidentiality agreements whereby BR agrees not to make the findings of the evaluation public, but gives copies of the report to the manufacturer and then uses them in-house to determine which equipment to purchase.

Deutches Bundesbahn's (DB's) main areas of interest in equipment are reliability, quality of performance, production speed and start-up and shut-down times.

Evaluations to determine the above are performed on liners, tampers, cleaners, regulators, rail loading and track renewal trains. The results of these evaluations are used in conjunction with time studies and are published as production planning standards for the machines. Small equipment is generally not evaluated in that it usually has little or no input to the overall timing of work.

At one time DB had competitive evaluation testing but has since discontinued this practice. DB found that in competitive testing the companies supplied their best machines and their best operations, with the results generally not being very realistic. DB feels that comparative ranking of machines is not practical as manufacturers always have many reasons why their equipment came in second or third. Machine tests are performed in areas where maintenance is being performed on high speed, high tonnage lines and are made prior to the acceptance of the equipment. The average tests are 500 meters of straight track and 500 meters of curved track with high superelevation.

The test sections are measured by stationary measurements taken on the unloaded track on every third tie and checked by geometry recording cars. Measurements are taken of horizontal and vertical alignment and cross level and are made immediately before and after lining and tamping, and after 500 thousand, 1 million and 5 million gross tons of traffic.

The International Union of Railways (Union Internationalle de Chemin de Fer or UIC) will soon publish a report with information concerning methods for testing tampers. The report will also contain information on a "standard track." DB thinks that in order to standardize criteria, a track of standard construction must be offered to the suppliers to determine the capability of the machine. It was recommended that FRA obtain the UIC reports, as they contain considerable amounts of useful information regarding track machinery.

The methodology for evaluating and purchasing smaller track equipment is to borrow one machine for testing. If the machine test is satisfactory, DB will then buy a large quantity. If not, the machine is returned to the supplier.

Equipment is also evaluated by long duration testing. Tests can be up to six month's duration. If evaluation tests show that similar machines supplied by both manufacturers are equally qualified, DB purchases the lower priced equipment.

In evaluation testing, DB employs a data gathering technique whereby each machine of a system is measured to determine its production capability. This information is developed under similar conditions, (e.g. type of tie, depth of ballast and condition of ballast) and as such it takes a considerable period of time to develop comparable values for similar types of equipment. In some instances it has taken from two to three years to obtain sufficient data to allow a comparative evaluation to be made, although the actual effort involved is only between 20 and 100 man days.

Because of the large amount of time and effort required to field test machines, and the fact that the American railroads are many separate companies and more diverse in nature than the European railroads, it appeared that field testing should only be performed to determine such items as production rate and production quality and only then for certain types of machines.

As contained in Appendix G, the methodology for standardizing published performance data includes a recommendation that the maintenance-of-way equipment manufacturers determine machinery production either theoretically or practically over a "reference MOW railroad track." The purpose of this recommendation is to assure that the production values established by different manufacturers are comparable.

3.6.4 Development of Design/Performance Interrelationship

A principal complaint of the railroads about MOW equipment is its unreliability, or more precisely, its limited availability. Availability is the amount of time that the machine can safely perform its intended functions at its designed performance level. The response of the manufacturers is that the limited availablility is due to poorly trained operators and mechanics.

It is reasonable to believe that track machines which are well maintained and operated correctly are fairly reliable. This has been demonstrated by foreign railroads which contract their maintenance to manufacturers, who supply machines and operators. Given two machines with similar design reliability, the machine which is easier to operate and maintain will have a better practical reliability.

Availability is of major concern to the railroads. This is a function of reliability and ease of servicing. Accordingly, it would be of value to be able to determine the ease of operation, serviceability, and design reliability of a given machine.

The method which gives the best or most accurate indication of reliability is testing, but as previously stated, testing was considered impracticable. Two other methods, a theoretical reliability analysis and a thorough design review, would also be costly and time-consuming. Although a reasonable estimate of reliability would result from these methods, there would be no exact indication of how the machine would perform in a particular railroad environment. In evaluating track machinery, the primary interest is knowing the relative reliability of the machines being compared. By adding the weighted population of the major components of a particular machine, it is possible to make a comparison of machines of similar type. A comprehensive report of the reliability phase of this project can be found in Appendix J.

The construction machinery industry has developed over a period of 20 years indexes for determining serviceability. These indexes are published in the Handbook of the Society of Automobile Engineers (SAE). This index has been adapted to determine the ease of maintaining and repairing track machines. Using this concept, indexes were also devised for determining a machine's ease of operation and its design reliability. These indexes are presented in Section 3.6.7.

3.6.5 Analysis of Functional Characteristics

Manufacturers offer machines which, although of different design characteristics, are of identical or similar purpose in that they perform the same task or generate the same end product. Because the design of one machine may enable it to perform better than others in a given environment or under particular track conditions, it is important to understand the unique qualities or functional characteristics of each machine, as well as the resultant advantages and disadvantages. For example, certain tampers align track more accurately than others provided that the original alignment is fairly accurate. Conversely, other tampers can correct gross alignment deviations but have difficulty in obtaining the close tolerances required for high speed track.

Accordingly, an analysis of the functional characteristics of machines is an important factor in the evaluation process. The analysis requires the determination of the interrelationship of key electrical and mechanical components, and the geometry of the machine technique for accomplishing its designed task.

3.6.6 Production Quality Testing

Production quality is an assessment of how well a machine performs its designed function, measured in such a way as to eliminate the effect of the operator and the track conditions. Track machines fall into three categories with respect to production quality:

- Category I - Machines for which production quality is immaterial. The machine either performs its function or it does not. These machines are listed in Table 3.
- Category II - Machines for which there is an identifiable production quality, but for which the economic benefit is tenuous or not easily demonstrated. These machines are listed in Table 3.
- Category III - Machines for which there is a production quality which is of self-evident economic benefit. These machines are listed in Table 3.

There is no valid method to determine production quality other than a practical test. As quality is a function of design, it is necessary to perform a test of only limited duration with only one machine of each model. The test involves limited machine time, limited track, and small variation in track conditions. Accordingly, it was considered economically feasible to test those machines to which quality testing is applicable.

Considerable work has been done in this field by British Rail, specifically with tampers. Their research indicates that quality projections can be determined within a test period of three months; the resulting information would therefore not be dated.

The Northeast Corridor Improvement Project is presently sampling the output of ballast cleaners. The information generated by this sampling would supply a significant part of a quality test for a ballast cleaner. Research has also been done on ballast consolidators. A study undertaken by the Federal Railroad Administration, "The Affects of Accelerated Ballast Consolidation" (Report No. FRA-OR&D-76-274, March, 1977), could be adapted to establish a quality test procedure for ballast consolidators.

TABLE 3 - QUALITY TESTING

CATEGORY I	CATEGORY II
Ballast Regulator	Ballast Shoulder Cleaner
Ballast Undercutter	Cleaner, Track/Yard
Brush Cutter	Rail Anchor Adjuster
Cranes, On-track Only	Rail Anchor Applicator, Manual
Crib Ballast Remover	Rail Anchor Applicator, Semi-Automatic
Gauging Machine	Rail Drill
Motor Car, Large	Rail Saw or Abrasive Cutter
Motor Car, Small	Spike Driver, Automatic
Rail Grinder	Spike Driver, Pneumatic
Rail Heater	Tie Injector/Inserter
Rail Joint Straightener	Tie Spacer
Rail Lifter	Tie Bed Scarifier/Inserter
Rail Puller	Track Fastening Wrench
Rail Slotter	Track Liner
Rail Threader Car	Track Vibrator
Spike Puller	Track Wrench
Tie Adzer	
Tie Boring Machine	
Tie Cribber	**CATEGORY III**
Tie Destroyer	Ballast Compactor
Tie Handler	Ballast Undercutter/Cleaner
Tie Plug Setter/Driver	Tamper
Tie Remover	Tamper with Jacks
Tie Saw or Shear	Tamper with J&A (Production)
Tie Sprayer	Tamper, Joint
Tie-End Remover	Tamper, Multi-head
	Tamper, Switch
	Tamper, Switch with Aligner

3.6.7 Maintainability, Operability, Repairability and Reliability Indexes (MORR Indexes)

An important aspect of MOW machinery evalution is the determination of why a machine performs as it does, specific-ally, the determination of the elements which affect its performance. This is of particular importance because if the railroads know why a machine's performance is what it is, they can then readily predict how the machine will respond in their environment.

The physical characteristics of track machines could be compared and evaluated using the Standardized Manufacturers' Published Data (See 3.6.1). An equally important aspect of machinery evaluation is the determination of the ease of accomplishing the man-machine interface for each piece of equipment and designed reliability.

Over a period of 20 years, the Society of Automotive Engineers (SAE) has developed indexes to assist engineers in determining the relative ease of maintaining and repairing equipment. Using a modified version of the indexes, a dimensionless number can be developed for each piece of MOW equipment, the difficulty of maintenance or repairing increasing with an increase in numerical value. For example, a machine having a maintainability index of 1,200 can be assumed to be somewhat more difficult to maintain than a machine having a maintainability index of 1,000.

Based on the SAE index principle, indexes were developed to measure ease of operation and designed reliability of MOW equipment. They could be used by railroads to compare the comparative ease of performing the man-machine functions and design reliability of machines of a similar type and performance. The indexes could also be used by the manufacturers to improve the design of their machines.

Only the feasibility of the indexes has been shown here. The indexes need to be more fully developed and substantiated by an independent agency under the guidance of either REMSA, AREA, AAR, or the FRA. After substantiation, these indexes could be included with the manufacturers' published data.

3.6.7.1 Maintainability Index

The maintainability index was developed as a system to rate machines, either existing or new in concept, in terms of the ease with which routine or periodic maintenance actions can be performed.

Under this system, lubrication and maintenance items are assigned a point value on the basis of certain considerations. The considerations are: where located (location), how easy to reach (access), how easy to perform (operation), and other factors that cannot be categorized (miscellaneous). The sub-total of the individual items is multiplied by a frequency multiplier. Frequency multipliers are numbers that represent the various hour service intervals. The sub-total of each item is multiplied by the appropriate frequency multiplier to obtain the point total for each item. The point total of all items is the maintainability index for a machine. A maintainability index approaching zero is ideal.

Any items which have a high point value must be scrutinized. In addition to offering an excellent opportunity for a reduction in the maintenance index, items with a high point value emphasize maintenance areas which are likely to be skipped by the serviceman because of the difficulty involved. Improvement in these areas can reduce the risk of machine or component failure because of neglect, as well as reduce critical machine down time for periodic maintenance.

The system establishes judgment factors and assigns points to approximate the values used to judge machines in the field. The limits of application are:

(a) The maintainability index is not expressed in time or cost.

(b) The maintainability index is best used to compare early and late versions of a particular machine, various sizes of machines in a model line, or machines of other manufacturers. It is suggested that the maintainability index not be used to compare vastly dissimilar machines.

(c) The criteria involved and points assessed may have to be altered to fit the needs of individual machines.

PROCEDURE:

List all required lubrication and/or maintenance items on the maintainability index chart. Although not essential, it is desirable to list these items according to frequency, with the shortest frequency first. Figure 2 will be used as a reference throughout this procedure.

Each phase of a multiple step operation should be listed and points assessed. For example, an oil change requires draining the crankcase as one operation and filling the crankcase as another operation. Each should therefore be listed. Each lubrication fitting should be listed individually, to give full credit when the number of fittings is reduced.

Search the list on page 46 under the considerations -- LOCATION, ACCESS, OPERATION, and MISCELLANEOUS -- for the characteristics which most closely resemble those of the item being rated. Enter the corresponding point value in the appropriate column. Select the frequency multiplier for the corresponding service interval for each item and enter it in the proper column.

Add the points across the chart for each item and enter this in the sub-total column. Multiply the sub-total by the FREQUENCY MULTIPLIER to find the total for each item. When the totals have been found for all maintenance items, add them to find the maintainability index (MI) for the entire machine. Sum the appropriate point values from the MAINTENANCE MANUAL section and insert the previously determined MI. The product should then be added to MI, and the result will be the total maintainability index (TMI).

CLARIFICATION OF CONSIDERATIONS:

1. LOCATION - Refers to the position in which an individual must place himself in order to do the job. No attempt has been made to rate the height an individual must climb on a machine. Machines of a similar size and configuration will usually be the same in this respect. If more than one operation can be accomplished from the same location at the same service interval or multiple thereof, the first operation is assessed points applicable to that location, and the remainder are assessed one point each.

2. ACCESS - Refers to the ease of reaching a lubrication or maintenance point. If more than one operation can be accomplished through the same access at the same service interval or multiple thereof, the first operation is assessed points applicable to that access, and the remainder are assessed one point each.

3. OPERATION - Refers to the action required to perform the servicing of the listed items.

4. MISCELLANEOUS - Items in this list cannot be categorized under any of the other headings. These requirements are generally considered undesirable and, as such, should be avoided if possible. In effect, the point values listed for

miscellaneous items are punitive points.

5. FREQUENCY MULTIPLIER (Maintenance Interval) - Maintenance interval refers to the frequency of performing a lubrication or maintenance item. Each lubrication and maintenance item is assigned a frequency multiplier once--the most frequent interval performed. For example, a schedule that stipulates that the engine oil level must be checked daily would be recorded on the form only once. This item would not enter the count again, even though it may be performed during a monthly oil change.

6. MAINTENANCE MANUAL - Refers to the effectiveness of the operator's service instructions provided with the machine by the manufacturer.

CONSIDERATIONS:

1. LOCATION

		Points
(a)	Ground level-working upright, within normal reach	1
(b)	Ground level--bending or stretching outside normal reach	2
(c)	Ground level--squatting, kneeling or lying (except under the machine)	3
(d)	Mount machine--normal reach	6
(e)	Mount machine--bending, stretching or squatting	8
(f)	Within reach but not visible	9
(g)	Any position (other than upright) under or within the confines of the machine	10

2. ACCESS

		Points
(a)	Exposed	1
(b)	Exposed--through opening	2
(c)	Flip up cover or flap	3
(d)	Door or cover--hand operated	4
(e)	Door or cover--single fastener	5
(f)	Door or cover--multiple fasteners	10
(g)	Tilt cab	10
(h)	Hood removal	12
(i)	Multiple covers--multiple fasteners	15
(j)	Radiator guard removal	15
(k)	Belly guard removal--hinged and bolted	15
	--bolted only	20

3. OPERATION

The operation considerations and their respective point values are grouped into categories of similar action for easy reference.

	Points
Compartment Checking	
(a) Visual check	1
(b) Dip stick	3
(c) Screw cap--hand removable	4
(d) Multiple screw cap--hand removable	6
(e) Screw cap or plug, tool required	8
(f) Multiple screw cap or plug, tool required	10
Component Checking	
(a) Visual check	1
(b) Non-precision tool	5
(c) Precision tool	10
Lubricating	
(a) Fitting	1
(b) Fitting, special adaptor required	3
(c) Brush-on lube	3
(d) Oil can lube	3
(e) Fitting requiring secondary action, such as rotating shaft to get fitting to accessible location	5
(f) Hand packing (each)	20
Draining	
(a) Drain valve (including removal of safety plug)	1
(b) Horizontal plug	6
(c) Vertical plug	8
(d) Cover plate	10
(e) Multiple plugs or covers	15

		Points
Filling		
(a)	Hand-removed cap	1
(b)	Tool-removed cap or plug--vertical	3
(c)	Tool-removed plug--horizontal	10
(d)	Multiple caps or plugs	15
Cleaning		
(a)	Blow with air	3
(b)	Single bath wash	5
(c)	Multiple bath wash or wash and oil	10
Replacement		
(a)	Spin on	1
(b)	Single fastener, no tool required	3
(c)	Single fastener, tool required	4
(d)	Multiple fastener, no tool required	5
(e)	Multiple fastener, tool required	6
Adjustment		
(a)	Single step	2
(b)	Multiple step	4
(c)	Multiple location multiple step	10
4. MISCELLANEOUS		
(a)	Drainage indirectly collectible into container, hose or pipe required	2
(b)	Interval not SAE standard	2
(c)	Bleeding required	3
(d)	Priming required	3

		Points
(e)	Special tool	4
(f)	Inadequately identified	4
(g)	Filler size inadequate	5
(h)	Vulnerable to contamination	5
(i)	Need to start engine	5
(j)	Drain and wash filter housing	8
(k)	Need for special instruction	10
(l)	Torquing required	10
(m)	Need to operate or position machine	10
(n)	Unable to collect fluid	10
(o)	Two persons required	20
(p)	Operation requiring caution	30
(q)	Position requiring caution	30

5. FREQUENCY MULTIPLIER

Maintenance Interval (hours)		Frequency Multiplier
(a)	2000--Annually	0.5
(b)	1000--Semi-annually	1.0
(c)	500--Quarterly	2.0
(d)	As required	2.0
(e)	250--Monthly	4.0
(f)	100--Semi-monthly	10.0
(g)	50--Weekly	20.0
(h)	10--Each shift	100.0

The hour intervals listed conform to SAE Standard J752b, "Maintenance Interval-Construction Equipment". If intervals other than those shown are used, apply the frequency multiplier of the nearest SAE standard interval plus a miscellaneous penalty of two points.

6. MAINTENANCE MANUAL

This factor is to be determined after the other considerations (maintainability index) have been totaled and then added to that total.

Type:	Points
1. Permanently attached to the machine and cannot be rendered illegible through use.	0
2. Permanently attached to the machine, but can be rendered illegible through use.	.006MI
3. Not attached and cannot be rendered illegible through use.	.014MI
4. Not attached, and can be rendered illegible through use.	.02MI
5. None.	.04MI

Schedule:	
1. Outlined by period, e.g., daily, weekly.	0
2. In narrative form.	.01MI
3. No schedule.	.02MI

Directive: (to service points)	
1. Pictorially, e.g., diagram, label.	0
2. Marked on machine by color coding or clearly shown labels.	.01MI
3. Narrative.	.02MI
4. Not explained.	.03MI

Miscellaneous	
1. Maintenance record book not included.	.02MI

An example of a completed Maintainability Tabulation Form is given in Appendix I.

FIGURE 2 - MAINTAINABILITY TABULATION FORM

MAKE:

MODEL:

TYPE

		CONSIDERATIONS							
ITEMS	SERVICE REQUIRED	LOCATION	ACCESS	OPERATION	MISCELLANEOUS	SUB-TOTAL	FREQUENCY-MULTIPLIER	TOTAL	COMMENTS
									MI
MAINTENANCE MANUAL									

TOTAL MAINTAINABILITY INDEX	

3.6.7.2 Operability Index

The operability index was established as a means to measure the amount of effort required to guide a particular machine through its designed work function(s). Each component contains specific criteria that indicate a machine's ease of operation, its operability. The determination of the values assigned to each item is based on operator preference. Involved in determining the final index figure are the following six components:

I. Initiation of Operation
II. Operation Indicators
III. Operation Controls
IV. Machine Stability
V. Environment
VI. Termination of Operation

The criteria for each component are assigned point values balanced in relationship to other criteria within the same section as well as with those criteria within other sections. The resultant index reflects evaluation of the operability levels of machines of the same size, type, and function.

I. INITIATION OF OPERATION

This component deals with the evaluation of the procedures required to place a machine into full operation. It incorporates all necessary procedures leading to and terminating in setting the machine in the operating mode. High point values are assigned to those features which are difficult or time-consuming to operate.

PROCEDURE:

In the comment column of Section I of the Operability Tabulation Form (shown in Figure 3), list all fluids to be checked. Determine the appropriate numerical value for LOCATION, METHOD, and ACCESS from the CHECK FLUIDS section. From the START section, determine the assigned point values for the applicable PRESTART features and the METHOD. Determine applicable TYPES and LOCATION from the COMPONENT OPERATION section. Record the point values on the attached form.

CLARIFICATION OF CONSIDERATIONS:

1. CHECK FLUIDS - Refers to the procedure necessary to determine that all machine fluids (e.g., lubricants, fuels) are sufficient for a work shift.
2. START - Refers to the procedures and methods necessary for igniting engine(s).
3. COMPONENT OPERATION - Refers to the device which requires activation to put the machine into operational readiness.

CONSIDERATIONS	POINTS
1. CHECK FLUIDS	
a. METHOD	
. Visual check	1
. Dip stick	3
. Screw cap - hand removable	4
. Multiple screw cap - hand removable	6
. Screw cap or plug, tool required	8
. Multiple screw cap or plug, tool required	10
b. ACCESS	
. Exposed	1
. Exposed through opening	2
. Flip-up cover or flap	3
. Door or cover - hand operated	4
. Door or cover - single fastener	5
. Door or cover - multiple fasteners	10
. Tilt cab	10
. Hood removal	12
. Multiple covers - multiple fasteners	15

	POINTS
. Radiator guard removal	15
. Belly guard removal - hinged and bolted	15
- bolted only	20
c. LOCATION	
. Ground level - working upright, within normal reach	1
. Ground level - bending or stretching outside normal reach	2
. Ground level - squatting, kneeling, or lying, except under the machine	3
. Mount machine - within normal reach	6
. Mount machine - bending, stretching, or squatting	8
. Any position other than upright, under or within the confines of the machine	10
2. START	
a. PRESTART	
. Preheat	2
. Compression Release - manual	2
. Choke - manual	3
. Battery switch	3
. Ether	4
. Necessary for operator to remount engine	6
b. METHOD	
. Electric start button or key	1
. Recoil rope or spring crank	3
. Hand crank	4
. Rope pull	6
3. COMPONENT OPERATION	
a. TYPE	
. Fail-safe mechanism	0
. Attached safety lock, no tools required (pin, chain, or catch)	1

	POINTS
. Attached safety lock, tools required (pin, chain, or catch)	3
. Unattached device, no tools required (pin, chain, or catch)	3
. Unattached device, tools required	6

b. LOCATION

. Within reach from driver's seat	0
. Ground level	
- working upright, within normal reach	1
- bending or stretching outside normal reach	2
- squatting, kneeling, or lying (except under the machine)	3
. Mount machine	
- within normal reach	6
- bending, stretching, or squatting	8
. Any position other than upright, under or within the confines of the machine	10

II. OPERATION INDICATORS

This component is intended to penalize those indicator layouts which are poorly placed from the operators' point of observance, in addition to those which are of a nature difficult to monitor.

The term INDICATORS refers to apparatus requiring regular surveillance to provide the operator with information necessary to the safe and proper operation of the machine.

PROCEDURE:

In the comment column of Section II of the Operability Tabulation Form, (Figure 3), list all indicators which require monitoring. In the TYPE column, enter the assigned point value for each indicator listed. Points from LOCATION and FREQUENCY columns should be applied to each indicator. The point value for OPERATION INDICATORS is the result of the product of the point values from the FREQUENCY and TYPE columns added to those of the LOCATION and NUMBER sections.

CLARIFICATION OF CONSIDERATIONS:

1. TYPE - Refers to the type of indicators.
2. LOCATION - Refers to where the particular indicator is situated in area of vision from the operator's position.
   a. Front - within 60° range - refers to the angle drawn on a vertical plane extending from the operator, equally spread above and below eye level.
   b. Degree of vision - refers to the range of vision to the left or right, i.e., 120° of vision is 60° to the left and 60° to the right of straight ahead.
3. NUMBER - Refers to the number of indicators of the same type which are grouped together.
4. FREQUENCY - Refers to the required or recommended number of times which a particular indicator must be monitored.

CONSIDERATIONS	POINTS
1. TYPE	
a. None	0
b. Sound	2
c. Warning lights	3
d. Gauges (warning zone, easy read)	
. 3" diameter	3
. 1½" diameter	4
e. Gauges (calibrated only)	
. 3" diameter	5
. 1½" diameter	6
2. LOCATION	
a. Front - within 60° range	
. 120° of vision	1
. 240° of vision	3
. 360° of vision	7

	POINTS
b. Overhead - above 60° range	
. 120° of vision	3
. 240° of vision	5
. 360° of vision	9
c. Floor - below 60° range	
. 120° of vision	3
. 240° of vision	6
. 360° of vision	10
d. Not visible from operator location	15
3. NUMBER - per same type in same location	
a. 1	1
b. 2-4	2
c. 5-8	3
d. 8+	5
4. FREQUENCY - per indicator	
a. After engine ignition only	0
b. As alerted	1
c. Periodic (approximately every 2 hours)	2
d. Intermittently (approximately every 15 minutes)	4
e. Once during each operating cycle	10
Note: The suggested frequency point values for some common indicators are as follows:	
. Fuel Level	1
. Engine tachometer	1
. Engine oil pressure	2
. Engine temperature	4

III. OPERATION CONTROLS

The term OPERATION CONTROLS refers to all machine components which require movement or activation by the operator to cause the machine to perform its designed function.

It is the purpose of the OPERATION CONTROL component to take into account the strength, coordination, training, and movement required of the operator as they relate to machine controls. Excess demand on the operator in any of these respects will result in poor operator performance, which is accordingly reflected in the high point value assigned.

PROCEDURE:

In the METHOD column of Section III of the Operability Tabulation Form (Figure 3), enter the appropriate point value listed in the METHOD section under CONSIDERATIONS (Page 61). In the COMMENT section, list all controls used, in order, during one complete work cycle and during additional work functions which the machine is designed to perform. For each control, select the appropriate point values from the TYPE, PHYSICAL REQUIREMENT, SENSITIVITY, CONTROL LOGIC, LOCATION, and LABELING sections. Enter the appropriate point value from the COMBINATION section in the corresponding column.

The value for the OPERATION CONTROL Section will be the points from the COMBINATION and LABELING sections, added to the product of the METHOD value times the sum of values from the TYPE, PHYSICAL REQUIREMENT, SENSITIVITY, LOGIC, and LOCATION sections.

CLARIFICATION OF CONSIDERATIONS:

1. METHOD
    a. Exception - Operator activity is initiated only when machine fails to maintain its pre-programmed operation.
    b. Fully Automatic - Operator performance is limited to supplying machine's feeding mechanism with materials.
    c. Semi-Automatic - Operator is required to perform manually part of the operation which the machine complements.

d. Manual - Operator is required to initiate manually all machine procedures.

2. TYPE

   a. Squeeze Activation - Function activated by grip pressure.

   b. Arm Lever - Function activated by movement of entire arm only (from the shoulder on down)

   c. Foot Pedal - Function activated by movement of leg (from the hip on down).

   d. Hand Lever - Function activated by movement from elbow on down only.

   e. Push Button - Self-explanatory.

3. PHYSICAL REQUIREMENT - The amount of force the operator must apply to the control mechanism to activate it.

4. SENSITIVITY - Refers to responsiveness of controls.

   a. On-off - Any switchlike mechanism in which sensitivity is absolute.

   b. Proportional - A control in which equal amounts of movement or pressure result in proportional amounts of function movement.

   c. Exponential - A control in which progressively increasing or decreasing amounts of movement or pressure result in disproportionate amounts of function movement.

5. CONTROL LOGIC - Refers to the reasonableness of a control's motion in relation to the controlled function, e.g., when pushed forward, a control for machine movement should activate the machine to move forward (logical), as opposed to causing the machine to move backward (illogical).

   a. Illogical - A control which is irrational in relation to its function.

   b. Logical - A control which is rational in relation to its function.

6. LOCATION - Refers to position of controls in relation to the position of the operator.

   a. SAE optimum range
   b. SAE maximum range
   c. Outside SAE ranges

   as per SAE recommended practice J898a, "Control Location for Construction and Industrial Equipment Design".

7. COMBINATION - Refers to the number of controls necessary to manipulate during any one operation.

8. LABELING - Refers to the quality of method used to designate the control function.

CONSIDERATIONS:	POINTS
1. METHOD	
a. Exception	0
b. Fully Automatic	1
c. Semi-Automatic	3
d. Manual:	
. 1 cycle/min. or less	7
. 2 cycle/min.	10
. 4 cycle/min.	15
. 6 cycle/min. or greater	25
2. TYPE	
a. Push Button	1
b. Hand Lever	2
c. Foot Pedal, one way	2
d. Foot Pedal, two way	4
e. Arm control	
. motion 1-2 way	2
. motion 2-4 way	4
. motion 4+	6
. wheel	8
f. Squeeze Actuation	5
3. PHYSICAL REQUIREMENT	
a. Squeeze Actuation	
. 0-1 lbs.	0
. 1-3 lbs.	3
. 3+ lbs.	6
b. Arm Motion	
. 0-5 lbs.	0
. 5-10 lbs.	3
. 10-20 lbs.	6
. 20+ lbs.	10

		POINTS
	c. Foot Pedal Force	
	. 0-5 lbs.	0
	. 5-10 lbs.	3
	. 10+ lbs.	8
	d. Hand Lever	
	. 0-2 lbs.	0
	. 2-4 lbs.	3
	. 4-6 lbs.	6
	. 6+ lbs.	12
4.	SENSITIVITY	
	a. On-Off	0
	b. Proportional	1
	c. Exponential	5
5.	CONTROL LOGIC	
	a. Logical	0
	b. Illogical	7
6.	LOCATION	
	a. SAE optimum range	0
	b. SAE maximum range	3
	c. Outside SAE ranges	10
7.	COMBINATION	
	a. 2	0
	b. 3	5
	c. 4	9
	d. 5+	15
8.	LABELING OF CENTRAL FUNCTIONS	
	a. Metal, raised or engraved letters	0
	b. Plastic, screw-on	1
	c. Painted	3
	d. Stick-on	5
	e. None	7

IV. MACHINE STABILITY

The MACHINE STABILITY component incorporates those features inherent to a particular machine which may cause operator apprehension. Those machines with a high degree of instability will reduce operator performance, resulting in poor machine performance because of undue operator concern. This component focuses not only on the cause of instability but also on the effects.

PROCEDURE:

In Section IV of the Operability Tabulation Form (Figure 3), enter the appropriate point values from the DIRECTION OF OPERATION, DAMAGE POTENTIAL, SAFETY ENVIRONMENT, and UPSET POTENTIAL sections. Add all entries to produce the total for the machine stability index.

CLARIFICATION OF CONSIDERATIONS:

1. DIRECTION OF OPERATION - Refers to direction of operation of work head.
2. DAMAGE POTENTIAL - Refers to the reasonable probability for damage due to operator error.
3. SAFETY ENVIRONMENT - Refers to injury that may possibly be suffered by the operator, using recommended operating practices and accepted safety precautions.
4. UPSET POTENTIAL - Refers to significant features which would tend to reduce the chance of derailing or tipping over, using recommended operating practices and safety precautions.

CONSIDERATIONS:	POINTS
1. DIRECTION OF OPERATION	
a. Forward	0
b. Forward and reverse	2
c. Forward, reverse, left and right	4
d. Forward, reverse, and rotational	5

	POINTS
2. DAMAGE POTENTIAL	
a. $0-1,000	0
b. $1,000-10,000	5
c. $10,000+	10
3. SAFETY ENVIRONMENT	
a. No apparent problems	0
b. Pinch points	20
c. Crush points	20
d. Tight operator hand work area	30
e. Exposed sharp edges	30
4. UPSET POTENTIAL	
a. Highly stable/low risk (anti-derail and rail sweep)	0
b. Stable/some risk (anti-derail or rail sweep)	10
c. Unstable/some risk	20
d. Unstable/high risk	30

V. ENVIRONMENT

The ENVIRONMENT component incorporates those intangible features which surround the operator and indirectly affect machine performance. High point values are assigned to those machines whose design results in undue stress, tension, and discomfort for the operator.

PROCEDURE:

In the comment column of Section V of the Operability Tabulation Form (Figure 3), list each operator position. For each operator position, enter the assigned point value from each of the seven components and total. The final index value will be the total of each operator position sub-total.

DEFINITION OF CONSIDERATIONS:

1. COMFORT - Refers to operator's position during operation.
2. NOISE - Measured according to SAE recommended practice J919b, "Operator Sound Level Measurement Procedure for Powered Mobile Construction Machinery."
3. EXPOSURE - Refers to exposure to weather and dust.
4. VISIBILITY (Work) - Refers to the ability to see the work area during total work cycle.
5. VISIBILITY (Environment) - Refers to the ability to see the environment other than work area.
6. MOTION - Refers to motion perceived by the operator due to machine ground speed only.
7. VIBRATION - Refers to the motion induced by the engine and machine functions.

CONSIDERATIONS:	POINTS
1. COMFORT	
a. Padded seat only	5
. padded seat with padded arm rest and padded back rest	1
. padded seat with padded arm rest	2
. padded seat with padded back rest	3
. padded seat with back rest	4
b. Metal - formed seat	7
c. Stand - no seat	10
d. Walk - with more than 5 feet clear vision of walkway	11
e. Walk - with less than 5 feet clear vision of walkway	15
2. NOISE - per 8-hour working shift	
a. 80 dBA or less	0
b. 85 - 80 dBA	6
c. 90 - 85 dBA	8
d. In excess of 90 dBA	10

	POINTS
3. EXPOSURE	
a. Pressurized cab	0
b. Enclosed cab	
. Metal	2
. Partial canvas	4
c. No cab	7
4. VISIBILITY (Work)	
a. Entirely visible from erect seated position	0
b. Requires head movement (entirely visible)	4
c. Not entirely visible	6
d. Visible by TV or mirror only	10
e. Visible only by straining	12
f. Not visible at all	25
5. VISIBILITY (Environment)	
a. Percentage of half circle obstructed	
. 0 - 15	0
. 15 - 30	3
. 30 - 60	6
. 60 - 100	10
b. Percentage of travel view obstructed	
. 0 - 15	0
. 15 - 30	10
. 30 - 60	17
. 60 - 100	25
6. MOTION - due to machine ground speed	
a. No motion	0
b. Constant motion	1
c. Constant with varying speed	3
d. Varying speed with stop start at frequency of 30 sec/cycle as part of its work cycle	5
e. Erratic intermittent motion - sec/cycle	
. 11 - 29	7
. 4 - 10	10
. 0 - 3	13

	POINTS
7. VIBRATION - independent of ground speed	
a. Zero	0
b. Comfort range	1
c. Intermediate range	5
d. Extreme range	15

VI. TERMINATION OF OPERATION

This component was established to evaluate the difficulty in securing the machine for an indefinite period of time. Those machines whose procedure is involved and/or difficult to perform may in fact not be accomplished by the operator.

This component incorporates all procedures necessary for the safe and proper release of machine from service. The meaning of safe is determined by the individual purchaser. The meaning of proper is determined by the manufacturer's recommended practice.

PROCEDURE:

In Section VI of the Operability Tabulation Form (Figure 3), list each OPERATION necessary for termination as described in the manufacturer's operating and maintenance manual, which includes safety devices and controls. For each OPERATION determine the point value for the appropriate TYPE and add to its corresponding LOCATION - TYPE. For each safety device, determine the appropriate point value from the SAFETY DEVICES section and add this value to an appropriate point value from the LOCATION-SAFETY section. Add the sum to the corresponding point value from the NUMBER OF OPERATIONS column. The final total will be the sum of all applicable considerations.

CLARIFICATION OF CONSIDERATIONS:

1. NUMBER OF OPERATIONS - The total number of items which require attention by the operator during the shutdown procedure.
2. TYPE - Refers to the type of controls to be manipulated by the operator for shutdown.
3. LOCATION - TYPE - Refers to the location of controls as per SAE recommended practice J898a, "Control Location for Construction and Industrial Equipment Design."
4. SAFETY DEVICES - Refers to the type of safety devices.
5. LOCATION - SAFETY - Refers to the location of safety devices.

CONSIDERATIONS:	POINTS
1. NUMBER OF OPERATIONS	
a. 2 - 3	1
b. 4 - 6	4
c 7+	9
2. TYPE	
a. Keys and switches	0
b. Valve (faucet type)	3
3. LOCATION - Type	
a. In SAE maximum range	0
b. Outside range	3
c. Outside cab	10
4. SAFETY DEVICES	
a. Fail-safe	0
b. Attached safety lock, no tools required (pin, chain, or catch)	1
c. Attached safety lock, tools required (pin, chain, or catch)	3
d. Unattached, no tools required (pin, chain, or catch)	3
e. Unattached, tools required	6
5. LOCATION - SAFETY	
a. Ground level	
. Working upright, within normal reach	1
. Bending or stretching outside normal reach	2
. Squatting, kneeling, or lying, except under the machine	3
b. Mount machine	
. Normal reach	6
. Bending, stretching, or squatting	8
c. Any position (other than upright) under or within the confines of the machine.	10

An example of a completed Operability Tabulation Form is given in Appendix I.

FIGURE 3 - OPERABILITY TABULATION FORM

I. INITIATION

COMMENT	CHECK FLUIDS: LOCATION	CHECK FLUIDS: METHOD	CHECK FLUIDS: ACCESS	START: PRESTART	START: METHOD	COMPONENT OPERATION: TYPE	COMPONENT OPERATION: LOCATION	SUBTOTAL

TOTAL

II. INDICATORS

COMMENT	TYPE (1)	FREQUENCY (4)	(1) x (4)	LOCATION (2)	NUMBER (3)	SUBTOTAL (1)x(4)+(2)+(3)

TOTAL

III. CONTROLS

COMMENT	METHOD (1)	TYPE (2)	PHYSICAL REQ'M (3)	SENSITIVITY (4)	LOGIC (5)	LOCATION (6)	(1)[(2)+(3)+(4)+(5)+(6)]	LABELING	COMBINATION	SUBTOTAL

TOTAL

TYPE

MAKE: ____________________

MODEL: ____________________

FIGURE 3 -(con't)

IV. STABILITY

COMMENT	DIRECTION OF OP.	DAMAGE POT.	SAFETY ENVIR.	UPSET POT.	TOTAL

V. ENVIRONMENT

COMMENT	COMFORT	NOISE	EXPOSURE	VISIBILITY (WORK)	VISIBILITY (ENVIR)	MOTION	VIBRATION	SUBTOTAL
							TOTAL	

VI. TERMINATION

COMMENT	NO. OF OPERATIONS	TYPE	LOCATION -TYPE	SAFETY DEVICES	LOCATION-SAFETY	SUBTOTAL
					TOTAL	

I	II	III	IV	V	VI	OPERABILITY INDEX
						( )

3.6.7.3 Repairability Index

The repairability index was developed as a system to rate machines, either existing or new in concept, in terms of the ease with which a part, assembly, system, or machine which has failed can be restored to a state of operational readiness.

By this system, diagnosis and repair operations are assigned a point value on the basis of certain considerations, which are: SPECIAL TOOLS AND EQUIPMENT (need for complex tools and equipment), LOCATION (when component(s) requiring repair is located within a machine), ACCESS (how easy the component(s) is to reach), and MISCELLANEOUS. The repairability index consists of the point total of all operations. The objective is to arrive at the lowest point total possible.

It is important that any operation having a high point value be carefully reviewed. Reduction of a high repairability index is desirable. A relatively high repairability index indicates that specific repairs are difficult to accomplish and as such may not be performed by a repairman during the early stages of a repair.

The system involves a judgmental analysis of various factors which relate to the repair of a machine. Repair, as referred to in this guideline, involves component removal and installation or gaining access to a location in order to repair a component in its installed position. The general objectives of the system are:

(a) The system can be used as a product design tool.

(b) The system can be used to evaluate the repairability of a machine by either reviewing engineering layouts or by evaluating a built-up unit.

(c) The system is devised so that the point value of the index is related to the time, ease, and caution required to perform the repair. As such, the designer can use this system to identify the repairability impact of various design choices.

The general limitations of the system are:

(a) The system is best used to compare early and late versions of a specific machine, various machine sizes in a model line, or machines of a size similar to those of other manufacturers. It is suggested that the index not be used to compare vastly dissimilar machines.

(b) The index is not directly expressed in time or cost.

(c) Machine cleaning is more related to its work environment and, as such, is not considered.

The system, as presented, is a guideline only and must be so considered because of the complexity and the number of variables involved in the operations being evaluated. Additional factors with their point values may have to be developed for specific individual products.

PROCEDURE:

To determine the repairability index of a machine, use a repairability index form as shown in Figure 4, which will be used as a reference throughout this procedure. List each step which needs to be performed in the diagnosis, or removal and installation (R & I) of each component from the machine operating and maintenance manual.

Next, examine the list under each consideration -- SPECIAL TOOLS AND EQUIPMENT, LOCATION, ACCESS, and MISCELLANEOUS-- for the conditions which most closely resemble those for the step being rated. Enter the assigned point value in the appropriate column. (The point value can be a combination of the various conditions listed.) Add the points across the form for each operation and enter each line total in the total column. Add the various line totals to determine the repairability index for the service performed. The repairability index of the machine is determined by totaling the index for all individual services performed.

The comments column is used to explain how the point value is derived for cases in which there are a combination of conditions involved, or for any other notes which would explain the entries made for a specific operation.

DEFINITION OF CONSIDERATIONS:

1. SPECIAL TOOLS AND EQUIPMENT - Refers to the need for special tools and/or equipment to perform the service required. This requirement applies to both diagnosis and R & I. Diagnosis deals with the availability of test points as well as the need for special tools and/or equipment to perform an adequate diagnosis. Removal and installation deals with the type of tools and/or equipment needed to perform the R & I.

2. LOCATION - Refers to the position in which an individual must place himself to perform the diagnosis and/or repair. No attempt has been to rate the height an individual must climb on a machine. Machines of similar size and configuration will usually be the same in this respect.

3. ACCESS - Refers to the number of disassembly and assembly steps required to reach a diagnostic check point or to reach a point at which a component is ready for removal. Reassembly operations after the component is installed are also considered.

4. MISCELLANEOUS - Items in this list cannot be categorized under the headings above. These operations are generally considered undesirable. As such, they should be avoided or limited to the extent possible. In effect, the point values listed for miscellaneous items are punitive points.

CONSIDERATIONS:	Points
1. SPECIAL TOOLS AND EQUIPMENT	
(a) No tools or test equipment needed	1
(b) Test panel available	1
(c) Standard test equipment or hand tools required (each)	2
(d) Existing special test equipment or special tools required (each)	3
(e) Individual test points available (each)	3
(f) Need to develop new special test equipment or special tools (each)	6
(g) No test points	9
2. LOCATION	
(a) Ground level--Outside the confines of machine	1
(b) Mount machine--Outside the confines of machine	2
(c) Ground level--Within the confines of machine	3
(d) Mount machine--Within the confines of the frame	7
(e) Any position (other than upright) under machine	11
3. ACCESS	
(a) Accessible without involving other parts or assemblies	1
(b) Fasteners easily accessible without tool (each)	1
(c) Fasteners easily accessible with tool (each)	2
(d) Fastener removal and installation limits rotating hand/special tool less than 180° per stroke (each)	3

CONSIDERATIONS: (cont.)		Points
(e)	Requires disconnecting or connecting minor parts such as lines, wires, ducts, hoses, etc. (each easily accessible)	3
(f)	Requires disconnecting or connecting minor parts such as lines, wires, ducts, hoses, etc. (each not easily accessible)	9
4.	MISCELLANEOUS	
(a)	Special instruction needed to perform service required	4
(b)	Multiple manpower required	6
(c)	Welding equipment needed	7
(d)	Hoist needed	9
(e)	Requires removal from work site to workshop	16
(f)	Location requires extreme caution	30
(g)	Procedure requires extreme caution	30

An example of a completed Repairability Tabulation Form is given in Appendix I.

FIGURE 4 - REPAIRABILITY TABULATION FORM

MAKE:

MODEL:

TYPE

OPERATION(S)	CONSIDERATIONS: SPECIAL TOOLS & EQUIPMENT	LOCATION	ACCESS	MISCELLANEOUS	TOTAL	COMMENT

REPAIRABILITY INDEX	

3.6.7.4 Reliability Index

The proposed reliability index which was developed quantifies the inherent tendency of one machine to fail relative to another. This index evaluates only those parameters inherent to the equipment design and does not consider the effects of maintenance and the operator. The process involves a truncated predictive analysis which is comprised of two key elements, the failure rate data base and the critical operational subsystems.

The failure rate data base can be used for comparative analysis as long as the actual reliability of the machine is not required. Uniform application of the data base to each subsystem being evaluated can result in machine indexes that allow meaningful comparative judgements to be made.

The data base will contain a reliability index for each type of component used in MOW equipment. The indexes are dimensionless and do not relate to actual failure rates. They do, however, maintain the proper proportionality relationship between component indexes.

The critical operational subsystems are those portions of a machine whose operation is either directly or indirectly critical to the performance of the work function. This refers to the portions of the machine that contact the work medium and their control functions. Those subsystems which perform ancillary functions are not analyzed because they have fewer critical wear and stress characteristics as a result of their use environment. Their exclusion should not have an appreciable impact on the overall index, and the simplification of the analytical process makes its implementation more practicable.

PROCEDURE:

Implementation of the Reliability Index is accomplished in four basic steps. The following discussion explains the process.

1. Identify each unique component and its population in the critical operational subsystems for the machine being evaluated. Record this information on a worksheet similar to that shown in Figure 5.

   In lieu of a specific definition of the critical operational subsystems, those subsystems which appear to be operationally representative can be selected. The comparative reliability evaluation will remain valid as long as the same subsystems of each machine are selected. The only constraint that should apply to the selection process is that a sufficient number of components should be included in the analysis. Table 4 contains the method for determining this number.

   It is not intended that the same number of components be evaluated for each machine; on the contrary, only the same functional areas need by analyzed regardless of the number of parts relative to another machine. This differential part count is a key element in the evaluation process, i.e., a design that can perform the same function with fewer parts will, in general, be more reliable. The minimum component count specified in Table 4 should be used only to assure that the number of components considered for each machine under evaluation is a reasonable sample of the total machine part count.

2. Find the index corresponding to each component in the reliability index listings in Table 5. This table is not a complete listing of all possible components. If the exact description is not listed, choose the closest description to the component in question. Place each

index in the column marked RIi opposite its description on the worksheet.

3. This step is optional and involves the stress level factor (Si). This factor can be used to enhance the reliability index by accounting for the amount of stress applied to a component, relative to its specified limits. The stress factor is calculated by finding the applied or peak operational stress level and relating it to the manufacturers' rated limits.

$$Si = \frac{Sa}{Sr}$$

where Si = stress factor of the ith component
Sa = applied stress
Sr = rated stress

The stress factor is multiplied by the product of population and reliability index to yield the product pRIiSi. Caution should be exercised in applying the stress factor. Different applications of the same type component may result in different applied stress levels. When this occurs, separate line entries for each stress level within a particular component type will be required.

4. Total each line entry in the pRIiSi column to find the reliability index for the machine being evaluated. The lower the final index, the more reliable the equipment, relatively speaking. The mathematical expression for the reliability index is as follows:

$$RI = \sum_{i=1}^{n} pRIiSi$$

Where p= population of the ith component in the critical operational subsystems

RIi= reliability index of the ith component

RI= Equipment Reliability Index

n= total number of component types in the critical operational subsystems

Si= stress factor of the ith component

An example of a completed Reliability Tabulation Form is given in Appendix I.

TABLE 4 - NUMBER OF COMPONENTS FOR RELIABILITY EVALUATION

Total Population	Minimum Number of Parts for Evaluation
1-90	All
91-1200	91+5% of excess above 91; 91+(x-91).05
1201 & up	147+0.5% of excess above 1201; 147+(x-1201).005

where x= total number of components in the machine being evaluated.

TABLE 5 - RELIABILITY INDEXES

Part Class	Description	Component Index
Accumulator	Hydraulic	15.0
	All Others*	29.8
Actuator, Linear	Electrical	67.0
	Mechanical Driver	58.0
Actuator, Rotary	Electrical	8.0
	All Others	172.0
Batteries, Rechargeable	General	27.0
Bearings	Ball	1.0
	Bushing (Rotational Motion)	14.0
	Needle	2.7
	Roller	0.6
	Sleeve (Linear Motion)	40.0
	All Others	22.0
Blowers and Fans	Axial	9.5
	Centrifugal	9.5
	All Others	5.6
Brakes	Electrical	$12.0/10^6$ Cycles
	Magnetic	$242.0/10^6$ Cycles
	All Others	$4.3/10^6$ Cycles
Capacitors	Paper & Plastic Film	0.01
	Mica	0.1
	Glass	0.02
	Ceramic	0.4
	Tantalum, Solid	0.05
	Tantalum, Non-Solid	0.6
	Aluminum Oxide	1.6
	Aluminum, Dry	3.0
	Variable, Ceramic	2.4
	Variable, Piston	0.4

* Where a specific component type is not known, the "all others" component index is to be used.

** To convert 10^6 cycles to the component index number, multiply the index value by cycles used/hour.

TABLE 5 (cont.)

Circuit Protection Devices	Circuit Breaker	2.0
	Circuit Breaker, 3-Pole	0.8
	Spark Gap	0.01
	Fuse	3.0
	Fuse Holder	0.02
Connector, Electrical	Circular	0.4
	Coaxial	0.4
	Rectangular	0.007
	Solder	0.005
	Welded	0.002
	All Others	0.5
Compressors	General	12.7
Crystals	General	0.2
Cylinders	Hydraulic	53.3
	Hydraulic Servo	126.0
	Pneumatic	12.0
	Pneumatic Piston	1.5
	All Others	33.2
Diodes	Silicon	0.7
	Germanium	1.7
	Zener	0.9
	Thyristor	0.9
	Varactor, Tunnel	8.1
Filters, Nonelectric	Gaseous	1.7
	Liquid	11.0
Fittings	Hydraulic, Hose	4.0
	Quick Disconnect, Liquid	13.0
	Swivel, Hydraulic	30.6
	All Others	1.0
Gaskets & Seals	Gaskets	1.6
	O-Rings	1.2
	Packing	0.3
	Seals, General	2.2
Generators	General	50.0

TABLE 5 (Cont.)

Hoses	General	2.5
Instruments	Ammeter	30.0
	Indicator, Air Pressure	2.0
	Indicator, Liquid Level	12.0
	Indicator, Tachometer	18.0
	Indicator, Temperature	62.0
	Indicator, Oil Pressure	20.0
	Indicator, All Others	3.7
Mechanisms, Power Transmittal	Arm	20.0
	Axle	5.0
	Bellcrank	6.0
	Cam	20.0
	Clutch, Friction	250.0
	Clutch, Magnetic	11.5
	Cord	240.0
	Coupling	10.0
	Drive Chain	50.0
	Drive Rod	20.0
	Drum	4.0
	Fan Belt	8.0
	Gear	0.1
	Gearbox	11.7
	Pulley	39.0
	Shaft	38.4
Motor, Electrical	Induction	20.0
	Fractional H.P., AC	7.6
	2 H.P., AC	4.0
	3 H.P., AC	3.0
	5 H.P., AC	6.0
	7.5 H.P., AC	5.0
	10 H.P., AC	3.0
	20 H.P., AC	3.0
	Permanent Magnet, DC	6.0
	Motor-Generator Set	167.0

TABLE 5 - (Cont.)

Mounts, Resilient	General	6.5
Pumps	Centrifugal	20.0
	Fuel	23.1
	Hydraulic	67.0
	Hydraulic, Variable Delivery	17.6
	Impeller	2.5
	Oil	40.0
	Water	342.0
	All Others	25.0
Regulator	Pressure	2.2
	Temperature	17.4
Relays	Armature	1.2
	Contractor	7.0
	Latching, Polarized	0.9
	Latching, All Others	0.57
	Non-Latching, General	0.1
	Reed	1.0
	Thermal	16.0
	Time Delay	4.2
	All Others	0.17
Resistor	Fixed Composition	0.04
	Fixed Film	0.1
	Power Film	2.3
	Fixed Wirewound, Accurate	0.95
	Fixed Wirewound, Power	0.80
	Thermistor	0.50
	Variable, Wirewound Precision	5.8
	Variable, Wirewound Semi-Precision	8.5
	Variable, Wirewound Power	8.1
	Variable, Non-Wirewound Trimmer	16.0
	Variable, Composition	20.0
Sensors	Torque	80.0

TABLE 5 - (Cont.)

Shock Absorbers	General	20.0
Solenoid	General	30.0
Switches	Centrigufal	20.0
	Coaxial	1.5
	Float, Liquid Level Indicator	95.0
	Limit	47.7
	Pressure, Hydraulic	10.0
	Pressure, All Others	6.1
	Pushbutton	0.3
	Rotary	3.0
	Sensitive	6.0
	Thermostatic	5.0
	Toggle	2.8
Thermocouples	General	62.0
Timers	Electromechanical	95.0
Transducers	Pressure	79.0
	Tachometer Generator	50.0
	Temperature	22.0
	All Others	80.0
Transformer	General	0.1
Transistors	Silicon	1.3
	Germanium	4.9
	Field Effect	2.7
	Unijunction	9.4
Tubing, Metal	General	4.0
Valves, Fuel	Check	2.4
	Float	10.0
	Gate	9.0
	Pressure Regulator	13.0
	Shut-Off	4.0
	Solenoid	2.0

TABLE 5 - (Cont.)

Valves, Hydraulic	Ball	1.4
	Check	6.0
	Control	80.0
	Pressure Regulator	8.4
	Relief	0.9
	Restrictor	16.0
	Sequencer	17.0
	Servo	25.0
	Shuttle	50.0
	Shut-Off	14.2
	Solenoid	$10.8/10^6$ Cycles
	Spool, 4-Way	100.0
Valves, Oil	General	8.0
Valves, Pneumatic	Bleed	1.7
	Check	3.0
	Control	40.0
	Pressure Regulator	20.4
	Relief	4.7
	Shut-Off	40.0
	Solenoid	$10.3/10^6$ Cycles
Valves, Water	General	153.0

FIGURE 5 - RELIABILITY TABULATION FORM

MAKE: ______________________ TYPE ______________

MODEL: ______________________

COMPONENT DESCRIPTION	CONSIDERATIONS: POPULATION p	INDEX RI_i	STRESS LEVEL S_i	TOTAL pRI_iS_i	COMMENT

RELIABILITY INDEX	

4. SUMMARY AND CONCLUSIONS

4.1 SUMMARY

In April 1978 the Federal Railroad Administration (FRA) issued a contract to De Leuw, Cather & Company (DCO) for the development of a "Master R&D Plan in the Field of Maintenance-of-Way Equipment Evaluation." The objectives of the contract were to develop: (1) a plan to identify criteria for the evaluation and selection of maintenance-of-way (MOW) equipment and (2) a master R&D plan depicting alternative proposals to develop such criteria.

To meet these objectives, an action plan outlining the tasks to be performed during the project was developed. The major work elements included:

- A review of existing literature to determine what efforts, if any, have been previously made in the field of equipment evaluation;
- The development of standard machine definitions and machine categories;
- Review of present equipment evaluation methods;
- Correspondence and visits with the Railway Equipment manufacturers to discuss the project, gain the industry's viewpoint, obtain manufacturers' equipment brochures, and review the manufacturers' production facilities;
- Correspondence and visits with American Railway Engineering Association technical committees and several individual railroads to discuss the project, gain the railroads' viewpoint, and learn of various railroads' equipment evaluation and monitoring techniques;
- Development of a plan for the evaluation of maintenance-of-way equipment.

4.1.1 Data Collection

The literature search was conducted using the Highway Research Information Service, Engineering Index, and Railroad Research Information Service abstracts. The search resulted in the discovery of the maintainability and repairability indexes developed by the Society of Automotive Engineers (SAE) and contained in the SAE Handbook. These indexes were developed by SAE to assist engineers in determining the relative ease of maintaining and repairing equipment and as such can be used in the evaluation of track machines.

Standard machine definitions and machine categories were developed in order to eliminate any misunderstandings during the study. A review of present equipment evaluation methods was undertaken which involved obtaining technical reports on evaluation studies in other industries, information on methods used by the U.S. Army in selecting construction equipment, and visits to the German National Railways (DB) and British Rail (BR).

4.1.2 Interface with Manufacturers

A meeting was held with an Ad Hoc Committee from the Railway Equipment Manufacturers Supply Association (REMSA) to inform the manufacturers about the program and generate input from them with regard to the direction of the program. At a later meeting, preliminary recommendations were presented to the committee for general discussion.

A list of the majority of equipment manufacturers in the United States and Europe was developed, and letters were sent to manufacturers requesting published literature, number of units in service, lease costs, and purchase price. Almost all major manufacturers in the United States responded. Of those responding, all sent published literature and several supplied the other requested information.

All equipment data pertinent to an evaluation was tabulated by machine.

A representative sample of manufacturers was surveyed to determine how they develop their published performance data, their quality control, production, and design practices; and their opinion regarding evaluation techniques and testing. Of the twelve who responded, ten expressed a willingness to participate in the program. Six of the manufacturers, considered a representative cross-section of those responding, were visited during the survey.

4.1.3 Interface with Railroads

A presentation was made to AREA Committee 27, Maintenance-of-Way Work Equipment, at a meeting held in Philadelphia on June 27, 1978. The purpose of the presentation was to inform the Committee of the general goals of the program and to solicit their guidance, advice, and comments. At a meeting held in February, 1979 in Shreveport, Louisiana, preliminary recommendations were presented to Committee 27 and Committee 22, Economics of Railway Construction and Maintenance. A group of 21 railroads was selected as a representative sample of the industry for a telephone or personal interview to ascertain their equipment selection techniques; to determine if their management information system is suitable for data collection from long-term field testing, possible validation of test results, and development of evaluation methodology; and to receive comments and suggestions for project direction.

Of the railroads contacted, 13 responded favorably, granting interviews.

4.1.4 Development of an Evaluation Plan

As a result of discussions with various railroads and manufacturers, it was determined that an evaluation plan should be constructed to allow each railroad to analyze the available machines in a structured manner and to decide on their own the preferred machine for each situation. Accordingly, analyses were made for performing the evaluation of MOW equipment, utilizing the following elements: published data, plant testing, field testing, design/performance interrelationships, functional characteristics, production quality testing, and indexes for determining the relative values of maintainability operability, repairability, and reliability (MORR indexes) of MOW equipment.

4.2 CONCLUSIONS

As a result of these efforts, it was determined that implementation of the following procedures would improve the railroads' ability to select the proper equipment for any given track maintenance situation:

1. Development and standardization of manufacturers' published data;
2. Development and utilization of indexes for the determination of relative values of maintainability, operability, repairability, and reliability of track machinery (MORR indexes);
3. Production quality evaluation and functional characteristics analysis of MOW equipment.

A discussion of these recommendations follows.

4.2.1 Development and Standardization of Manufacturers' Published Data

At present, all track machinery manufacturers determine the information to be included in their brochures and calculate the values of the data by whatever means they choose. This method results in a wide disparity of information and does not allow easy comparison of similar machines sold by different manufacturers. Accordingly, it appears that the establishment of standards for published data would be beneficial to the railroad industry.

In the contractor's visits to the railroads and equipment manufacturers, a positive response was received from virtually all parties concerning the standardization of published data. In general, standardization would allow the railroads and manufacturers to determine the relative capabilities of track machines by simply reviewing the information contained in the manufacturers' brochures.

Initially, manufacturers' brochures and data were gathered and reviewed. Nearly all significant American manufacturers submitted documents for review. Based upon this information and discussions with railroad personnel, the following proposals were developed:

- Proposed Manufacturers' Published Data Matrix (Figure 1)
- Proposed Manufacturers' Published Data Definitions (Appendix F)
- Criteria for Determination of Equipment Production Rates (Appendix G)

These contain a draft of the information proposed for inclusion in future manufacturers' brochures and the parameters to be followed in determining the data values.

All data values would be determined by the manufacturers. It is recommended that with the standardization of published data, a third party be retained to publish the data in one manual.

4.2.2 Development and Utilization of Indexes for the Determination of Relative Values of Maintainability, Operability, Repairability, and Reliability of Track Machinery (MORR Indexes)

The physical characteristics of track machines could be compared and evaluated using the Standardized Manufacturers' Published Data. An equally important aspect of machinery evaluation is determining the factors affecting overall machine performance.

The Society of Automotive Engineers (SAE) has developed indexes to assist engineers in determining the relative ease of maintaining and repairing equipment. These indexes are also used as a design and marketing tool. Using these indexes, a dimensionless number may be developed for all types and models of equipment to express the difficulty of maintaining and repairing them.

The SAE index concept has been utilized to develop a method of determining relative reliability and operability indexes as well. Three of these indexes could be used by the railroads to determine the comparative ease of performing the man-machine functions of track machines, and by the manufacturers to improve the design of the man-machine aspects of their products. The fourth index, reliability, could be used to compare the design reliability of machines and to enable the manufacturer to improve his design.

These indexes need a great deal of work to be more fully developed and substantiated by an independent agency under the guidance of either REMSA, AAR, or the AREA. After substantiation, these indexes could be included with the manufacturers' published data or used by railroads as an evaluation tool.

4.2.3 Production Quality Evaluation and Functional Characteristics Analysis of MOW Equipment

For certain machines, such as tampers and ballast compactors, an important part of the evaluation process is knowing how well each machine performs its tasks. Similarly, the functional characteristics of certain machines, such as tampers, could cause them to be more efficient under some conditions than others (e.g., certain tampers align track more accurately than others provided that the original alignment is fairly accurate; conversely, other tampers can correct gross alignment deviations but have difficulty in obtaining the close tolerances required for high speed track, due to the electromechanical interrelationship and the geometry of the aligning system).

Accordingly, it is recommended that tests for determining the production quality of various machines be developed and a functional characteristics analysis of those machines which are affected by varying operating environments be performed. After development, these production quality capabilities could be included with the manufacturers published data. These tests should be conducted under the guidance of REMSA, AAR, or the AREA.

The evaluation data developed during the evaluation program could be placed on a consolidation table as shown in Figure 6 to facilitate review by railroad management.

Manufacturer Model	Dimension	Weight	Production Rate	Transport./Travel	Transport./Load	Company: Size	Company: Location	Company: Organization	Maintainability	Operability	Repairability	Reliability	Production Quality	Other Characteristics	Price
	PUBLISHED DATA								INDEX RELATIONSHIPS				ANALYSIS OR TESTING		

Figure 6 - EVALUATION PLAN CONSOLIDATION TABLE

APPENDIX A - LIST OF ARTICLES OBTAINED THROUGH LITERATURE SEARCH *

Railroad Research Information Service

1. "How Automated Tracklining and Raising Systems Work, 3-Fairmont System", Railway Track and Structures, October, 1976.
2. "How Mechanized Tracklining and Raising Systems Work, 4-The Rexnord System," Railway Track and Structures, December, 1976.
3. "How Automated Tracklining and Raising Systems Work, 5-The Tamper System", Railway Track and Structures, January, 1977.
4. "Productivity: What is Needed to Get the Most from Track Gangs", Railway Track and Structures, April, 1977.
5. "Towards a More Stable Ballast Bed", Railway Gazette International, March, 1977.
6. "Attaining the Durability of the Track Level", Rail Engineering International, September, 1974.
7. "A New Generation of Switch and Tamping Machines", Rail Engineering International, June, 1973.
8. "Change-out of Defective Rails is Mechanized on L&N", Railway Track and Structures, September, 1972.
9. "New Tamper Emphasizes Versatility", Railway Track and Structures, December, 1972.
10. "Manufacturers Have Their Say on Getting the Most out of M/W Machines", Railway Track and Structures, March, 1973.
11. "Track Contractor Tried out New Small Tamper", Railway Track and Structures, July, 1973.
12. "Developments in BR Track Maintenance Procedures and Mechanization Equipment", Railway Gazette, May, 1970.
13. "Work Equipment Repair Organizations of North American Railroads", AREA Bulletin, September, 1975.
14. "A Study of Failures in Track Maintenance Machines", Usenbahntechnisehe Rundschau, October, 1976.

15. "Mechanized Maintenance Machine Development", Permanent Way Institute, 1973.

16. "Mechanized Appliances for Permanent Way Maintenance", Railway Gazette, November, 1951.

17. "Effect on Rail of Kershaw Track Liner", Test Report, March, 1972.

18. "Present Trends in Machines for Track Maintenance", Railway Gazette, November, 1968.

19. "Mechanized Maintenance of Track on the JNR", Railroad Technical Research Institue: JNR, September, 1960.

20. "Ballast Compactor", Railway Gazette, August, 1971.

21. "Ballast Consolidation and Distribution on the Track", Railway Gazette, September, 1969.

22. "Mechanization of Permanent Way", Railway Gazette, May, 1954.

23. "Track Maintenance Problems", Railway Gazette, February, 1954.

24. "Comprehensive Trade Maintenance Systems", Railway Gazette, June, 1970.

25. "The Effects of Accelerated Ballast Consolidation", FRA-OR&D-76-274, March, 1977.

Highway Research Information Service

26. "Specifications for Your Files - How to Select Hydraulic Backhoe Excavators", Construction Methods and Equipment, May, 1976.

27. "Specifications for Your Files", Earthmoving, Construction Methods and Equipment, December, 1974.

28. "The Role of Equipment in Maintenance Operations", Highway Research Board, Highway Research News, Vol. 100.

29. "How to Buy A Truck, Engine and Power Train", Rural and Urban Roads, April, 1971.

30. "Think Sharp, Save Money on Equipment Costing", Road and Streets, March, 1975.

31. "Scraper Selection: Guides Zero in on Earth Moving Gains", Construction Methods and Equipment, October, 1975.

32. "How to Specify a Loader: Getting the Right Machine", Public Works, April, 1972.

33. "To Select a New Scraper Go Back to Basics", Road and Streets, March, 1975.

34. "Production Efficiency Study on Rubber-Tired Scrapers", Federal Highway Administration, FHWA-DP-PC-920, April, 1977.

35. "Production Efficiency Study in Large-Capacity, Rubber-Tired Front-End Loaders", Federal Highway Administration, FHWA-RDDP-PC-520, May, 1973.

36. "Production Efficiency Study of Slipformed Concrete Median Barrier Construction", Federal Highway Administration, FHWA-DP-PC-820, June, 1977.

37. "Vibratory Roller Evaluation Study", Louisiana Department of Highways - Research and Development Section, March, 1976.

Engineering Index

38. "What Machines for Branch Line Maintenance", Railway Track and Structures, December, 1975.

39. "What is New in Maintenance-of-Way Machinery", Railway Age, December, 1974.

40. "Track Maintenance Machines", Railway Engineering Journal, May, 1975.

41. "Santa Fe Test Track: What It Will Look for and Why", Railway Age, September, 1970.

42. "Establishing Working Procedures for the Selection of R.R. Freight Car Truck", FRA-ORD&D-58(A), December, 1975.

43. "Mechanization of Track Maintenance on BR", Railway Gazette, November, 1966.

* Very late in this study, the contractor became aware of AREA Committee 27 1973 Bulletin 645 Report on Assignment 5 "Proposed Minimum Information About Machines for Manufacturers to Give in Advertising Fliers and Brochures Sent to Railroads" which encourages standardization of publish data.

APPENDIX B - STANDARD MOW MACHINE DEFINITIONS

AIR COMPRESSOR

A machine capable of compressing air from an initial pressure to a higher pressure, storing it temporarily in a storage reservoir, and releasing it through valves, pipes, and hose where it expands with considerable force to operate pneumatic machines or tools. Compressors are rated in size by the number of cubic feet of air compressed in one minute at a specified PSI.

BALLAST COMPACTOR

A machine which uses a vibratory action and pressure to pack loose ballast in cribs, shoulders or both for the purpose of improving vertical and lateral track stability.

BALLAST UNDERCUTTER

A machine used for removing ballast from beneath the ties in locations unsuitable for using a plow. The machine uses a mining undercutting blade mounted in such a way as to permit it to dig under the track. Many methods are used for elevating and disposal of the fouled ballast.

BALLAST UNDERCUTTER/CLEANER

An on-track machine that removes the fouled ballast from the shoulders and beneath the ties by means of a toothed digging-type chain conveyor which deposits the ballast onto a screening device where the dirt or fines are conveyed to rail cars or the shoulder of the track. The cleaned ballast is then returned to the track.

BALLAST UNDERTRACK PLOW

A machine that straddles the track with an attached plow blade under the ties. The machine is capable of plowing to the shoulder a minimum of the crib material and up to 8" of ballast material from below the ties. The machine is pulled by either a winch or a locomotive.

BALLAST UNDERTRACK SLED

A machine that straddles the track with an attached blade device under the ties. The machine is pulled forward by a winch-cart, allowing the ties to be lifted and the crib and shoulder ballast to be leveled to approximately one-half the original height of the ties.

BALLAST REGULATOR

A self-propelled on-track machine that is designed for redistributing track ballast both laterally and longitudinally by means of attachments consisting of side and center plows, shaping blades, regulating boxes and scarifiers.

BALLAST REGULATOR WITH BROOM

A ballast regulator with a rotating brush attached to the front or rear of the machine used for sweeping ballast from the top of the rail, ties, and tie plates.

BALLAST SHOULDER CLEANERS

An on-track machine used to remove the fouled ballast at the shoulder of the track bed by means of scoops, bucket conveyors or wheels. The ballast is then elevated to a screening device where the dirt is removed and the clean ballast returned to the shoulder.

BALLAST SHOULDER CLEANER, SMALL

A low capacity machine for removing the fouling material from shoulder ballast in problem areas only. The machine elevates the ballast by methods similar to the standard size shoulder cleaners; however, the screening capacity is limited to approximately 100 cubic yards per hour.

BRUSH CUTTER

An on-track machine that, by rotating knives attached to counterbalanced or hydraulically-controlled extending arms, is used for cutting brush and undergrowth along the right-of-way. Several off-track types are also available.

CLEANER, TRACK/YARD

A machine specifically designed for removing all material such as weeds, ballast and debris from above the top of the tie level both in the cribs and on the shoulders of the bed. The material is usually conveyed directly into cars for transporting away from the area.

CRANES, ON/OFF TRACK

A truck-mounted crane fitted with auxiliary rail wheels capable of traveling on both rail and highway, which is suitable for various track-highway maintenance assignments.

CRANES, ON-TRACK

A crane with a maximum capacity of approximately 15 tons mounted on rail wheels. The crane may have the capacity to pull a limited number of railroad cars.

CRIB BALLAST REMOVER

An on-track machine with hydraulically or mechanically actuated arms that, by digging into the ballast in the center of the crib, pushes the ballast from the tie crib to the shoulders.

DETECTOR CAR, RAIL FLAW

A specially-instrumented self-propelled car, either rail mounted or with rail/road capability, that ultrasonically and/or inductively tests the rail for flaws such as cracks. The location of the flaws are indicated by various means such as a paper printout, painting the rail, etc. Depending on the design, there is considerable variation in size, operating speed, and data translation ability of rail inspection vehicles.

GAUGING MACHINE

A small manually-operated on-track machine used for fastening every fourth or fifth tie plate to the ties so that when the rail is set, no further gauging is needed. The machine drills two holes through the anchor-spike holes in the tie plate and dowels are inserted to anchor the plate at gauge.

INSPECTION CAR, GEOMETRY

A specially-instrumented car, either self-propelled or locomotive-hauled, that is capable of measuring and recording on either paper or magnetic tape some or all of the following track parameters: rail gauge, alignment, cross-level, and superelevation. Depending on the design, there is considerable variation in geometry car sizes, recording ability and operating speed.

MOTOR CAR, SMALL

A self-propelled rail car for carrying track maintenance personnel, of a size suitable for transporting track inspectors or a small (four or fewer persons) track gang.

MOTOR CAR, LARGE

A self-propelled rail car capable of pulling or pushing several trailors for transporting a large (more than four persons) track gang.

RAIL ANCHOR ADJUSTER

An on-track machine used for repositioning rail anchors against the tie without having to remove them completely from the rail.

RAIL ANCHOR APPLICATOR, MANUAL SETTING

A machine that drives and positions rail anchors that have been manually set on the rail.

RAIL ANCHOR APPLICATOR, SEMI-AUTOMATIC

A machine designed to set, drive, and position a rail anchor on the rail. The operator is required to feed the anchors into a magazine or bin where they are fed automatically to the work head.

RAIL CHANGER

An on-track or highway/rail machine with a telescoping crane able to lift the standard rail length from its carrier to the site of change. This machine can also be used for lifting jobs other than changing rail strings.

RAIL DRILL

A specially designed tool that is clamped onto the rail for use in drilling bolt holes. The drill is powered by a small gasoline engine.

RAIL GRINDER

An on-track, self-propelled machine that is used on a continuous basis for grinding rail in track primarily to remove corrugations from the ball of the rail. This machine is sometimes used to correct the rail profile.

RAIL HEATER

An on-track machine with a heat source that is passed back and forth over the rail to increase the temperature of the rail to the mean temperature for the geographic location before anchoring so that the rail is less apt to excessively expand or contract in future temperature extremes.

RAIL JOINT STRAIGHTENER

By means of hydraulic pressure, an upward force is applied by this on-track machine on the end of a length of rail to remove the downward bend that is formed through use.

RAIL LIFTER

A small machine specifically designed for lifting the rail above a specific tie to enable the easy removal or installation of a tie plate.

RAIL PULLER

A hydraulic device for pulling two strings of continuous welded rail so that they can be anchored with the stress equal to that of the mean temperature for the geographic location. This device also has sufficient clearance to permit Thermite welding of the two strings of rail.

RAIL SAW OR ABRASIVE CUTTER

A small machine that is clamped to the rail and is used for cutting rail to a precise length by either sawing or abrasive cutter.

RAIL SLOTTER

A small machine that is clamped on a rail above a joint and by grinding, removes the overflow rail head metal. This is done to prevent chip-out, and restore rail-end chamfer and expansion gap.

RAIL THREADER CAR

A specially-equipped rail car used for supporting and threading continuous welded rail onto or off a rail train.

SPIKE DRIVE, AUTOMATIC

An on-track machine with tubes or magazines into which a spike is dropped, then automatically set and driven. This machine is manually controlled to move to the next tie. Depending on machine design, it is capable of driving two or four spikes simultaneously.

SPIKE DRIVER, PNEUMATIC

A pneumatically powered hammer, usually mounted on a wheeled support frame, used to complete the driving of a spike which has previously been manually set. The air compressor for this tool is a separate piece of equipment.

SPIKE PULLER

A hydraulically or mechanically powered on-track machine that clamps onto the spike and with an upward pull, brings the spike out of the tie. Depending on design, this machine can remove one or two spikes at a time.

SPREADER/DITCHER

A locomotive-propelled machine equipped with hydraulically or pneumatically adjustable blades shaped to conform with the contour of the ballast section, which is used primarily for creating, cleaning or improving drainage ditches, distributing ballast and snow removal.

TAMPER

A machine for maintenance of track surface that by inserting tools or tines into the tie cribs compacts the ballast under the ties in the area of the rails by a vibrating squeeze action. The machine is manually indexed but the actual compaction can be done under an automatic cycle.

TAMPER, HAND

A hand-held, hydraulically, electrically, or pneumatically powered device that is used for compacting the ballast under the ties.

TAMPER WITH JACKS

A machine for leveling track that clamps onto the rail and by means of a jacking arrangement raises the track to a level set by a light, laser beam, wire or eyesight. The machine then penetrates tools or tines into the tie cribs and by a vibrating squeeze action compacts the ballast under the ties in the area of the rails so that the track remains at the level set by the jacks. The machine is manually indexed and the raising and compacting can be either semi-automatic or manual.

TAMPER WITH JACKS AND ALIGNER (PRODUCTION TAMPER)

A machine for leveling and aligning that clamps onto the rail and by means of jacking arrangement raises and aligns the track to a level and alignment set by a light or laser beam. The machine's tools then penetrate into the tie cribs, and by a vibrating squeeze action, compact the ballast under the ties in the area of the rails so that the track remains at the level and alignment set by the jacks. Alignment correction in curves is controlled by a separate semi-automatic device. The machine is manually indexed and the raising, aligning, and compacting can be either semi-automatic or manual.

TAMPER, JOINT

For use on jointed rail, it improves ride qualities by tamping joints only. This machine clamps onto the rail and by means of a jacking arrangement raises the track to a level set by a light or laser beam. The machine's tools then penetrate into the tie crib and by a vibrating squeeze action, compact the ballast under the tie in the area of the rail so that the joint is at a level set by the jacks. The joint is tamped slightly higher than the rest of the rail. The machine is manually indexed, but the jacking and compacting may be semi-automatic. The machine is equipped with only sufficient tools or tines to tamp under one rail at a time.

TAMPER, MULTI-HEAD

A machine for leveling and aligning track that clamps onto the rail and by means of jacking arrangement raises and aligns the track to a level set by a light or laser beam. The machine's tools then penetrate into several tie cribs simultaneously, and by a vibrating squeeze action compact the ballast under the ties in the area of the rails so that the track remains at the level and alignment set by the jacks. The machine is manually indexed and the raising, aligning, and compacting can be either semi-automatic or manual.

TAMPER, SWITCH

A machine specially designed for compacting ballast under switches and crossovers. This machine clamps onto the rail and by means of a jacking arrangement raises the track to a level set by a light or laser beam. The machine then penetrates into the tie crib with tines that are moved both horizontally and angularly by remote control which permits, by a vibrating squeeze action, the compacting of the ballast under the ties in the area of the rails so that the track remains at the level set by the jacks.

TAMPER, SWITCH WITH ALIGNER

A machine specially designed for aligning and compacting the ballast under the ties of switches and crossovers. This machine clamps onto the rail and by means of jacking arrangement, raises and aligns the track to a level set by a light or laser beam. The machine's tools then penetrate into the tie crib with tines that are moved by remote control both horizontally and angularly which permits, by a vibrating squeeze action, the compacting of the ballast under the ties in the area of the rails so that the track remains at the level set by the jacks.

TIE ADZER

The mechanical adzer, gasoline or diesel-powered and rail-mounted, has an adjustable rotating cutting head which cuts a uniform and smooth seat for the tie plate when pressed into the tie.

TIE BORING MACHINE

A machine used for drilling spike holes in ties, essentially a small engine-powered machine that can drill one or two holes simultaneously.

TIE CRIBBER

A machine powered by a small engine which is used to remove ballast from tie cribs in the area of the tie plates during a rail laying operation. The purpose of this machine is to permit the adzing of the tie without the tool being damaged by the ballast and to permit the installation of rail anchors without interference from the ballast.

TIE DESTROYER

A rail-mounted machine that cuts up tie butts into small chips so that they can be left along the right-of-way.

TIE HANDLER

A small rail-mounted, self-propelled machine specifically designed for moving tie butts from the track to the shoulder and for handling new ties from beside the track to a position from which they can be installed.

TIE INJECTOR

A rail-mounted machine that is capable of picking up a new tie that has been previously placed at right angles on the shoulder and inserting the tie under both rails. There are several variations of this machine; some have the capability of removing the old tie while others are capable of moving the ballast to facilitate the tie installation. These machines vary considerably in production capacity.

TIE INSERTER

A small rail-mounted machine that basically functions as a tie inserter. It is used where the ballast has been removed to permit pulling the new tie into place without jacking the track. The machine consists of a clamp that is manually fixed to the end of the tie and the tie is pulled under the rails by means of a small winch.

TIE PLUG SETTER AND DRIVER

A small machine used for inserting wooden plugs into old spike holes and clipping off the excess plug when the hole is filled.

TIE REMOVER

An on-track machine used for removing a tie in one piece from under the rail.

TIE-END REMOVER

A small rail-mounted machine generally used after a tie saw or shear that, by means of a hydraulic ram, pushes the two end pieces of the tie out from under the rail to simplify later removal.

TIE SAW OR SHEAR

An on-track machine that when positioned over a tie, either by a sawing or shearing action, cuts the tie just inside the tie plates into three pieces.

TIE-BED SCARIFIER/INSERTER

A track-mounted machine which removes ballast laterally from the ballast section to facilitate the installation of cross ties. Additionally, it has the capability of placing a tie in the crib area without lifting the track.

TIE SPACER

A machine that by means of a hydraulically controlled lever mechanism spaces ties. The machine is capable of straightening and respacing ties and is primarily used during a heavy tie renewal or ahead of a tamping operation.

TIE SPRAYER

A small rail-mounted machine that is used for spraying the freshly adzed tie plate area of a tie with wood preservative.

TRACK LAYING SYSTEM

A large machine or series of machines that by five different principles can rebuild track, lay new track, or take up abandoned track. Depending on the type of track laying system, these machines are capable of removing the rail, placing it on the shoulder, picking up and semi-automatically loading the ties on flat cars, picking up the ballast, cleaning it, replacing, leveling and compacting the ballast, semi-automatically laying new ties that are being carried on flat cars ahead of the machine, installing the new rail that has been previously layed on the shoulder, and leaving the track in such a condition that with no further attention it can handle trains up to 35 mph. These machines vary considerably in size as well as production capability.

TRACK LINER

An on-track machine designed to automatically move the track laterally to bring it to the exact required position. The amount of movement can be controlled by either a light beam or a wire lining device.

TRACK VIBRATOR

An on-track machine used to assist in getting rail to assume its natural position, relative to the temperature of the steel, before rail anchors are applied. The vibration relieves the friction forces between rail and tie plates.

WELDER, MOBILE RAIL

An electric flash butt rail welder, mounted and powered from a mobile vehicle. This machine is used for welding rail lengths together where it does not warrant the use of a welding plant and rail train or, for example, welding into track, switches or insulated joints.

WRENCH, TRACK

This self-propelled, on-track machine has a series of hydraulically powered wrenches for tightening or removing track bolts at either rail joints or switches.

WRENCH, TRACK FASTENING

Powered by a small engine, this machine drives a wrench for the purpose of applying, tightening or removing joint bolts, or with an optional feature, rail to tie fasteners (coach bolts), or screw spikes.

APPENDIX C - SUMMARY REPORT OF VISITS TO BRITISH RAIL (BR) AND GERMAN NATIONAL RAILWAYS (DEUTCHES BUNDESBAHN OR DB)

Report of Meeting with Transmark on June 5, 1978 at Transmark's London Office

Attendees:	R. Shipley	- DCO
	W. Frank	- DCO
	D. Burns	- DCO Consultant
	A. Gross	- FRA
	J. Price	- BR
	P. Watts	- BR
	C. Frederick	- BR
	J. Powell	- Transmark

The British Rail's maintenance procedures were discussed. Track renewal and general maintenance work are performed on Sundays only. Virtually all production track work is performed in shops, the track units being constructed in panels. The completed panels are then moved to the site and installed. British Rail allows very few speed restrictions on any particular line in order to always maintain high service levels. The length of a speed restriction cannot exceed three quarters of a mile, and only three or four speed restrictions are allowed throughout the length of a route. The total engineering budget for British Rail is approximately £340 million per year, of which £200 million is spent on renewal and maintenance-of-way. Of this amount, £6 to £10 million are spent on plant renewal; the remainder is spent on maintenance-of-way functions.

Each year the engineering staff prepares a five and ten-year plan defining the plant renewal and maintenance-of-way requirements. This plan is the basis for the contract (subsidy) negotiated yearly with the government. British Rail can purchase equipment from anyone, but the government prefers that they buy British. The general procedure for purchasing maintenance-of-way equipment is through specifications and bidding. No reliability requirements are contained in the specifications. British Rail buys the lowest priced equipment responding to the specification. The present maintenance-of-way equipment fleet is worth approximately £160 million.

Peter Watts stated that a major consideration for purchasing maintenance-of-way equipment is the availability of replacement parts and service. Plasser has a 24-hour replacement service throughout Britain.

Charles Frederick then discussed the Derby Testing Facility's organization and work program. Derby has a staff of approximately nine hundred, one-half of which are college graduates. Derby performs the following work functions:

1. Service work for British Rail,
2. Project work -- long timeframe research projects (one or two years). The cost of long term research projects is generally shared by British Rail and the Government,
3. Consulting for Transmark,
4. Work for outside parties (work is never solicited)

Derby has performed evaluations of track machinery at the request of British Rail Engineering. Some comparative testing of track surfacing machines has been performed including fatigue testing. Track machines are sometimes borrowed from the suppliers for testing purposes. For long duration tests, however, British Rail usually purchases a machine.

Report of Meeting at British Rail's Derby Research Facilities, Wednesday, June 7, 1978.

Attendees:	Robert Shipley	- DCO
	Mike Shenton	- BR
	Alastair Gilchrist	- BR
	Winn Frank	- DCO
	Arnold Gross	- FRA
	David Burns	- DCO Consultant

The British Rail's Derby R&D division has performed comparative evaluations on tampers, liner tampers, and consolidators--machines that affect the alignment through ballast movement. These evaluations are performed to determine which machines are best and to find out what improvements are required if any. At present, Derby has only evaluated standard type equipment.

An explanation was given of the workings of Derby's inertial type and Atlas absolute measuring systems. The BR inertial measuring system measures horizontal and vertical alignment and cross level. BR does not have an inertial base lateral measurement system. The Atlas absolute measuring system measures the absolute level of loaded track and is used to determine alignment quality. The slow speed of the measuring system (500 ties in eight hours) limits its use to test tracks, however. Inertial measuring systems are used on railroad test sites.

British Rail uses multiple sites to evaluate equipment. The number of sites ranges from four to nine per machine, with the sites paired so that each machine will be working under similar conditions. British Rail has determined that four sites are too few and is hoping to have as many as 20 test sites per machine in the future. The test sites are typically a minimum length of one-half mile. This length is the distance equal to ten times the longest wavelength (80 meters) measured by the measuring equipment.

The measurement of track geometry is one of BR's prime methods for determining the comparative value of tampers, liners, and consolidators. In the particular comparative evaluation discussed with us, geometry measurements were taken over a three-year period using BR's Atlas absolute measuring system and plotted by computer to show deterioration with time. Measurements were taken immediately prior to maintenance, immediately after maintenance, and 1, 3, 9, 20, 47, 63, 82, 134 and 183 weeks after maintenance. The measurements were plotted to show absolute variances instead of variance from a mean. The purpose of this large number of measurements is to determine the machine's immediate performance and what happens to the track over the long term. British Rail has found that some machines have better initial accuracy, but deterioration with time is greater than other machines having lower initial accuracy. Accordingly, the measurement of track deterioration over the long term (1-2 years) is important to British Rail. [A number of the plots that we reviewed gave a good indication of long-term performance after only several months, however.]

Tests for tampers usually require 1½ to 2 man years of effort. Additional tests beside the measurement of geometry include:

- the measurement of unloaded and loaded lateral strength of track
- settlement
- pressure distribution under tie
- bending in ties
- effect of machine on ballast
- effect on subballast
- damage to structure from vibration and loads
- effect on lateral resistance
- noise and vibration of equipment

Most of the above tasks are performed on tampers, liners and consolidators. The lateral resistance test, one of the hardest to perform, requires specially constructed rolling equipment.

British Rail tests approximately one machine per year and has been testing for seven years.

Parameters affecting the quality of work performed by tampers includes the rate of production (speed) and the technique of the operator. In the particular test reviewed with us, one of the tampers worked at virtually double the speed of the other. However, the slower tamper produced better results. It was postulated that if the other tamper had worked at a slower rate, its results would have improved also. In this test, BR had informed the manufacturers that they were going to measure the quality of workmanship only and that speed would not be a criteria.

The equipment being evaluated is usually borrowed or rented for the period of testing. In some cases, however, equipment has been purchased. The tests are usually performed under confidentiality agreements whereby Derby agrees not to make the findings of the evaluation public, but gives copies of the report to the manufacturer and then uses them in-house to determine which equipment to purchase. Performance graphs are usually plotted with standard deviations in millimeters versus months since tamping. British Rail has also used tons of traffic instead of months but finds that plotting against time gives more valid results.

British Rail uses the following standard deviations in millimeters to determine the quality of track:

- 0.70mm variation is very good
- 1.08mm variation is good
- 2.61mm variation is medium
- 3.74mm variation is poor

The medium reading, 2.61mm variation, generally gives a ride during which writing is possible with good vehicles; at 3.74mm variation, coffee will generally spill. British Rail main line tracks are generally tamped once a year with the average lift being three-quarters to one inch. It is thought that axle loads have a greater effect on track deterioration than speed or gross tons. BR's heaviest axle loads are 25 long tons.

<u>Report of Meeting at British Rail's Derby Research Facilities, Thursday, June 8, 1978.</u>

Attendees:	Robert Shipley	- DCO
	Winn Frank	- DCO
	Arnold Gross	- FRA
	David Burns	- DCO Consultant

Ray Lewis	- BR (part time)
Robert McLester	- BR (part time)
Colin Stanworth	- BR (part time)

Presentation by Ray Lewis - Instrumentation

British Rail's high speed track recording coach (geometry measuring system) can record at any speed up to 125 mph, the maximum presently used on BR, and has been found to be accurate at speeds up to 135 mph. The coach travels in passenger trains and can cover 80,000 miles per year. The equipment was developed by BR and has been operational for approximately two years.

The on-board computer is calibrated prior to the recording run of the high speed coach. Calibration is performed at low speed with an operator pushing a botton as the train passes each quarter mile post. Depressing the button places a signal into the computer thereby locating each post. The calibration runs are made only once for each route. Using this system, distance measurements are accurate to within several inches per mile. The measurements made by the high speed coach are as follows: 3-meter twist, dynamic cross-level (dynamic means irregularities only, normal changes such as curves are filtered out), dynamic left hand top of rail, dynamic right hand top of rail, dynamic alignment, gauge, absolute cross level, absolute curvature. The high speed coach has an automatic system for marking track defects with paint spray; however, the system has not been perfected.

Vertical measurements are taken of the loaded truck through the coach's wheels. Lateral measurements are taken with an optical system. BR is presently developing a rail wear detector system.

Mr. Lewis concluded the presentation by stating that to be effective, a measuring coach must be able to repeat measurements, must be able to measure over a full range of wavelengths and must provide data that allows analysis by computer.

Presentation by Robert McLester - Structure and Integrity of Track Machines

BR has performed structural analysis on tamping machines, track lifters, rail lifters, and rail tensioners. The analyses have been involved with structural integrity and safety. In general, the tests are performed on machines that involve high energy and groups of men working closely with the machines where a structural failure could result in injuries. Safety problems do not generally occur with large equipment, but with those machines involving high loads such as lifters and tensioners.

Tamping machines tend to have problems with fatigue cracking of welded frames. These types of failures are not safety related but are economic in nature, the tradeoff being life expectancy vs. initial cost.

BR is of the opinion that the manufacturers tend to lack structural design expertise and as such their structural designs are somewhat hit or miss although some basic stress analyses may be performed. BR's methods of analysis is as follows:

1. Estimate loads to be encountered under working conditions or transportation
2. Perform theoretical computer analysis
3. Perform static laboratory tests to check accuracy of analysis (sometimes destructive testing is performed)
4. Dynamic field tests (strain gauge and brittle lacquer test)
5. Life expectancy prediction (e.g., the amount of tamps to the first fatigue failure).

At this time BR does not have a standard procedure for the structural analysis of each type of equipment evaluated. Specifications do have some structural requirements; however, there is no section specifically devoted to the subject. Derby reviews the manufacturers' drawings and determines if the specifications have been met. No field or lab tests are performed to determine conformance with specifications. If problems occur, BR contacts the manufacturer. BR's buying power is such that the manufacturers generally rectify any problems.

Presentation by Colin Stanworth - Acoustics

Mr. Stanworth, responsible for all acoustic specifications on British Rail, discussed the work that he has performed on track machinery and gave us his opinion of railroad acoustical problems in general.

The noise levels producted by track machinery are generally high and are of concern to BR. These noise levels affect the adjacent communties, the operators of the equipment, and cause safety problems in that the noise masks the noise generated by on-coming trains.

Track renewal trains are a particular problem in that they are at one location for extended periods (several nights running). British Rail generally informs the local inhabitants one week before maintenance of any type is performed by notices in newspapers, informing the police, or by placing notices in letterboxes. BR has placed families in hotels during certain maintenance operations.

BR has provided design assistance to one manufacturer to develop designs for quieting the engines of their tampers. By covering the engines, noise levels were reduced from 100 dBA to 85 dBA at one meter from the noise source. However, after approximately one month, the noise from the tamper bearings had increased to the point that the noise level reduction gained from the engine covers was lost. Many attempts have been made to quiet tamper bearings but have been unsuccessful at this time. The problem lies in the ability to lubricate the bearings. Southampton University is doing some work sponsored by Plasser (originally sponsored by BR) on bearing noise. BR still specifies covered engines on the tampers and hopes that a solution to the tamper bearing noise problems will be developed and can be retrofitted.

Comparative noise evaluations have not been performed on equipment because most of the major equipment is produced by Plasser.

BR has an acoustic standard of a continuous equivalent noise level of 85 dBA for an eight hour shift and 83 dBA for a 12-hour shift.

Report of Meeting with British Rail at London Headquarters June 9, 1978

Attendees:	J. Price	- BR
	S. Standbower	- BR
	I. Olney	- BR
	P. Watts	- BR
	R. Shipley	- DCO
	W. Frank	- DCO
	D. Burns	- DCO Consultant
	A. Gross	- FRA

As Resources Engineer, Mr. Price is responsible for the justification, the authorization to purchase and the checking of performance of all purchased equipment.

Forty-seven tampers were purchased by BR in 1977. The purchase of this equipment resulted in the elimination of 70 older machines. Equipment can be purchased on BR only if savings can be proved. Elimination of jobs is the main method. Actual job elimination is by attrition only, however. BR specifications are very tight and usually result in the purchase price of the equipment being approximately 20 percent above the "off the shelf" price. BR is presently buying only double bank tampers.

Specifications for a tamper liner (£190,000±), 4 KVA hand held ballast tamping equipment (£2,000), and rail stressing sets for gap welding (£2,000) were discussed. The specification for the 4 KVA hand held tamping equipment has evolved over years of use of similar types machines and has become more sophisticated with experience.

BR always goes to tender except under the unusual circumstances where only one manufacturer produces the equipment. In this case, the price is negotiated. When a new type of major equipment is produced by a manufacturer, BR attempts to borrow one machine and send it to the Derby Research Facility for evaluation.

BR has very strict rules concerning the possession of track by maintenance equipment. In general, a three-quarter mile possession is the maximum allowable. Many possessions are only one-half mile in length. The average tamper has a possession time of 27 hours per week and actual productive work time of 16 hours per week.

For large track machines, BR keeps daily records on availablility (occupation hours vs. non-occupation hours), production (track renewals, track maintenance, yards), cost (repair, operating and service), and cost per mile. The machine operator is responsible for furnishing the information on a daily basis. The data is analyzed by computer with individual records being kept on each major machine and then summarized by region. Each printout covers a 28-day period.

Although BR uses a five-year plan for maintenance, the authorization for expenditures is on a year to year basis. In general, there is no deferred maintenance and all necessary work is performed. Every track machine has a supervisor and two operators and therefore the ability to keep accurate records is easily achieved.

BR has performance standards for each manual work task, including the method of performance and time expected to perform the task. They used to have a performance bonus system whereby employees were rewarded for work performed at a rate greater than that contained in the standards manual. Union problems have caused this system to be dropped, however.

The BR standards are contained in the following three books:

- Booklet of Allowed Time -Permanent Way of Maintenance
- Relaying Handbook - Specifications and Allowed Times
- Renewal of Way Planning Data

The standards books are very detailed in nature and have allowed times to the nearest minute for virtually every task imaginable. BR keeps a daily record of the work performance of each gang.

Various planning and monitoring systems used by the Chief Civil Engineer's Department were discussed. One of the major systems is the permanent way renewals planning and control systems (CROWS). We were told that the Chessie System is in the process of purchasing CROWS from BR.

Report of Meeting with Deutches Bundesbahn (DB) at Munich Office, June 13, 1978.

Attendees:	Messrs. Weiss, Riebold, Keiss, and Lutz	- DB
	Messrs. Shipley, Frank and Burns	- DCO
	Mr. Gross	- FRA

Mr. Weiss, Track Engineering Department Director, explained the organization and function of the department. DB is divided into 10 regions with the railroad headquaters located in Frankfurt and the design and administration office located in Munich.

The track engineering department is responsible for the development of criteria, specifications and purchase of track machinery. Specifications are prepared in close coordination with the equipment manufacturers and were first developed in 1972. At present DB only has specifications for ballast cleaning machines and track renewal trains. They are now preparing specifications for liner-tampers. Virtually all track machinery used by DB is manufactured by either Plasser and Matissa. DB does not build any track machinery.

Specifications are separated into two discrete segments: one pertaining to manufacture of the machine, the other pertaining to machine performance . Manufacturing specifications vary between machine types but usually include such items as welder qualifications, parts standardization, materials quality, etc. Performance specifications usually include operating speed, work quality, tolerances, noise levels, safety appliances, etc.

Specifications are circulated to manufacturers for bid. As DB is able to order in quantity, manufacturers are responsive to specification requirements and economies are realized due to machine uniformity. Block purchases also increase DB's clout with manufacturers, favorably affecting production schedules, quality of work, construction inspection, etc.

Upon receipt of bids, DB manufacturer selection is based upon three main performance criteria: speed, quality, and reliability. Machine cost is evaluated in relation to the performance criteria.

A testing lab is located 10 kilometers from Munich. The track engineering department has 900 employees at the central office and 300 at the testing laboratory. Approximately 150 of these employees are university graduates.

Eight hundred million dollars was spent for rolling stock and track equipment in 1977. Twenty million DM are spent per year on equipment, of which 60 percent is spent on large equipment and 40 percent on small. Most of this money is spent on replacement of machines that are wearing out. DB headquarters in Frankfurt decides how much money is to be spent for maintenance each year.

DB has track renewal, track exchange and track maintenance programs. Track renewal consists of the complete replacement of ties and rails and is generally performed every 250 million gross tons of traffic. The ties and rail removed from the track are taken to inspection plants and examined for reuse. The reusable ties and rail are then placed in lower density lines (track exchange). Track maintenance is performed on an as-needed basis with high density lines being maintained on a two-year average and lower density lines on a four-year average.

Approximately 1,200, 800, and 13,000 kilometers of track are renewed, exchanged and maintained respectively each year. In addition, ballast cleaning is performed with track renewal and track exchange programs every 15 to 25 years depending upon the condition of the ballast. There are 60,000 kilometers of track in the DB system. Sixty percent of the annual track renewal is performed by DB crews, the remaining 40 percent by contractors. Twenty percent of track maintenance is performed by DB crews and 80 percent by contractors.

Some very short lines in Northwest Germany are freight only (3-5 percent of total trackage). These lines are maintained to less stringent standards than lines having passenger traffic.

High speed trains travel at speeds up to 200 kilometers per hour. The heavy tonnage lines have approximately 65,000 metric tons of traffic per track per day, of which 40 percent is from freight trains. The heaviest tracks have 120,000 metric tons per day. The average axle load on DB is 14 metric tons, the maximum axle load is 20 metric tons. Approximately 20 percent of the vehicles have 20 ton axle loads.

DB performs evaluation testing on major track equipment. A main criteria for selection of equipment is production speed and quality of performance. Another important aspect of machinery effectiveness is the training of operators. In Germany, all operators must be craftsmen, serving apprenticeships with examinations at the end of the apprenticeship before they are allowed to become operators.

At one time DB had competitive evaluation testing but has discontinued this practice. DB found that in competitive testing the companies supplied their best machines and their best operators and had a number of employees monitoring the test operations, with the results generally not being very realistic. DB now tests one machine at a time in relative privacy, with no contractor personnel present except the machine operator. DB feels that comparative ranking of machines is not practical as manufacturers always have many reasons why their equipment came in second or third. Machine tests are performed in areas where maintenance is being performed on high speed, high tonnage lines and are made prior to the acceptance of the equipment. The average tests are 500 meters of straight track and 500 meters of curved track with high super elevation.

One-third of the track machinery is owned by DB, the other two-thirds is owned by contractors. Contractors are allowed to use any equipment that has been qualified by DB (equipment previously tested and accepted by DB personnel).

The test sections are measured by stationary measurements taken on the unloaded track on every third tie and checked by geometry recording cars. Measurements are taken of horizontal and vertical alignment and cross level and are made immediately before and after lining and tamping and after 500 thousand, 1 million and 5 million gross tons of traffic.

A discussion was then held concerning track memory (the condition where a track after tamping tends to return to its original alignment with time). DB is of the opinion that track memory is a function of ballast cleaning and that the tamping of dirty ballast is a worthless endeavor. DB utilizes ballast cleaners that run on the rails and also cleaners that run on ballast with the rails removed. Ballast cleaners are evaluated for the quality of cleaning and the production speed. DB is recommending that new ballast cleaning machines be outfitted with measuring devices to measure and control the depth and width of ballast.

The International Union of Railways (Union Internationalle de Chemin de Fer or UIC) will soon publish a report with information concerning methods for testing tampers. The report will also contain information on a "standard track." DB thinks that in order to standardize criteria, a track of standard construction must be offered to the suppliers to determine the capability of the machine.

The methodology for evaluating and purchasing smaller track equipment is to borrow one machine for testing. If the machine test is satisfactory, DB will then buy a large quantity. If not, the machine is returned to the supplier. Most of these tests are performed at Mainz under the direction of the Munich office.

Equipment is also given to the regions for long duration tests. Tests can be up to six month's duration. If evaluation tests show that similar machines supplied by both manufacturers are equally qualified, DB purchases the lower priced equipment.

DB is of the opinion that relative values cannot be assigned to various evaluation parameters such as reliability, maintenance, costs, etc. and then used mathematically to determine which machine is best for a given situation. DB lets the engineer make the choice and stressed that we should be practical in our evaluation and decision making process. A possible solution may be to test several machines by each type and then make the results available to the railroads, allowing them to determine which equipment is best for their environment.

DB has plant inspectors at the manufacturer's site to check on the fabrication of equipment. Each large machine is also functionally tested before acceptance and is inspected and tested again at the end of the one year warranty period.

Report of Inspection of Liner-Tamper Track Renewal Train at Trier, June 14, 1978.

Attendees:	Robert Shipley	- DCO
	Winn Frank	- DCO
	Arnold Gross	- FRA
	David Burns	- DCO Consultant
	Klaus Meuser	- DB

During the day of June 14 we visited two work sites at Trier. The first was a lining-tamping operation being performed by contractor. The second was a track renewal being performed by DB personnel. Of particular interest were the machine performance recording devices that were located on the track renewal train. Details of these devices are discussed in the June 15 meeting report.

The standard DB rail sections are 60, 54 and 49 kilograms per meter. These weights are equivalent to 120, 108 and 98 pounds per yards. The 60 kilogram per meter sections are used on track having more than 25,000 gross tons per day of traffic. In general, rails are transposed at 5 millimeter side wear and changed out at 250 million gross tons. This varies slightly depending upon the rail section in question.

The track renewal train inspected is claimed by the manufacturer to have a productivity of up to 350 meters per hour. However, DB achieves an average of only 200 meters per hour. DB crews work 10 hours a day with a crew of 70, not including supervision.

While watching the track renewal train, it was noticed that concrete ties were being replaced with wood ties. We also noticed steel ties located on some of the side tracks. Herr Meuser told us that DB uses both concrete and wood ties according to their availability and market price and does not prefer one type over the other. Timber and wood ties are not intermixed, however. The steel ties were originally developed to provide competition to the wood tie market. The price of a steel tie over its life is similar or less than wood ties. All existing steel ties were constructed prior to World War II and because of their age are now only used on tracks with less than 20,000 gross tons per day. DB is considering purchasing more steel ties to keep tie competition high. In Germany, all three types of ties perform similarly. The stability of wood and concrete tie tracks is similar, provided that the surface areas of the ties are the same.

Report of Meeting with DB Personnel at Mainz Office, June 15, 1978.

Attendees (Morning session)

Klaus Meuser	-	DB
Robert Shipley	-	DCO
Winn Frank	-	DCO
David Burns	-	DCO Consultant
Arnold Gross	-	FRA

(Afternoon session)

Dietrich Hock	-	DB
Robert Shipley	-	DCO
Winn Frank	-	DCO
David Burns	-	DCO Consultant
Arnold Gross	-	FRA

DB's schedule for track maintenance was discussed. The schedule is organized by machine type and is revised every six months. Schedules are developed for three years in advance to allow for coordination with other countries regarding the scheduling of international trains. The schedules are developed for DB-owned equipment only. This type of planning began in 1972.

DB has a book listing the desired performance criteria for different types of machines. The criteria are compared to the manufacturer's stated machine capabilities. For example, using ballast cleaners, DB requires a maximum capacity of 600 cubic meters per hour and an average capacity of 500 cubic meters per hour. They also specify travel speed (60 kilometers per hour, self-powered; and 80 kilometers per hour in trains), clearances, depth of cleaning and allowable noise levels.

DB has found that the difference between the manufacturer's stated capabilities and the machine's actual performance is very large. For example, one manufacturer states that their largest ballast cleaner can clean 650 cubic meters per hour, whereas DB has found that the maximum performance is 580 cubic meters per hour and the average performance is 400 cubic meters per hour. Another ballast cleaner, which is rated at 450 cubic meters per hour, averages only 280 cubic meters per hour. DB keeps accurate records on the performance of all major equipment.

One of DB's tampers has an average production rate of 278 meters per hour on concrete and wood ties after ballast cleaning or renewal without the use of laser guides. Another tamper model can achieve 400 meters per hour. Lasers are used on tracks designed for speeds of 140 kilometers per hour and above. They are not used on tracks of lower speed as the accuracy is not required.

DB's main areas of interest in equipment are reliability, production speed and start-up and shut-down times. Evaluation tests are performed on liners, tampers, cleaners, regulators, rail loading and track renewal trains and field thermit welding. DB has a book containing the results of all their evaluation testing. Small equipment is generally not tested in that it usually has little or no input to the overall timing of work.

In evaluation testing, DB employs a data gathering technique whereby each component of the system is measured to determine its production capability. This information is developed under similar conditions, (e.g., type of tie, depth of ballast and condition of ballast) and as such it takes a considerable period of time to develop comparable values for similar types of equipment. In some instances it has taken from two to three years to obtain sufficient data to allow a comparative evaluation to be made, although the actual effort involved is only between 20 and 100 man days. These production figures are determined mainly to allow accurate scheduling of future work, with the ability to perform comparative evaluations between different equipment being a secondary benefit.

DB installs a performance measuring system in all ballast cleaners, tampers and track laying systems -- approximately 100 machines in all. Measuring systems are also installed in some of the contractor's equipment which varies from that owned by DB.

The unions agreed to use the devices after DB promised not to use the performance measuring system information against the unions in salary or other negotiations. DB does not have a performance bonus system. Employees work a forty hour week and the unions have agreed to allow work up to ten hours a day without overtime provided that the cumulative time does not exceed 80 hours in two weeks.

DB utilizes a measuring system consisting of a nine channel recording device that accounts for different aspects of machine utilization. The types of data recorded are as follows:

Channel No.	Information Recorded
1	Travel between work storage sites and preparing machine for work.
2	Travel time from storage to work site and from work site to storage.
3	Set-up time at work site.

Channel No.	Information Recorded
4	Shut-down time at work site.
5	Break time (lunch, etc.)
6	Delays caused by interdependent machines.
7	Delays caused by material shortage.
8	Railroad operational delays
9	Machine breakdown.

The recording is activated by the machine operator who presses the appropriate button on the device. The device has no way of automatically determining which channel is appropriate at a given time, thus the system is dependent upon human channel selection. In addition, the machine operator must also complete daily record sheets. Several of the columns on the daily record sheets are to be used when the operator forgets to push the buttons on the recording device. The recording system was implemented in 1972 and it took approximately one year for the employees to become accustomed to the system.

Computer print-outs are made for the daily production of each machine. The computer automatically reads the disks from each channel recording device. A typist types in the information which is hand-written on the cards. Print-outs contain the results of the information on the performance measuring system disks and forms filled out by the operators. The print-outs list the sum of times recorded for each button. After each three months of operation the average figures for each button on each machine are determined. A five percent breakdown time is the point above which breakdowns are not acceptable. DB also keeps accurate accounting records for repair costs for every machine and compares these repair costs to replacement costs, thereby helping to determine when machines should be replaced. All costs are accounted for in the DB system. In general, DB expects to spend between 15 and 18 percent of current replacement costs on maintaining each machine each year. DB spreads the purchase cost over four to six years depending on the machine in question. Tampers are scrapped after eight years. Track renewal trains are scrapped after seven years.

DB has thirty tampers. The output of each is determined by noting the kilometer and hectare posts located along the wayside. Every three months the production of each machine is checked against the others.

APPENDIX D - LIST OF MOW EQUIPMENT MANUFACTURERS

1. ABEX CORPORATION
   RAILROAD PRODUCTS GROUP
   R.E. ANTHONY, GEN. MGR.
   VALLEY ROAD
   MAHWAH, NJ 07430

2. AMERICAN ALLIED
   RAILWAY EQUIPMENT COMPANY
   J.A. WIDMER
   302 W. HOLLAND STREET
   WASHINGTON, IL 61571

3. ATLANTIC TIE SPACER
   K.L. LINDMARK, V.P.
   5602 PIKE ROAD
   ROCKFORD, IL 61111

4. AUTOMATIC EQUIPMENT CO.
   G.M. EGART
   80 E. JACKSON BOULEVARD
   CHICAGO, IL 60604

5. BANKHEAD RAILWAY ENGINEERING
   FRANK ROSS, SALES MANAGER
   P.O. BOX 93006
   MARTECH STATION
   ATLANTA, GA 30318

6. BE'LHACK G.M.B.H.
   82 ROSENHEIM
   POSTFACH 160, GERMANY

7. BROSPEC LIMITED
   J. CAMPANELLI, U.S.A. REP.
   466 WESTWOOD DRIVE
   WOODBURY, NJ 08096

8. BURRO CRANE, INC.
   R. McDANIEL, V.P. & GEN. MGR.
   1300 S. KILBOURN AVENUE
   CHICAGO, IL 60623

9. CANRON RAILGROUP
   J.K. STEWART, PRES.
   2401 EDMUND ROAD
   W. COLUMBIA, SC 29169

10. J.I. CASE COMPANY
    RONALD E. SYMS, PROD. SUPVR.
    700 STATE STREET
    RACINE, WI 53404

11. CATERPILLAR TRACTOR CO.
    H.W. HINTZE, IND. ENG.
    100 N.E. ADAMS STREET
    PEORIA, IL 61602

12. CHEMETRON CORPORATION
    RAILWAY PRODUCTS DIVISION
    R.M. ANSEI, CHIEF ENG.
    111 E. WACKER DRIVE
    CHICAGO, IL 60601

13. CLEVELAND FROG & CROSSING CO.
    SUBSIDIARY OF PETTIBONE CORP.
    T.M. CAVENDER, V.P. & GEN. MGR.
    6917 BESSEMER AVENUE, S.E.
    CLEVELAND, OH 44127

14. COMET INDUSTRIES, INC.
    F. PICHT
    4800 DERAMUS AVENUE
    KANSAS CITY, MO 64120

15. DAPCO INDUSTRIES, INC.
D.A. PAGANO, PRES.
199 ETHAN ALLEN HIGHWAY
RICHFIELD, CT 06877

16. DEFIANCE MECHANICAL
PHILIP BAROVSKY, SALES MGR.
3329 KIFER ROAD
SANTA CLARA, CA 95051

17. DU-WEL STEEL PRODUCTS CO.
I. ZOSO, MGR.
80 E. JACKSON BOULEVARD
CHICAGO, IL 60604

18. ELEKTRO-THERMIT GMBH
P.O. BOX 420
GERLINGSTRASSE 65
43 ESSEN, WEST GERMANY

19. ELLCON NATIONAL, INC.
E.P. KONDRA, PRES.
30 KING ROAD
TOTOWA, NJ 07512

20. ESCO-EQUIPMENT SERVICE CO.
G.F. CARPENTER
80 E. JACKSON BOULEVARD
CHICAGO, IL 60604

21. FAIRMONT RAILWAY MOTORS, INC.
O. BUSCHO, DOMESTIC SALES MGR.
332 S. MICHIGAN AVENUE
CHICAGO, IL 60604

22. FARREL COMPANY DIVISION
USM CORPORATION
A.W. SAMPSON, V.P. & GEN. MGR.
565 BLOSSOM ROAD
ROCHESTER, NY 14610

23. L. B. FOSTER COMPANY, INC.
J.L. FOSTER, V.P.
415 HOLIDAY DRIVE
PITTSBURGH, PA 15220

24. GENERAL MOTORS OF CANADA LTD.
DIESEL DIVISION
P.G. BREWER, GEN. SALES MGR.
P.O. BOX 5160
LONDON, ON N6A 4N5

25. GREAT LAKES RAIL LTD
WILLIAM BAZIUK, JR., PRES.
359 BURBIDGE STREET
THUNDER BAY, ONTARIO P7B 5R3

26. GREENSIDE HYDRAULICS LTD.
G.L.THOMPSON, DIRECTOR
GREENSIDE FOUNDRY
CHAPELTOWN, SHEFFIELD S30 4RY
SOUTH YORKSHIRE, ENGLAND

27. HOLLAND COMPANY
RAILWELD DIVISION
J.A. LIDDELL, PRES.
1020 WASHINGTON AVENUE
CHICAGO HEIGHTS, IL 60411

28. HUCK MANUFACTURING CO.
WACO DIVISION
C.J. JAHANT, MGR. ADMIN. SERV.
PO BOX 8117
8001 IMPERIAL DRIVE
WACO, TX 76710

29. HUNSLET ENGINE CO. LTD
HUNSLET ENGINE WORKS
LEEDS, LS10 1BT
ENGLAND

30. INDUSTRY-RAILWAY SUPPLIERS, INC.
N.J. GREGORICH, PRES.
15501 COMMERCE PARK
CLEVELAND, OH 44142

31. INGERSOLL-RAND COMPANY
TOOL & HOIST DIV.
J. FISKE, NAT'L. SALES MGR.
28 KENNEDY BLVD.
EAST BRUNSWICK, NJ 08816

32. JACKSON VIBRATORS, INC.
J.H. BUSH, V.P.
8550 W. BRYN MAWR AVENUE
CHICAGO, IL 60631

33. JORDAN COMPANY
DIV. OF JACKSON VIBRATORS, INC.
J.H. BUSH, V.P.
8550 W. BRYN MAWR AVENUE
CHICAGO, IL 60631

34. KANGO ELECTRIC HAMMERS LTD
LOMBARD ROAD, SOUTH WIMBLEDON
LONDON S.W. 19, ENGLAND

35. KERSHAW MANUFACTURING CO., INC.
R. KERSHAW,JR., PRES.
2205 W. FAIRVIEW AVE.
MONTGOMERY, AL 36108

36. KOLMEX
P.O. BOX 236 MOKOTOWSKA 49
WARSAW 1, POLAND

37. KRAUTKRAMER
5 KOLN-KLETTENBERG
LUXEMBURGER STR.
449 WEST GERMANY

38. LINCOLN ELECTRIC RAILWAY SALES
M.H. FRAMK, PRES. & TREAS.
ONE PUBLIC SQUARE BUILDING
CLEVELAND, OH 44113

39. LITTLE GIANT CRANE &
SHOVEL, INC
DES MOINES, IA 50333

40. LORAM MAINTENANCE OF WAY INC.
R.A. PEPPIN, PRES.
3900 ARROWHEAD DR.
HARMEL, MN 55340

41. LUCKY MANUFACTURING CO. INC
FRED CONKLIN, SALES ENG.
P.O. BOX 3051
HUNTSVILLE, AL 35810

42. MAPP PRODUCTS
F.L. SYME, GEN. MGR.
P.O. BOX 486
UNION, NJ 07083

43. MASCHINELLER GELEISEUNTERHALT
HANS MULLER DIPL. INC
VOGELSANGSTRASSE
EFFRETIKON, 2H8307 SWITZERLAND

44. MIDWEST CORPORATION
STEEL DIVISION
L. HUTCHINSON
14TH FLOOR, UNION BUILDING
CHARLESTON, WV 25321

45. MKT GEOTECHNICAL SYSTEMS
JOSEPH F. RIGLER
V.P., MARKETING
BOX 793
DOVER, NJ 07801

46. MTM-STUMEC INC.
GENERAL OFFICE
J.W. LAWSON, EXEC. V.P.
1061 DAVIS ROAD
ELGIN, IL 60120

47. THE NOLAN COMPANY
W. RICHARD WERNER, PRES.
BOX 201
BOWERSTON, OH

48. NRDC
KINGSGATE HOUSE
66-74 VICTORIA STREET
LONDON, S.W. 1, ENGLAND

49. ORTON/MC CULLOUGH CRANE CO.
GENERAL OFFICE
J.F. McCULLOUGH, PRES.
1211 W. 22ND STREET
OAK BROOK, IL 60521

50. OZARK RAILWAY SUPPLIES, INC
ROGER A. COOPER PRES.
3259 E. SUNSHINE, SUITE L
SPRINGFIELD, MO 65804

51. PETTIBONE CORPORATION
RAILROAD PRODUCTS DIVISION
T.M. CAVENDER
V.P. & GEN. MGR.
4700 W. DIVISION STREET
CHICAGO, IL 60651

52. PLASSER AMERICAN CORPORATION
GEN. OFFICE & PLANT
E. TROELSS, EXEC. V.P.
2001 MYERS ROAD
P.O. BOX 5464
CHESAPEAKE, VA 22324

53. PLUTO
B.P. 63; LES MUREAX (78),
FRANCE

54. PORTEC INC.
RMC DIVISION
R.D. JACKSON,JR., GEN. MGR.
P.O. BOX 1888
PITTSBURGH, PA 15230

55. POWER PARTS CO.
R. FIGIEL
1860 N. WILMOT AVENUE
CHICAGO, IL 60647

56. PRORAIL
JOHN L. HARMSEN
TECH. DIR., USA
16/18 BLVD. DE LA REPUBLIQUE
92100 BOULOGNE, FRANCE

57. THE PURDY COMPANY
R.J. BOYLE
2400 W. 95TH STREET
CHICAGO, IL 60642

58. QUAKER R.R. EQUIPMENT
SALES CORPORATION
W.N. TAGGART, PRES.
P.O. BOX 627
HAVERTOWN, PA 19083

59. RACINE RAILROAD PRODUCTS, INC.
G.W. CHRISTIANSEN, CHMAN OF BD.
1524 FREDERICK STREET
RACINE, WI 53404

60. RAILROAD REPAIR & SUPPLY CO.
C.J. DUFFY, PRES.
332 S. MICHIGAN AVE.
CHICAGO, IL 60604

61. THE RAILS COMPANY
G.N. BURWELL, PRES.
187 MAPLEWOOD AVENUE
MAPLEWOOD, NJ 07040

62. RAILTRACK INC.
R.P. UNDERWOOD, PRES.
15 SPINNING WHEEL ROAD
SUITE 310
HINSDALE, IL 60521

63. RAILWAY PRODUCTS COMPANY
MARMON TRANSMOTIVE
J. ALBERT
GENERAL JOHN SEVIER HIGHWAY
P.O. BOX 1511
KNOXVILLE, TN, 37901

64. RAILWAY TECHNIQUES, INC.
JOHN E. SCROGGS, PRES.
3316 BROADWAY
KANSAS CITY, MO 64111

65. RAILWAY TRACK-WORK CO.
G.W. BARRETT, PRES.
2381 PHILMONT AVENUE
BETHAYRES, PA 19006

66. REXNORD INC.
RAILWAY EQUIPMENT DIV.
R. LEHMAN, RY. EQUIP. DIV.
P.O. BOX 383
MILWAUKEE, WI 53201

67. ROBEL AND CO.
THALKEICHNER STRAUSSE 210
P.O. BOX 420
MUNICH 25, GERMANY

68. SAFERAIL S.A.
C.A. SFEZZO, PRES.
2, ROUTE D'ORON
1010 LAUSANNE
SWITZERLAND

69. SAFETRAN SYSTEMS CORP.
R.B. WYLAND, PRES.
7721 NATIONAL TURNPIKE
LOUISVILLE, KY 40214

70. SCHRAMM, INC.
R.D. HARLOW, V.P., SALES
670 N. GARFIELD AVENUE
WEST CHESTER, PA 19380

71. SECMAFER S.A.
JEAN J. BOYER, PRES.
28 BD. ROGER SALENGRO
F8200 MANTES, FRANCE

72. SHIBAURA ENGINEERING WORKS, LTD
1-12, 1-CHROME
AKASAKA, MINATO-KU
TOKYO, JAPAN

73. SLUGGER CORP. OF AMERICA
TIMOTHY A. MERTZ, SALES MGR.
5045 COLUMBIA AVENUE
HAMMOND, INDIANA 46320

74. SOCADER
JEAN RONCO
2 RUE LENINGRAD
F5.008 PARIS, FRANCE

75. SPENO INTERNATIONAL S.A.
22 PARC CHATEAU BANQUET
1202 GENEVA, SWITZERLAND

76. TELEWELD, INC.
L.R. FIZGERALD, V.P.
416 N. PARK STREET
STEATOR, IL 61364

77. TEMPLETON, KENLY & CO.
B.H. MC BRIDE, V.P. MKTG.
2525 GARDNER ROAD
BROADVIEW, IL 60153

78. TRUE TEMPER CORPORATION
RAILWAY APPLIANCE DIV.
R.W. LUEBKE, V.P. & GEN. MGR.
1623 EUCLID AVENUE
CLEVELAND, OH 44115

79. UNION CARBIDE CORPORATION
LINDE DIVISION
R.H. BENNEWITZ, MGR.
120 RIVERSIDE PLAZA
CHICAGO, IL 60606

80. U.S. RAILWAY EQUIPMENT CO.
AFFILIATE OF EVANS PRODUCTS CO.
W.M. SHEEHAN, REG. SALES MGR.
2200 E. DEVON AVENUE
DES PLAINES, IL 60018

81. U.S. THERMIT, INC.
H.D. FRICKE, PRES.
RIDGEWAY BLVD.
LAKEHURST, NJ 08733

82. WACKER CORPORATION
J.S. SCOT, GEN. SALES MGR.
3808 W. ELM STREET
P.O. BOX 09402
MILWAUKEE, WI 53209

83. WARNER & SWASEY COMPANY, THE
R.L. CLEVER, SALES MGR.
406 MILL AVENUE, S.W.
NEW PHILADELPHIA, OH 44663

84. WESTERN-CULLEN-HYES, INC.
R.L. McDANIEL V.P. & GEN. MGR.
2700 W. 36th PLACE
CHICAGO, IL 60632

85. D. WICKHAM & CO. LTD
WARE
HERTFORDSHIRE, ENGLAND

86. WICKMAN MACHINE TOOLS, INC.
H. WILLIAMS, PRES.
950 MORSE AVENUE
ELK GROVE, IL 60007

87. D.A. WILSON COMPANY
D.A. WILSON
2017 E. LINCOLNWAY
AMES, IA 50010

88. WINDHOFF AG
POSTFACH 1160
4440 RHEINE
GERMANY, EUROPE

89. WOOLERY MACHINE CO.
L.E. WOOLERY, PRES.
2919 COMO AVENUE, S.E.
MINNEAPOLIS, MN 55414

90. YORK ENGINEERING COMPANY
D.P. SILVER, V.P.
211 SPANGLER AVENUE
ELMHURST, IL 60126

91. ZWEIWEG-FAHRZEUG, GMBH
D-82 ROSENHEIM, WEST GERMANY

APPENDIX E - INFORMATION CONTAINED IN CURRENT MOW MANUFACTURERS' BROCHURES

Introduction

The MOW equipment data shown in this Appendix was obtained through requests sent to all manufacturers listed in Appendix D. This data was compiled from equipment manufacturers' brochures obtained in the first and second quarters of 1978. No attempt has been made to verify the accuracy of the data with regard to equipment manufactured at that time. This data is not a complete compilation of all MOW equipment manufactured, and additional models and manufacturing companies may exist. The compilation is restricted to data on machines in the evaluation program and is of value to an initial evaluation only.

All machines in the compilation are defined in the Standard Machine Definitions in Appendix B.

All entry values are shown in the following units, unless otherwise noted:

Item	Unit of Measurement
Dimension	Feet - Inches
Capacity	U.S. Gallons
Weight	Pounds
Travel Speed	Miles per hour

In the table on page E-2, the figures represent the number of models available of the particular machine type by the corresponding manufacturer.

FIGURE E-1 - MATRIX OF EQUIPMENT TYPE AND NUMBER OF MODELS BY EACH MANUFACTURER

	Atlantic Power Tie Spacer	Burro Crane, Inc.	Canron Railgroup	Fairmont Railway Motors	Ingersol-Rand	Jackson Railroad Equipment	Little Giant	Marmon Transmotive	Modern Track Machinery	Orton/McCullough	Plasser American Corp.	Portec, Inc.	Racine Railroad Products	Railway Techniques, Inc.	Railway Trackwork Co.	Rexnord-Nordberg	Saftran Systems Corp.	Teleweld	True Temper Corp.	Western-Cullen-Hayes	Windhoff	Woolery	Greenside Hydraulics
Ballast Compactor			4								1												
Ballast Regulator			2	1				1	1		1												
Ballast Shoulder Cleaner												1											
Ballast Undercutter			1					1															
Ballast Undercutter/Cleaner			2								1	1											
Brush Cutter			2	1								1											
Cleaner, Track/Yard								1															
Cranes, On-track only		2					1			1													
Crib Ballast Remover											1		1								1		
Gauging Machine																1							
Motor Car-Large									1														
Motor Car-Small									2					1									
Rail Anchor Adjuster												1	1										
Rail Anchor Applicator-Manual													2						1				
Rail Anchor Applicator-Semi-Auto												1	1			1							
Rail Drill					1				3				4			1	1			1			
Rail Grinder																							
Rail Heater			1						2									1				1	
Rail Joint Straightner												1											
Rail Lifter				1												1							1
Rail Puller																							
Rail Saw or Abrasive Cutter									3				3										
Rail Slotter									1						2								
Rail Threader									1														
Spike Driver/Automatic			1	1								3				2							
Spike Driver/Pneumatic			1	2								2				1							
Spike Puller				2					1							2							
Tamper			1								2												
Tamper with Jacks			1			1																	
Tamper with J&A (Production)			2			1					1												
Tamper, Joint			1									3											
Tamper, Multi-head																							
Tamper, Switch			3								1	1											
Tamper, Switch with Aligner						4																	
Tie Adzer									1						1	1							
Tie Boring Machine									4							1	2						
Tie Cribber															1								
Tie Destroyer								1															
Tie Handler															2								
Tie Injector/Inserter				2		1			1			1											
Tie Plug Setter/Driver				1					1														
Tie Remover				2																			
Tie Saw or Shear				1																		1	
Tie Spacer	1											1				1							
Tie Sprayer				1																			
Tie-bed Scarifier/Inserter				1												1							
Tie-end Remover																						1	
Track Fastening Wrench									8								1						
Track Liner				1					2			1				1							
Track Vibrator													1		1								
Track Wrench												1					1						

BALLAST COMPACTOR

	DIMENSION				CAPACITY				ENGINE																OPTIONS	COMMENTS
COMPANY / MODEL	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT (TONS)	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	VIB'N. FREQ.	KINETIC FORCE	PRODUCTION							BASE-PRICE		
CANRON TAMPER CSC			10-0		16.5				2 Cycle	GM	3-53-N	92 @ 2300			30			500-800 m/hr								Tachygraph Air Conditioning	Enclosed Cab Air Horn Acrylic Windows
CANRON W/BALLAST BOX & PLOW	28-11	10-0	10-0		18.5																					Same as CSC	Same as CSC
CANRON W/BROOM	28-7		10-0		19.8																					Same as CSC	Same as CSC
CANRON MATISA D912	34-0	8-0	10-0	16	17							115			40	50 Hz	2500 Kp									Tachygraph Air Conditioning Stone Clearer	Enclosed Cab Safety Glass Horn Air Conditioning
CANRON MATISA D-9					14																						

	DIMENSION				CAPACITY				ENGINE																OPTIONS	COMMENTS
COMPANY/ MODEL	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	VIB'N FREQ.		KINETIC FORCE							BASE-PRICE		
CANRON MATISA D-912R					19 Tons							180			56 MPH												
PLASSER CPM-800-R	31-5	9-6	9-10	26-4	19 Tons				Diesel	Caterpillar		150@2800(1)	8		30 MPH											Tie-End Compactor Turntable, Set-Off Fully Enclosed Cab	Illumination Partially Enclosed Cab

(1) Intermittent

BALLAST COMPACTOR

COMPANY/ MODEL	DIMENSION				CAPACITY				ENGINE							SIDE PLOW										OPTIONS	COMMENTS
	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT (TONS)	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	REACH (6)	DEPTH (3)		DRIVE	BOX CAPACITY	MAX. TOE LINE				BASE-PRICE		
CANRON BEB-17	22-6	10-0	10-0		14.5	100	100		2 Cycle Diesel	General Motors	3-53-N	92 @ 2800			30	10-6			Hydraulic	3/4 Yd	10-6					4-71 General Motors Diesel Snow Blower or auger Brush Cutter	Fully Enclosed Cab Horn Transfers Ballast
FAIRMONT W23-D	24-0	10-11	9-7	8-4	11	40	40		Diesel			81 @ 2500	3													Cab Heater Spark Arrestor Ether Starting Aid	Turntable, Set-Off 2-Man Cab
MATISA R-7D	23-0	9-6	9-6		15.5							110 @ 2000			50												
PLASSER PBR-103	31-4	11-4 (1)	10-6	6-5	20.5				Diesel	Caterpillar		160@2800(2)	8	Fluid	30	8-2	30 (3)									Insulated Wheels Manual Set-Off	Turntable Illumination
RAILWAY PRODUCTS TRACK PATROL	37-0	10-0	12-6		19	(4)				General Motors	4-53				25	(5)											Pressurized Cab Heater

(1) with broom
(2) Intermittent
(3) Measured from top of rail
(4) 20 Hour Capacity
(5) 10' Width-front flows, dressing wings 28" - 48" width
(6) Maximum, measured from Track

BALLAST REGULATOR

	DIMENSION					CAPACITY			ENGINE						SIDE PLOW										OPTIONS	COMMENTS
COMPANY/ MODEL	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	REACH (6)	DEPTH (7)			WORK SPEED					BASE-PRICE		
MTM - STUMEC * MODEL PSD-4	35-1	8-10	9-10	10 5	17 tons					Vancini		122			40					9850 l/hr							

* Modern Track Machinery, Inc., Geismar, Stumec

BALLAST REGULATOR

COMPANY/ MODEL	DIMENSION: LENGTH	DIMENSION: WIDTH	DIMENSION: HEIGHT	DIMENSION: BASE	CAPACITY: WEIGHT	CAPACITY: FUEL	CAPACITY: HYDRAULIC	CAPACITY: OIL	ENGINE: TYPE	ENGINE: MAKE	ENGINE: MODEL	ENGINE: H.P. @ RPM	ENGINE: NO. CYL.	ENGINE: COOLING	TRAVEL-SPEED	OPERATING SPEED FT.-HR.									BASE-PRICE	OPTIONS	COMMENTS
RMC/PORTEC* BALLAST DIST./ CLEANER	21-6	12-0	12-0		32,000							60			30	1600 - 1800											

* Railway Maintenance Corporation (Portec, Inc. - RMC Division)

BALLAST SHOULDER CLEANER

COMPANY/ MODEL	DIMENSION LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	CAPACITY FUEL	HYDRAULIC	OIL	ENGINE TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	BRAKES	MAX. CUT DEPTH	MIN. CUT DEPTH	Undercutting Speed-	Trench Speed	TRENCH DEPTH	Conveyer Drive			BASE-PRICE	OPTIONS	COMMENTS
CANRON GO-4 TRAC-GOPHER	20-8	8-0	9-8	11-8	24,000	55	77		2 Cycl. Diesel	General Motors	4-71	160 @ 2250 (1)	4	Water	20	4 Wheel Pneumatic	26 in. (2)	6.5 in. (3)	2-4 FPM (4)	5-12 FPM(4)	3-2" (2)					Trailer	Wheels: AAR Standard, contour, cast steel Side Trencher
RAILWAY PRODUCTS UNDERCUTTER	47-8	10-6	13-0		65,000				Diesel	Detroit	6-71				25	Fail safe						Hyd					Fully enclosed cab w/ air conditioning Turntable Couplers (5)

(1) BHP (Continuous)
(2) From top of rail
(3) From bottom of ties
(4) Depending on ballast conditions
(5) Can handle waste material and ballast cars

BALLAST UNDERCUTTER

BALLAST UNDERCUTTER/ CLEANER

	DIMENSION				CAPACITY				ENGINE																	OPTIONS	COMMENTS
COMPANY/ MODEL	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT (TONS)	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	MOTOR TORQUE	CUT DEPTH	CUT DEPTH	LAT. DISPL.	MIN. CURVE	MAX. GRADIENT	PRODUCTION			BASE-PRICE		
CANRON MATISA C-311	88-0	8-8	12-6	48-0 (1)	59 (2)										48	155 @ 1450 (3)	8" Min. (4)	2-5 Max. (5)	+ 10-1/2" Max.	328' Radius	35%	500-1000 Ft/Hr (6)				17½" lateral displ. Tight curves Steeper gradient	
CANRON MATISA C330	96-0	9-10	13-4		80	155	52		Diesel			286 @ 2300			48		1 Ft. Min.	2 Ft. Max.		984 Radius		1804 Ft/Hr (7)					Paganelli System Power car engine data shown only
PORTEC SECMAFER 400 MH-02	152-3	9-3	13-9		203							1600 @ 1800						2 Ft. Max.				1000 Ft/Hr (8)					
PLASSER RM-62	109-4	10-0	15-6		70							270					10 in. Min. (4)	34 in. Max. (5)				1095 Yds/Hr (9)					

(1) Measured Between Bogie Pivots
(2) Machine Weight; Power Unit Weighs 22 Tons
(3) MKP @ RPM
(4) Without Lifting Track, Measured From Beneath Tie
(5) Measured From Top of Rail
(6) Or Up To 450 Yd^3/Hr
(7) Or Up To 785 Yd^3/Hr
(8) 14" Undercut; 785 Yd^3/Hr
(9) Or 549 Yd^3/Hr

COMPANY/ MODEL	DIMENSION LENGTH	WIDTH	HEIGHT	BASE	CAPACITY WEIGHT (TONS)	FUEL	HYDRAULIC	OIL	ENGINE TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	SPEED TRAVEL	WORK	CUTTING RANGE MAX. FROM CL (FT.)	MIN. FROM CL	MAX. CUT (IN)						BASE-PRICE	OPTIONS	COMMENTS
CANRON KTBC KAL TRAC BRUSH CUTTER	22-6	8-0	11-6	7-6	10.5				Diesel	GM	4-53N	136 @ 2800	4	Fluid	32		25		9							Couplers	Fully Encl. Cab On-Off Track Air-Oil Accumulator Emergency Hyd.
CANRON OTBC ON TRAC BRUSH CUTTER	18-6	10-2	15-0		14.5	100	100		2 Cycle Diesel	GM	4-53	125 @ 2600			30	3	28		9							4 Wheel Fail Safe Brakes	
FAIRMONT W24-C WEED MOWER	11-1	10-2	8-10	6-4	3.0		30		Gas			37 @ 2400	4	Air	25	7	14'-8"	3'-2"								4 Wheel Fail Safe Brakes	Sickle Repair Items. Tools, Sick.-Grinder Extra Sickles (4) Horn Roof Unit Insulated Wheels
RMC/PORTEC* BRUSH CUTTER															24	4	28		14								

* Railway Maintenance Corporation (Portec, Inc. - RMC Division)

BRUSH CUTTER

COMPANY/ MODEL	DIMENSION LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	CAPACITY FUEL	HYDRAULIC	OIL	ENGINE TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	AIR COMP. CFM	DRIVE	BRAKES	WORK WIDTH		BUCKET CAP.	DISCHARGE	BROOM DIA.		BASE-PRICE	OPTIONS	COMMENTS
RAILWAY PRODUCTS	53-6	10-6	13-2		60,000				Diesel	General Motors	471				25	12	4-Wheel Hydra	4-Wheel Fail-Safe	17 ft.		100 yd ^{3}/hr	(1)	4-8"			Air Conditioning Web Sweeps	Fully enclosed pressurized cab Heater Sweeps through switches

(1) Waste to car on adjoining track, or across adjoining track

CLEANER, TRACK/YARD

CRANES, ON-TRACK ONLY

COMPANY/ MODEL	DIMENSION					CAPACITY			ENGINE																OPTIONS	COMMENTS
	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	HOIST DRIVE	HOIST PULL	LINE SPEED	MAX. BOOM LG.	ROT. SPEED	TAILSWING	DRAWBAR PULL			BASE-PRICE		
BURRO MODEL 40	16-4 (3)	9-6	10-7 (4)	9-0	70,000				Diesel						28		12,000 lbs	91-187 FPM		2.5-5 RPM	6'-3"	15,000					Enclosed Cab
BURRO MODEL 30	16-3 (3)	8-3	11-0	9-0	42,000				Diesel						22		10,000 lbs	80-167 FPM		2.2-4.6 RPM	6'-3"	7,500					
ORTON/ McCULLOUGH MODEL 17 H		9-4	11-0	9-0	84,000		115		2 Cycle Diesel	4-71		132 @ 1800	4		28	Hydraulic Planetgears	12,000 lbs.	130 FPM	55 ft.	0-3 RPM	6'-6"	16,500 lbs				"Free Fall" 5' & 10' Boom Inserts Cab Heat Auto. Air Brake Alternate Diesel Engs.	Hydraulic boom hoist Dead man Controls Hydraulic swing
LITTLE GIANT SPR-48 WORKRANE	41-8 (1)	10-4 (2)	10-10		70,000					DD-4-71		140@2100 (5)					11,000 lbs.	180 FPM		0-6 RPM	6'-3"						

(1) W/30' boom
(2) Width for travel
(3) Between knuckles
(4) Cab only
(5) BHP

COMPANY/ MODEL	DIMENSION					CAPACITY			ENGINE						CRIBBING DATA											OPTIONS	COMMENTS
	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	CRIB. DEPTH	HYD.	VIB. RATE	DIG. FORCE	RUNNING TIME	PRODUCTION				BASE-PRICE		
PLASSER CR 312 CRIB CLEANER					19 Tons				Diesel	Caterpillar		150@2800 (3)	8		30	10										Heating/Air Conditioning Insulation	Fully Enclosed Cab Shoulder Plows Set-Off, Two Cribs Simul., Illumination
RACINE BALLAST CRIBBER	12-0	5-4	7-9		4,000 lbs	16	17		Gas	Wisconsin	VH4D	30		Air	20		1000 Psi.	2500 (1)	7,000 lbs	8 hrs.	5-15 (2)						Emergency Handpump Electric start Fail-Safe brakes
WINDHOFF																											

(1) Strokes per minute
(2) Seconds per crib
(3) Intermittent

CRIB BALLAST REMOVER

	DIMENSION				CAPACITY				ENGINE																OPTIONS	COMMENTS
COMPANY/ MODEL	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	SPINDLE SP'D									BASE-PRICE		
NORDBERG DUN-RITE GAUGING MACHINE	9	7	4-6		2630					Briggs & Stratton		6.8 @ 2800				1700 RPM											

GAUGING MACHINE

COMPANY/ MODEL	DIMENSION LENGTH	WIDTH	HEIGHT	BASE	CAPACITY WEIGHT	FUEL	HYDRAULIC	OIL	ENGINE TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	Max. Grd.	Load Cpct.	Carry Cpct.							BASE-PRICE	OPTIONS	COMMENTS
MTM-STUMEC* Gang Trolley donelli D721 standard (1)	27	9.8	9.8	13.1	26000							106		Air	40	30 0/00	36000	19								Various Models	Automatic Air Brakes

* Modern Track Machinery, Inc., Geismar, Stumec

(1) 5 additional models - D721 ST:Power 106 H.P.
- D721 M:Power 140 H.P. (Maximum speed 50 mph)
- D721 P:Power 170 H.P. (Mountain Railways)
- D721 G:Fitted with crane
- D721 E:Specially designed for electrification work

MOTOR CAR-LARGE

	DIMENSION					CAPACITY			ENGINE																	OPTIONS	COMMENTS
COMPANY/ MODEL	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	TRAVEL RANGE	PAY LOAD	SEAT CAPACITY	MPG						BASE-PRICE		
MTM/STUMEC* Model RH	2100 (2)	1400 (2)	1100 (2)		484	7.9			4 Stroke Gas	Bernard	810	8.5 @ 3600		Air	28 (1)	199 miles	771									Electric Start	Rope or crank start Drum brakes both drive wheels Complete set of tools
(5) MTM/STUMEC* Model AF	2390 (4)	1680 (4)	1275 (4)	1500	1213				Gas	Renault	4L	23 @ 4000 (3)	4		37 (3)			7									Derailing device to on-off track machine by two men
RAIL TECH Trackscoot				43½	188				4 Cycle	Clinton	410	4			15 max. (6)		700		100 max.								two drive wheels w/brake quick disassembly frame: 3/4" tubular

* Modern Track Machinery, Inc., Geismar, Stumec
(1) Under full load, on gradient, up 1/40 - can be increased on request
(2) Dimension given in mm. 6.9' x 4.6' x 3.6' - which dimension in length, width or height not stated
(3) Engine speed is governed to 3000 rpm maximum, speed on 2% gradient
(4) Dimension given in mm. 7.8 x 5.5 x 4.2
(5) Data for 1435 mm (56.5")gauge machines
(6) 20 mph available

MOTOR CAR - SMALL

COMPANY/ MODEL	DIMENSION LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	CAPACITY FUEL	HYDRAULIC	OIL	ENGINE TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	OPERATING SPEED	RUNNING TIME (HRS.)	HYD. PUMP TYPE	MAX. FORCE	WORK RANGE	PRODUCTION	HYD. PRES.			BASE-PRICE	OPTIONS	COMMENTS
RACINE DUO ANCHOR TIGHT	8-2	6-0	7-3	5-6	3500	16	25		Gas	Wisconsin	VH4D	30			20	2000 RPM	8		30,000 lbs.	110# - 155#	9 (1)	1200 PSI				High-Temp Cut-Off Diesel-Perkins 38 H.P.	Electric start
RMC/PORTEC* ANCHOR ADJUSTER	10-3	7-5	7-6		4800				Gas						22			Vickers 20-10			32-36 (2)					Diesel Engine Set-off Insulation	

* Railway Maintenance Corporation (Portec, Inc. - RMC Division)

1. Ties/Min. on normal CWR anchor pattern
2. Anchors/Min.

RAIL-ANCHOR ADJUSTER

COMPANY/ MODEL	DIMENSION LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	CAPACITY FUEL	HYDRAULIC	OIL	ENGINE TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	STARTING	RUNNING TIME	WORK RANGE	NIPPER FORCE	BOXING PRES.	PRODUCTION				BASE-PRICE	OPTIONS	COMMENTS
RACINE ANCHOR FAST	8-0	7-3	5-0	5-6	2560	10	13		Gas	Wisconsin	TJD				20 (4)	Elec.	8 hrs.	90# - 140#	32,000 lbs.	3,000	24 (1) 22 (2)					Air Cooled Diesel One Cyl. 12 H.P. High Temp Cut-Off Low Oil Indicator	Turntable Single rail Hydraulic hand pump
RACINE DUO-ANCHOR-FAST	10-8	7-11	7-2	6-2	5000 (5)	16	32		Gas	Wisconsin	VG4D	37 @ 2400	4		20			90# - 140#	32,000 lbs.	3,000	20 (1) 18 (2)					Diesel Perkins 38 H.P. High Temp. Cut-Off Low-Oil Gauge Extra Tools-Other anchor Sizes	Emergency Hand Pump Jack Turntable Both rails
TRUE TEMPER MHD	6-0	4-0	3-0		550					Briggs & Stratton						Recoil					300 (3)						

(1) Ties/Min. all ties
(2) Ties/Min. every other tie
(3) Anchors/Hr.
(4) Level track
(5) With diesel engine

RAIL ANCHOR APPLICATOR

(MANUAL SETTING)

COMPANY/ MODEL	DIMENSION LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	CAPACITY FUEL	HYDRAULIC	OIL	ENGINE TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	STARTER	RUNNING TIME	WORK RANGE	NIPPER FORCE	BOXING PRES.	PRODUCTION	HYD. PRES.	HOPPER CAP.	LOAD BUCKET CAP.	BASE-PRICE	OPTIONS	COMMENTS
NORDBERG ANCHOR APPLICATOR	11-2	8-6	8-0 (4)	6-4	11000	40	48		Diesel	General Motors	2-53	47 @ 2200 (1)			20				40,000		540 (2)	2000	700	400			Turntable Set-Off Hand Pump Vickers Hyd. Pump
RACINE ANCHOR MATIC	12-0	6-5	6-0		6050 (6)	16	20		Gas	Wisconsin	VH4D	30 @ 1800 (1)			10	Elec.	8 hrs. (5)	100# - 140#	40,000	700	7-8 (3)	1200	400	100		Diesel-Perkins High Temp Cut-Off Low Oil Indicator 20 MPH Travel Speed	Horn Turntable
RMC/PORTEC* ANCHOR MASTER	11-7	9-6	6-6		5400				Diesel						20						12-16 (3)		200			Gas Engine Hyd. Cent. Lift & Turntable, Hyd.Anchor Loading Hoist Set-Off	Air Brakes Anchor Conveyor Insul. Wheels Horn Cushioned Seat

* Railway Maintenance Corporation (Portec, Inc. - RMC Division)
(1) Operating speed
(2) Ties boxed/hr.
(3) Ties/min.
(4) 6-0 without canopy and muffler
(5) Per full tank
(6) Gas engine, no anchors

RAIL ANCHOR APPLICATOR

(SEMI-AUTOMATIC)

COMPANY/ MODEL	DIMENSION: LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	CAPACITY: FUEL	HYDRAULIC	OIL	ENGINE: TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	GEAR REDUCTION	STARTER	OPERATING SPEED	MAX. DIA.	FEED	WORK RANGE	PRODUCTION	SPINDLE SPEED	FINAL DRIVE	BASE-PRICE	ACCESSORIES: Additional to Basic Price	COMMENTS
INGERSOLL-RAND R44A																											No data provided
NORDBERG MODEL CD					132							2				6:1											
RACINE MODEL A AUTOMATIC FEED	3-5	1-9	1-10		147	Gas 3 qt.			Gas	Briggs & Stratton	80352	3		Air		6:1	Recoil	3100 RPM		Auto-power	60# - 155#	1¼ - 2 (1)	110	Roller Chain		5/16" Drill Chuck Coolant Tank Roll Bar Taper Drill Adapt.	3/8" Drill Chuck Spirit Level Torque Clutch
RACINE MODEL M MANUAL FEED	3-5	1-9	1-10		142	Gas 3 qt.			Gas	Briggs & Stratton	80352	2-3/4		Air		6:1	Recoil	3100 RPM		Man-screw	60# - 155#	1¼ - 2 (1)	110	Roller Chain		SAME AS	MODEL A
RACINE MODEL AP	3-5	1-9	1-10		142	3 qt.				Briggs & Stratton	8BR6	2-3/4		Air		6:1	Recoil	3300 RPM		Auto-power	60# - 155#	1¼ - 2 (1)	110	Roller Chain		Coolant Tank Roll Bar Index Fixtures Taper Drill Adapt.	Hole Index

(1) Holes/Min.-1 5/16" dia.

RAIL DRILL

COMPANY/ MODEL	DIMENSION				CAPACITY				ENGINE																	ACCESSORIES	COMMENTS
	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	GEAR REDUCTION	STARTER	OPERATING SPEED	MAX. DIA.	FEED	WORK RANGE	PRODUCTION	SPINDLE SPEED	FINAL DRIVE	BASE-PRICE		
RACINE MODEL APC	3-11	1-9	2-4		138	3 qt.			Gas	Briggs & Stratton	80352	3		Air		6:1	Recoil	3300 RPM			60# - 140#	1¼ - 2 (1)	110	Roller Chain		Index Chucks; Chuck 5/16 or 3/8 Coolant Tank; Roll Bar; Clamp Blocks For Other Rail Sizes	Self Adj. Torque Clutch Chuck 3/8 - 5/16
MTM-STUMEC* PR 3	2-7	1-6	1-9		116					Bernard	W328A								1 - 3/8				150 RPM			Slow speed addition 70 RPM Rubber wheeled Trolley Drilling Jib	Optional: B&S 92 902 engine; Manual hand wheel drill advance.
MTM-STUMEC* PR 3AA					121														1 - 3/8							Slow speed addition 70 RPM; Rubber Wheeled Trolley: Drilling Job; B&S 92 902 engine optional	Device for automatic advance and halting High precision machine.
MTM-STUMEC* PR 3C	2-6	1-6	1-10		115														1 - 3/8							Slow speed addition 70 RPM; Rubber Wheeled Trolley; Drilling Jib; B&S 92 902 engine optional	Compact version of PR3: Articulated Advance Lever.
MTM-STUMEC* SAFETRAN					360	1.5						6 @ 2700											85 - 90 RPM (2)	Gears			Direct drive through gears.

* Modern Track Machinery, Inc., Geismar, Stumec
(1) Holes/Min.-1 5/16" dia.
(2) Engine Speed of 2200 RPM

RAIL DRILL

	DIMENSION					CAPACITY			ENGINE																	OPTIONS	COMMENTS
COMPANY/ MODEL	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED										BASE-PRICE		
WESTERN-CULLENS -HAYES, INC. MODEL P					130	1/2			4 Cycle	Briggs & Stratton	8BR6	3		Air													

RAIL DRILL

COMPANY/ MODEL	DIMENSION				CAPACITY				ENGINE																	OPTIONS	COMMENTS
	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	CAPACITY BTU/HR	HEATER FUEL	TANK CAPACITY (GAL)	TOWING SPEED	NO. OF CRUCIBLE	NOZZLE HEATER CAP.	CONSUMPTION		BASE-PRICE			
CANRON MODEL RH									Gas or LPG	Wisconsin	TDH		2		0-13	1 Mill.	Propane			12							
TELEWELD						- -	- -	N/A	- -	- -	- -	- -	- -	- -		1.7 Mill.	Propane	500 (1)	25	16							Not Self Propelled.
WOOLERY	14-0 (2)	3-0 (2)			2000 net							16		Air	15		No. 1,2,or3 Diesel	100			7½G.P.H.						Hydraulic Turntable
MTM-STUMEC * S. H. 4	12-0 (7)	3-0 (7)	2-0 (7)		198 (8)											(3)	Propane					(5)					
MTM-STUMEC * S. H. 8	12-8 (7)	6-7 (7)	5-8 (7)		615 (8)											(4)	Propane					(6)					Insulated

* Modern Track Machinery, Inc., Geismar, Stumec

(1) Gallons at 80% Full

(2) Overall

(3) 200,000 Kcal/hour @ 1 atm; 264,000 Kcal/hour @ 2 atms.

(4) 400,000 Kcal/hour @ 1 atm; 528,000 Kcal/hour @ 2 atms.

(5) 8 lbs - 13 ozs/hour @ 1 atm; 13 lbs - 3 ozs/hour @ 2 atms.

(6) 17 lbs - 10 ozs/hour @ 1 atm; 26 lbs - 6 oz/hour @ 2 atms.

(7) Which dimension is length, width or height not stated.

(8) Without bottle

RAIL HEATER

COMPANY/ MODEL	DIMENSION LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	CAPACITY FUEL	HYDRAULIC	OIL	ENGINE TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED										BASE-PRICE	OPTIONS	COMMENTS
RMC/PORTEC* JOINT STRAIGHTNER	15-6	8-0	7-10		12,000																					Center Lift Set-Off Enclosed Cab w/Heat Impact Wrench Crib Reducer	

* Railway Maintenance Corporation (Portec, Inc. - RMC Division)

RAIL JOINT STRAIGHTNER

	DIMENSION					CAPACITY			ENGINE																	
COMPANY/ MODEL	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL	COOLING	TRAVEL-SPEED	LIFT WEIGHT	LIFT CAPACITY (TONS)	STROKE							BASE-PRICE	OPTIONS	COMMENTS
FAIRMONT HYDRAULIC RAIL LIFTER	4-8	7-9	2-10		780	6	10		Gas 4 Cycle			9.2@3200(1)	1	Air		225											Set-Off Wheels Insulated Clamps Hyd. Rail Clamp
REXNORD PLATE PLACER	3-0	6-7	2-2	2-4	450					Briggs & Stratton		5.75					7										
GREENSIDE HYDRAULICS TRACK LIFTING MACHINE																	12 or 15	18 "									

(1) BHP

RAIL LIFTER

COMPANY/ MODEL	DIMENSION: LENGTH	WIDTH	HEIGHT	BASE	CAPACITY: WEIGHT (TOTAL)	FUEL	HYDRAULIC	OIL	ENGINE: TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	OPERATING SPEED	STARTER	DRIVE	WORK RANGE	BLADE SPEED	PRODUCTION	CUTTER TYPE	BLADE SIZE	STROKE	BASE-PRICE	ACCESSORIES	COMMENTS
RACINE TRAK-KUT	2-2	1-3	1-5		59 (5)	1 1/2 qts.			2 Cycle	McCulloch				Air			Recoil	V Belt	85# - 140#	4800 RPM	3 Min. (1)	Abra. Wheel	14" Dia.	N/A		Wooden Carrying container	Clamp Adapter 60#-80# Workhead Wt-37 lbs
RACINE MODEL 155	3-0	1-8	1-10		225 (6)	2 Qts.			4 Cycle Gas	Briggs & Stratton	80301	2-3/4		Air		2800	Recoil	Worm	80# - 155#	110 - 115 SPM (2)	5-8 Min.			5"		Attachment For 60# Rail	Blade Lift Water Tank
RACINE MODEL 140	3-0	1-8	1-10		194	2 Qts.			4 Cycle Gas	Briggs & Stratton	80202	3		Air		3300	Recoil	Worm	80# - 140#	115 SPM (2)	5-8 Min.					Attachment For 60# rail	Blade Lift
MTM-STUMEC* MODEL SR	3-5	1-5	1-8		174				4 Cycle Gas	Bernard	W 18A	1.3 @ 3300		Air			Rope				8 Cuts/Hr.	Blade	13-3/4 - 15-3/4				Cooling Jet
MTM-STUMEC* MODEL MT 40	2-7 (4)	1-5 (4)	1-4 (4)		44				2 Cycle											5100 RPM	Approx. 3 Min. (3)		12" Dia.				

* Modern Track Machinery, Inc., Geismar, Stumec

(1) 115 lbs. rail
(2) S.P.M. = Strokes/Min.
(3) 136 lb. rail
(4) Which dimension is length, width or height, not stated.
(5) Work head weighs 37 lbs.
(6) With full tank

RAIL SAW OR ABRASIVE CUTTER

	DIMENSION					CAPACITY			ENGINE																	OPTIONS	COMMENTS
COMPANY/ MODEL	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT (TOTAL)	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED		STARTER	DRIVE	WORK RANGE	BLADE SPEED	PRODUCTION	CUTTER TYPE	SIZE	STROKE	BASE-PRICE		
MTM-STUMEC* MODEL MT 45	2-7 (1)	1-5 (1)	1-5 (1)		44				2 Cycle											4,800 RPM			14" Dia.				

* Modern Track Machinery, Inc., Geismar, Stumec

(1) Which dimension is length, width, or height, not stated.

RAIL SAW OR ABRASIVE CUTTER

COMPANY/ MODEL	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	ROTATION SPD	LAT. ADJ.	PENETRATION							BASE-PRICE	OPTIONS	COMMENTS
	DIMENSION					CAPACITY			ENGINE																		
RAILWAY TRACK-WORK COMPANY X 60 CROSS GRINDER	33	21	24		130					Wisconsin		5														Briggs & Stratton Engine	
MTM -STUMEC* MJ-18	1-7 (1)	1-8 (1)	2-7 (1)		67				Gas 4 Cycle	Bernard	W.18A	1.5 @ 3600	1	Air		6500 RPM	30 mm	70 mm								Other Engines, by specification	
RAILWAY TRACK-WORK COMPANY JG-970 CROSS GRINDER	7-9	3-0	2-0		230											4500											

* Modern Track Machinery, Inc., Geismar, Stumec

(1) Which dimension is length, width or height, not stated.

RAIL SLOTTER

	DIMENSION				CAPACITY			ENGINE																	OPTIONS	COMMENTS
COMPANY/ MODEL	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	PRODUCTION	NO. OPERATORS	GAUGE RANGE	LIFT POWER	LIFT TRAVEL				BASE-PRICE		
MTM-STUMEC* MODEL MPR HYDRAULIC RAIL THREADER	12-3	3-11	5-3		1940				Gas or Diesel			7				545-765 yds/hr.	1	3'to5'-63/4"	7 Tons (1)	1'-7"						

* Modern Track Machinery, Inc., Geismar, Stumec
(1) Metric

RAIL THREADER CAR

COMPANY/ MODEL	DIMENSION				CAPACITY				ENGINE																	OPTIONS	COMMENTS
	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	COMPRESSOR	HAMMERS	MAGAZINES	SPIKES/MAG.	SPIKE STORAGE	HYD.PRES.	PRODUCTION			BASE-PRICE		
FAIRMONT W96 SERIES B SPIKE SETTER DRIVER	16-3	9-0	7-4		12000	27	49		Diesel 2 Cycle			64 @ 2200 (1)	3		25	7.5 SCPM @ 100 PSI	700 cycle/ min.	4	20							Set off Curtain	
CANRON TYPE A, B, C	20-6	10-2	8-0		28000	140	135		2 Cycle	General Motors	N Series 4-53	136 @ 2800								(2)						Air Conditioning	Fully enclosed cab
RMC/PORTEC* AUTO SPIKER	14-6	7-11	6-11		11200				Diesel	General Motors	3-53				30	150 cfm										Hydraulic centerlift and turntable Demountable set-off	
NORDBERG RAIL GANG SPIKER	12-6	8-10	8-0		11500	24	48		Diesel	General Motors	2-53	40			20						2000 PSI						Insulated Emergency hand pump
NORDBERG HYDRA-SPIKER	12-0	10-7 (3)	6-3	5-3	12,750	21	108		Diesel			62			18						2500 PSI	100-120 (4)					

* Railway Maintenance Corporation (Portec, Inc. - RMC Division)
(1) Continuous BHP at SAE conditions
(2) Enough for four hours operation
(3) Traveling, 12'-13" working
(4) Ties/hour

SPIKE DRIVER, AUTOMATIC

COMPANY/ MODEL	DIMENSION: LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	CAPACITY: FUEL	HYDRAULIC	OIL	ENGINE: TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	HYD. PRES. (PSI)			PRODUCTION						BASE-PRICE	OPTIONS	COMMENTS
RMC/PORTEC * ZAPPER TIE GANG SPIKER	17-11	7-11	7-6		15,000														20-24 (1)								
RMC/PORTEC* ZAPPER RAIL GANG SPIKER	14-7	7-11	7-7		11,100														20-24 (1)								

* Railway Maintenance Corporation (Portec Inc. - RMC Division)
(1) Spikes/minute

SPIKE DRIVER; AUTOMATIC

COMPANY/ MODEL	DIMENSION					CAPACITY		ENGINE																	OPTIONS	COMMENTS
	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	HYD. PRES. (PSI)	BLOWS/MIN.	BLOW FORCE	PRODUCTION (2)					BASE-PRICE		
CANRON TAMPER SPIKE DRIVER	8-6	9-1	4-11	4-2	1950	11.5	40		Gas 4 Cycle	Wisconsin		18		Air	10.6	2000	1800 (Max.)	80 Ft/Lbs								Hyd. Spike Puller Nipper
FAIRMONT W100 SERIES B	6-0	7-10	4-2		2160 (1)	6	9		4 Cycle			15 @ 2300	2	Air											Tie Nipper Wt. 300 lbs.	Turntable w/Aux. hand Pump Set-Off
FAIRMONT W-100 SERIES C	6-0	7-10	4-2		1340	8	9		4 Cycle			15 @ 2300	2	Air											Tie Nipper Wt. 300 lbs. Fact. Appl. Field "	Turntable w/Aux. Hand Pump
RMC/PORTEC* SPIKEMASTER	11-0	7-0	6-6		7000				Diesel	General Motors	3-53				20-30										Hydraulic Center Lift & Turntable Demountable Set-Off	Air-Operated Tie Nippers
RMC/PORTEC* WALKING SPIKER	16-0	16-10	6-7		11,000																				Air Oper. Tie Nipper Hyd. Center Lift & Turntable; Demountable Set-Off	Insulated

*Railway Maintenance Corporation (Portec Inc. - RMC Division)
(1) With set-off
(2) Spikes/minute

SPIKE DRIVER, PNEUMATIC

COMPANY/ MODEL	DIMENSION: LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	CAPACITY: FUEL	HYDRAULIC	OIL	ENGINE: TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	PRODUCTION									BASE-PRICE	OPTIONS	COMMENTS
NORDBERG SPIKE HAMMER					1010							6	1	Air	950	400 (1)											

(1) Spikes/hour

SPIKE DRIVER, PNEUMATIC

	DIMENSION					CAPACITY			ENGINE																	OPTIONS	COMMENTS
COMPANY/ MODEL	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED		PRODUCTION	EXTRACTION	PULL TRAVEL						BASE-PRICE		
FAIRMONT W84-H HYDRAULIC SPIKE PULLER	6-2	7-10	3-9		920 (5)	6	10			4 Cycle		9.2 @ 3200 (1)	1	Air													Locking Hasps Set-Off
FAIRMONT W113-B DUAL SPIKE PULLER	7-4	7-3	5-1			2300	15	20		4 Cycle		26 @ 2400 (1)	4	Air	20											Turntable Set-Off Partial Pulling Cyl. Shell	
NORDBERG BP						2200				2 Cycle				Air			30-45 Spikes/Min.	12,000									
MTM-STUMEC* AC-1	2-11 (4)	6-0 (4)	1-8 (4)			180 (2)				4 Cycle Gas		4		Air				(3)	7"								Can pull elastic spikes Easy On-Off
NORDBERG MODEL C	8-3	5-10	3-4	3-0	650	1.5	3.5				Briggs & Stratton	9						11,048 lbs.									Insulated

* Modern Track Machinery, Inc., Geismar, Stumec
(1) BHP
(2) Trolley Weighs additional 77 lbs.
(3) Hydraulic ram 6 metric tons
(4) Which dimension is length width or height, not stated.
(5) Lift weight 180 lbs.

SPIKE PULLER

	DIMENSION					CAPACITY			ENGINE																	OPTIONS	COMMENTS
COMPANY/ MODEL	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT (TONS)	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	NO. TOOLS	DRIVE	VIB. FREQ.	VIB. AMPL.						BASE-PRICE		
PLASSER ASSISTANT ROADMASTER	25-8	9-6	9-8	20-4	14.5				Diesel	Caterpillar		150@2800 (1)	8		30	16										Switch Tamping Heads Insulated Man. Set-Off	Partially Enclosed Cab Illumination Turntable
PLASSER PTT-16	19-4		9-1	8-4	8.5				Diesel	General Motors	353				30	16											Fail-Safe Brakes
CANRON ELECTROMATIC	22-9	9-2	10-11	8-3	18				Diesel	General Motors	4-71	118 @ 1600			32	16	Hydraulic	3200 VPM	3/8"								

(1) Intermittent

TAMPER

COMPANY/ MODEL	DIMENSION LENGTH	WIDTH	HEIGHT	BASE	WEIGHT (TON)	CAPACITY FUEL	HYDRAULIC	OIL	ENGINE TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	HYD. PRES.	NO. TOOLS	VIB. FREQ.	AMPLITUDE	JACK CAPACITY	GRADABILITY	SURFACE	CROSS LEVEL	BASE-PRICE	OPTIONS	COMMENTS
CANRON VIBRATOOL					5	30	70		Diesel	General Motors	N Series 353	97 @ 2800			35	1800	16	3200 VPM		(3)					Fail Safe Brakes Lining Device	Insulated Wheels Turntable Chain Drive To Front Axle Cross Level Indicator
JACKSON 900	15-0	8-0 (1)	8-2	6-8	5	35	75		Diesel	John Deere	3164 D				20						3%	0-6" Lift	0-6" (2)			Center Turntable Chain Drive

(1) Travel; 11-0 when working
(2) Superelevation
(3) Two manually operated ten ton hydraulic cylinders

TAMPER W/JACKS

COMPANY/ MODEL	DIMENSION: LENGTH	WIDTH	HEIGHT	BASE	WEIGHT (TONS)	CAPACITY: FUEL	HYDRAULIC	OIL	ENGINE: TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	PRODUCTION	VIB. FREQ.	AMPLITUDE (IN)	BUGGY LENGTH	P BAR LENGTH	NO. TOOLS				BASE-PRICE	OPTIONS	COMMENTS
RMC/PORTEC* 8-TOOL SPOT TAMPER	16-4	8-0	7-11		8																					Hydraulic Rail Clamps Jacking Cylinders Demount. Set-Off Centerlift & Turntable Ballast Dressing Blades; Cab	Four Wheel Drive Insulated Roof
RMC/PORTEC* McWilliams	16-4	8-0	7-11		8																						Single 8-Tool head, split.
RMC/PORTEC* McWilliams	16-4	8-0	7-11		8																						W/Two 4-Tool heads.
CANRON MODEL JP JOINT PEAK TAMPER	20-9	9-10	8-4	8-4	7	85	85		2 Cycle Diesel	General Motors	3-53	90 @ 2500 (2)	3	Water	20	60 (1)	3200 VPM	3/8	4-0	21-8	8						Insulated Turntable Hydraulic Drive

* Railway Maintenance Corporation (Portec, Inc. - RMC Division)
(1) Joints/Hr.
(2) BHP

TAMPER - JOINT

COMPANY/ MODEL	DIMENSION: LENGTH	WIDTH	HEIGHT	BASE	WEIGHT (TONS)	CAPACITY: FUEL	HYDRAULIC	OIL	ENGINE: TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	MAX. LEVELING (FORCE)	MAX. LIFT	LINING FORCE	MAX. SLEW(IN)	NO. TOOLS	PRODUCTION	DRIVE	VIB. FREQ.	VIB. AMPL.	BASE-PRICE	OPTIONS	COMMENTS
MATISA B200	53-1	9-8	11-2	(1)	(2)				Diesel	Gen Motors or Deutz		205 or 260 @ 2100			50	24 Mp	9-3/4 "	15 Mp	7-3/4 "		765 - 1315 (4)					Consolidator	
CANRON ELECTROMATIC	26-11	9-2	10-11		19				Diesel	General Motors	4-71	118 @ 1600			32					16		Hydraulic	3200 VPM	3/8"			
PLASSER URM 06-16 UNIVERSAL ROADMASTER	37-3	9-6	9-8		20.5				Diesel	Caterpillar		150 @ 2800 (3)	8		30					16						Auto Lift & Leveling Insul'd. Wheels Man. Set-Off Auto lining.	Illumination Turntable
JACKSON 6000	48-0	12-0			21.5	120	120		Diesel	Detroit	6V-71N	240 @ 1800			40 (5)		4"		4"			Hydrostatic				Air conditioning	Fully enclosed 4,500 multi-ton blows/min

(1) 2 Axles 32-1; 1 Axle/1 Bogie 34-4; 2 Bogies 34-4; Bogie Wheebase 5-5
(2) 32-38 Mp
(3) Intermittent
(4) Yards/hr.
(5) 0^{o} grade; 20 MPH 2% grade

TAMPER - PRODUCTION

	DIMENSION				CAPACITY			ENGINE																	OPTIONS	COMMENTS
COMPANY/ MODEL	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT (4)	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	HYD. PRES. (PSI)	NO. TOOLS	V.B. FREQ. (VPM)	AMPLITUDE (IN)	JACK CAP.	DRIVE				BASE-PRICE		
CANRON VIBRATOOL	SEE TAMPER WITH JACKS (page E-36)																										
RMC/PORTEC * McWILLIAMS TAMPER	16-4	8-0	7-11																								W/Split head, four 2-Tool heads
CANRON SWITCH TAMPER	19-0 (2)		10-11 (2)	8-3	16.5	90	90		Diesel 2 Cycle	General Motors	4-71 N Series	118 @ 1600 (1)	4	Water	40	1800	16	3200	3/8							Four Wheel Drive Fail-Safe Brakes Air conditioning	Turntable Encl. Cab w/Heat, Safety Window Horn
CANRON VIBRATOOL (SWITCH)					5.5	30	70		Diesel	General Motors	N Series 353	97 @ 2800			35	1800	16	3200		2 @ 10 Ton						Fail-Safe Brakes Lining Device	Insulated Turntable
PLASSER UYT 2W75 YARD SWITCH & SPOT TAMPER	34-9	9-6	9-8		19.5				Diesel	Caterpillar		150 @ 2800 (3)	8		30						Hyd.					Insulated Set-Off Turntable Lifting & Lining Fully Encl. Cab - Heat/Air Conditioning	Illumination Fail Safe Brake System

* Railway Maintenance Corporation (Portec, Inc. - RMC Division)
(1) B.H.P.
(2) Basic Machine, with shoulder jacks 22-6; with torsion beam 45-4
(3) Intermittent
(4) Shown In tons

TAMPER - SWITCH

COMPANY/ MODEL	DIMENSION: LENGTH	DIMENSION: WIDTH	DIMENSION: HEIGHT	DIMENSION: BASE	WEIGHT TONS	CAPACITY: FUEL	CAPACITY: HYDRAULIC	CAPACITY: OIL	ENGINE: TYPE	ENGINE: MAKE	ENGINE: MODEL	ENGINE: H.P. @ RPM	ENGINE: NO. CYL.	ENGINE: COOLING	TRAVEL-SPEED	NO. VIB. MOTORS	VIB. POWER	VIB. FREQ.	LIFT FORCE	LIFT (IN)	THROW (IN)	LINING FORCE (LBS)	TURNTABLE	SET-OFF	BASE-PRICE	OPTIONS	COMMENTS
JACKSON 2300	15-0	10-0	9-10	6-8	6.5	24	45		Diesel	General Motors	3-53N	72 @ 1930 (1)			20	8	4500 (2)			6	5		Yes	Yes		—	Chain Drive
JACKSON 2600	18-0	9-11	11-0	7-6	16	75	70		Diesel	General Motors	4-71	101 @ 1875			25	8	4500 (2)			6	5		Yes	No		Set-Off	
JACKSON 2800	22-6	9-11	11-0	7-6	19	70	70		Diesel	General Motors	4-71	101 @ 1875			25	8	4500 (2)			6	5		Yes	No		Set-Off	
JACKSON 7000	53-0	10-6	10-6		33				Diesel	General Motors	6V-71	240 @ 1800			40				43,000 (3)	6 Max.	4 Max.	44,000					
																											Chain Drive

(1) BHP
(2) Multi-ton blows/min.
(3) Max., per rail

TAMPER - SWITCH W/ALIGNER

COMPANY/ MODEL	DIMENSION: LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	CAPACITY: FUEL	HYDRAULIC	OIL	ENGINE: TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	WORKING SP'D.	ROTATION SP'D	PRODUCTION							BASE-PRICE	OPTIONS	COMMENTS
NORBERG MODEL CZ	6-8	9-0	4-5	4-0	2230	9	22.5		Gas			37				130 FPM											2 Cutter Heads 50 Extra Bits Self-sharpening Blades
RAILWAY TRACK-WORK COMPANY REGAUGE ADZER																											No data provided
MTM-STUMEC* MODEL REEN	5-1 (2)	8-4 (2)	3-7 (2)		1345				2 Cycle Gas			12 @ 3000		Air			4000 RPM	5-6 Secs. (1)									2 Engines Automatic Centrifugal Clutch

*Modern Track Machinery, Inc., Geismar, Stumec
(1) Seconds/tie @ 2 notches - 200 - 300 ties/hr.

(2) Which dimension is length, width, or height, not stated

TIE ADZER

	DIMENSION					CAPACITY			ENGINE																	OPTIONS	COMMENTS
COMPANY/ MODEL	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	GOVERNED SP'D	SPINDLE SPEED	DRIVE	MAX. DRILL	DRILLING SP'D					BASE-PRICE		
SAFETRAN SINGLE SPINDLE TIE BORER	4-0	6-2	3-3		233							9 @ 2400					1450 RPM	V Belt									
SAFETRAN MODEL TSB TWIN SPINDLE TIE BORER	4-5	7-4	4-7		780		15					9 @ 3600				2800 RPM	1000 RPM			2 Sec./ Hole							Insulated Carrier
MTM-STUMEC* MODEL PT8	7-1 (1)	2-1 (1)	4-1 (1)		250 (5)				Gas 4 Cycle	Bernard	W110	4 @ 2500		Air			1400 RPM		33 mm Dia.	2 Sec./ Hole (4)							
NORDBERG TIE DRILL	3-8	8-0	4-3	2-10	795					Briggs & Stratton	14-B	5¼ @ 3600				2920 RPM	1700 RPM			48 holes in 2 1/2min							Drills two holes at the same time
MTM-STUMEC* PTSL	2-11 (1)	1-6 (1)	1-11 (1)		73 (2)				4 Cycle			3		Air			970 RPM		7/8 "	5 sec. (3)							Single or double head.

*Modern Track Machinery, Inc., Geismar, Stumec

(1) Which dimension is length, width or height, not stated.
(2) Machine weight, trolley weighs 26 lbs.
(3) For 8" hole
(4) With standard size auger
(5) Trolley additional 77 lbs.

TIE BORING MACHINE

	DIMENSION					CAPACITY			ENGINE																	OPTIONS	COMMENTS
COMPANY/ MODEL	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED										BASE-PRICE		
MTM-STUMEC* PT2T					37 (1)	DATA FROM MODEL PT8 APPLIES (SEE PAGE E-42)										1070 (1)											Second head for truncated conical boring
MTM-STUMEC* PTL					8				Gas			3 @ 3600		Air		1200											3-wheeled trolley

* Modern Track Machinery, Inc. Geismar, Stumec
(1) Data for second spindle

TIE BORING MACHINE

	DIMENSION					CAPACITY			ENGINE																OPTIONS	COMMENTS
COMPANY/ MODEL	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	CRIB. DEPTH	WORK SPEED	ELEMENTS/ SWEEP	DIA. REEL						BASE-PRICE		
RAILWAY TRACK-WORK COMPANY DWDS-4 ANCHOR CRIBBER	9-2	7-10	4-3		4780		20			Wisconsin	VH-4D	24.7 @ 2000	4		250 ft/min	3" to 6" (1)	20 to 80 ft/min	8	44"							Air Cooled Diesel Spark Arrestor 4-STD. Gauge Drive Wheels - 10 MPH	

(1) Below top of tie

TIE CRIBBER

COMPANY/ MODEL	DIMENSION					CAPACITY			ENGINE																	OPTIONS	COMMENTS
	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	AIR COMPRES.	BRAKES	DISCHARGE REACH	PRODUCTION RATE	TURNTABLE					BASE-PRICE		
RAILWAY PRODUCTS/ MARMON TRANSMO- TIVE TIE EXTERMINATOR	40-0	10-3	11-10	13-6	45,000	(2)				General Motors	671 Series	180 @ 2000			25	12 CFM	Air (1)	21 (4)	450 (3)	Yes						Horizontal Flite Receiving Conveyor; Tie Handler Boom	Air Horns Two Wheel-Hydromatic 96"-Chunk Lading Tray Lifting Points

(1) Fail safe
(2) 12 hour capacity
(3) Chunks (150) per hour
(4) Feet from track center line

TIE DESTROYER

	DIMENSION					CAPACITY			ENGINE																OPTIONS	COMMENTS
COMPANY/ MODEL	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	DECK ROTATION	DECK DRIVE	BOOM REACH	TRAVEL (BOOM)	CAPACITY @ MAX	CAPACITY @ MIN	TRAVEL SPEED			BASE-PRICE		
RAILWAY TRACK-WORK COMPANY 2170-A	27-6	7-4	8-0		9250	30	55		Diesel	General Motors					360°	HYD.	12'-6 to 24-0	36° up 46° dn	800 lbs. @ 24'	1500 lbs. @ 12-6	20				Emerg. Hydraulic Pump; Power Set-Off Wheels; Encl. Cab; Single Dual Tie Head; Tie Grapple Head	Tool Box Horn Tie Head Hyd. Boom
RAILWAY TRACK-WORK COMPANY 2170																	24'	31° up 37° dn								

TIE HANDLER

COMPANY/ MODEL	DIMENSION: LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	CAPACITY: FUEL	HYDRAULIC	OIL	ENGINE: TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	HYD. PRES.	DRIVE	Insertion Force	PRODUCTION	BEAM RANGE	Max. Stroke	NO. OPERATORS		BASE-PRICE		OPTIONS	COMMENTS
FAIRMONT W90-D TIE HANDLER	6-3	7-5	4-11 (1)		1650	8	8.5		4 cycle			11.7 @ 1800	2	Air		2000 PSI	HYD.									Remote Control Tie Handling Boom Tie Removing Boom Concrete Tie Thong	Set-off Wheels
FAIRMONT W119-B	12-0	8-0	8-0		13250	27	43		Diesel 2 Cycle			64 @ 2200 (5)	3		22			8850 lbs.								Set-Off Group	Enclosed Cab Turntable
MTM-STUMEC* MRT TIE RENEWER	9-2 (4)	7-5 (4)	8-8 (4)		5100		36		Diesel or Gas			30		Air	20 (2)				40 (6)	± 30° (3)	4'-3"	1					Off Track in 2 min. Rail Raising Jacks Turntable Fully Hydraulic
RMC/PORTEC** TIE MASTER	19-6	10-7	9-11		36,000				Diesel										60-70 (6)							Add.hyd. tie hoist Ballast plow Ballast dressing wings Centerlift and Turn-table; Insulated	
JACKSON 125 TIE REMOVER/ INSERTER	8-0	8-0	7-0	4-9	9,500	24.5 (7)	24		Gas	Wisconsin	VH4D	30	4	Air	20			6,000 lbs									Extraction force 14,000 lbs. Scarifies

*Modern Track Machiner, Inc., Geismar, Stumec

**Railway Maintenance Corporation (Portec, Inc., RMC division)

(1) Set-off wheels raised
(2) Level Track
(3) From horizontal
(4) Which dimension is length, width or height, not stated.
(5) Continuous BHP at SAE standard conditions
(6) Ties/hr.
(7) Approx. 8 1/2 hr. running hours.

TIE INJECTOR/INSERTER

COMPANY/ MODEL	DIMENSION					CAPACITY			ENGINE																	OPTIONS	COMMENTS
	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	PRODUCTION	CYCLES								BASE-PRICE		
FAIRMONT W104-D	7-0	10-0	4-2		1450	6	5					15 @ 2300	2	Air		40 (1)										Narrow Crawler	
MTM-STUMEC* MODEL CC3	6-7	2-2	4-1		217 (3)				Gas			1.5 @ 3600		Air			180 (2)										

*Modern Track Machinery, Inc., Geismar, Stumec
(1) Plugs/min.
(2) Blows/min.
(3) 4-Wheel trolley add't 77 lbs.;3 wheel trolley add't 66 lbs.

TIE PLUG SETTER & DRIVER

COMPANY/ MODEL	DIMENSION LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	CAPACITY FUEL	HYDRAULIC	OIL	ENGINE TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	RAM FORCE									BASE-PRICE	OPTIONS	COMMENTS
FAIRMONT W68-C					1900		10					14.5 @ 2200	2	Air		14,500 lbs.										Set-Off Turntable	Lift Weight - 350 lbs.
FAIRMONT W115-B	13-0	11-0	8-0		12500	23	42		2 Cycle Diesel			80 @ 2200	3	Air	27	12,000 lbs.										Set-Off	Turntable Enclosed Cab

TIE REMOVER

COMPANY/ MODEL	DIMENSION					CAPACITY			ENGINE																OPTIONS	COMMENTS
	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED									BASE-PRICE		
FAIRMONT W114-B	16-9	6-8	9-7	10-8	16,600	65	65		2 Cycle Diesel			122 @ 2500	4												Set-Off 4 Wheel Parking Brake Farr Air Cleaner	Anti-Derail Wheels Tie-End Pusher
WOOLERY MODEL NU TIE CUTTER					608 (1)				4 Cycle	Wisconsin			1	Air											Tie Removing Bar Tie Plate Bar Ballast Removing Spoon	

(1) Grated weight less bars

TIE SAW OR SHEAR

	DIMENSION					CAPACITY			ENGINE																OPTIONS	COMMENTS
COMPANY/ MODEL	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	CLAMPING	MAX. SHIFT (IN)	PUSHING FORCE	TONG OPENING	PRODUCTION					BASE-PRICE		
NORDBERG TIE SPACER	9-5	10-0	7-2		5900					Wisconsin		55			18	Rail Clamp	19	31,400		8-10 Rail Lgth Per Hr							
RMC/PORTEC* TIE SPACER	12-0	7-9	7-9		5400				Diesel						25	Rail Clamp	19								28,950	Long Pusher Unit Max. 31"; Gas Engine Hyd. Centerlift & Turntable; Insulation Demountable Set-Off	Horn Roof
ATLANTIC POWER TIE SPACER	16'-7"	8-2¼	7'-5¼	9-8¼		50	60		Diesel	General Motors	353			Fluid	30	Magnet	24		Max. 15¼ Min. 6¼	700 to 800 (1)							

*Railway Maintenance Corporation (Portec, Inc. - RMC division)

(1) With two machines; ties/hour, every tie

TIE SPACER

COMPANY/ MODEL	DIMENSION LENGTH	WIDTH	HEIGHT	BASE	WEIGHT (LBS.)	CAPACITY FUEL	HYDRAULIC	OIL	ENGINE TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	PRESERVATIVE CAPACITY	HEATER TYPE	SPRAY PRES.	CONSUMPTION						BASE-PRICE	OPTIONS	COMMENTS
FAIRMONT W71-B	6-8	7-8	3-5		600							5.4 @ 2400	1			26 gal.	Exhaust	100 PSI	25 gal/mile (1)							Tank Maint.	Tank Maint.1/2 Full Temp & Pres. Gauge Fittings Provided.

(1) Preservative

TIE SPRAYER

COMPANY/ MODEL	DIMENSION: LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	CAPACITY: FUEL	HYDRAULIC	OIL	ENGINE: TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL SPEED (MPH)	PUMP GPM	PRES. (PSI)	INSERTION FORCE	TRENCH LENGTH (FT)	TRENCH DEPTH (IN)	TRENCH WIDTH (IN)	PRODUCTION		BASE-PRICE	OPTIONS	COMMENTS
FAIRMONT W87-E	12-7	10-0	10-2	4-4	10,000		40		Diesel	General Motors	3-53	65 @ 1800	3				2500		9-0 (2)							Portable Set-Off Cab Heater Emerg. Pump Cable Inserter
NORDBERG OMSI	15-8	14-0	11-4	6-0	30,100	36	100		Diesel	General Motors	5044 - 2401	87 @ 1800 (1)			25	44	2500	8000 lbs.max		9	14	200 Ties/ Hr.				Ties Inserted Square Auto Work Cycle

(1) BHP
(2) Extensions provide 15 1/2" and 29" additional length

TIE-BED SCARIFIER /INSERTER

	DIMENSION					CAPACITY			ENGINE																	OPTIONS	COMMENTS
COMPANY/ MODEL	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	PUMP PSI	RAM BORE								BASE-PRICE		
WOOLERY TIE-END REMOVER					360		1			Wisconsin		4-6		Air		1500	3"										

TIE-END REMOVER

COMPANY/ MODEL	DIMENSION LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	CAPACITY FUEL	HYDRAULIC	OIL	ENGINE TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	SPINDLE SPEED RPM	OPERATING SP'D.								BASE-PRICE	OPTIONS	COMMENTS
SAFETRAN MODEL VHW DUAL HYDRAULIC WRENCH	4-5	7-4	4-7		860		15		4 Cycle Gas			15 @ 3600	1			40 or 130	2000 RPM										Vertical Chucks not incl. Hyd. Raise and Lower Workhead.
MTM-STUMEC* TG 1									4 Cycle Gas	Bernard	W110	4		Air		(1)											
MTM-STUMEC* TB 2 TB 1	6-10	2-0	2-10		291				4 Cycle Gas	Bernard	W110	4 @ 2500		Air		50 or 170											TB2-2 Speed TB1-1 Speed Coach Screwing and fishbolt fastening
MTM-STUMEC* TEM L1	5-0	1-1	2-9		212				4 Cycle Gas	Bernard	W318	2 @ 8600		Air		50 RPM (2)											
MTM-STUMEC* TEM L2	5-2	1-3	2-9		128				4 Cycle Gas	Bernard	W117	3.3 @ 3600		Air		30 or 90 (2)											

*Modern Track Machinery, Inc., Geismar, Stumec
(1) Coachscrewing 170 RPM; gouging 660 RPM
(2) Engine speed at 3600 RPM

TRACK FASTENING WRENCH

	DIMENSION					CAPACITY			ENGINE									OPTIONS	COMMENTS
COMPANY/ MODEL	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	SOCKET SP'D RPM	BASE-PRICE		
MTM-STUMEC* TEM-1	5-3	1-2	2-9		123				Gas 4 Cycle	Bernard	W117	3.3 @ 3600		Air		80			
MTM-STUMEC* TG	6-4	2-2	3-5		139				Gas 4 Cycle	Bernard	W110	4 @ 2500		Air		170 (3)			Coachscrewing and Gouging
MTM-STUMEC* TS 2	6-10	2-0	3-0		120											170 (4)			Other data similar to Model TB 2, TB 1
MTM-STUMEC* TS 1	6-10	2-0	3-0		247														Same features as TB2

*Modern Track Machinery, Inc., Geismar, Stumec

(3) Gouging auger 630 RPM
(4) When engine runs at 2000 RPM

TRACK FASTENING WRENCH

	DIMENSION				CAPACITY				ENGINE																OPTIONS	COMMENTS
COMPANY/ MODEL	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	LINING FORCE	MAX. THROW	PRODUCTION	LIFT POWER	LIFT STROKE					BASE-PRICE		
FAIRMONT W111-B	10-3	6-0	10-0	6-0		15	43		Diesel 2 Cycle			65 @ 2000	3	Fluid	25	43,900										Emergency Hand Pump Cab Encl. Spud Attach. Spud Limiter Portable Set-Off	
REXNORD MODEL B	11-7	6-0	8-11	7-4	5000	9.1	16.5			Wisconsin		18			18	5,000	2.5										Set-Off Rails Oper. Switch Liners Insulated
RMC/PORTEC* LINE MASTER	11-0	6-0	7-8		6500				Gas					Water		45,000		1 Mile Plus Per Day								Hydraulic Center Lift & Turn Table Demount Set-Off Vibrator Attach. Diesel-Add'T.	Horn Insulated
MTM-STUMEC** RV 17	5 11	7-11	5-9		1675				Diesel			10			5		8"		17 Metric tons	23 5/8"							
MTM-STUMEC** RV 22	5-10	8-2	6-10		4050				Gas			10			6	10 Metric tons	6"		22 Metric tons	35 3/8"						11 H.P. Diesel engine	Can be coupled to work train

*Railway Maintenance Corporation (Portec, Inc. - RMC division)

**Modern Track Machinery, Inc., Geismar, Stumec

TRACK LINER

COMPANY/ MODEL	DIMENSION				CAPACITY				ENGINE																OPTIONS	COMMENTS
	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	FREQ.	WORK SPEED	HRS/TANK	FORCE						BASE-PRICE		
RACINE TRAK-VIBE	8-10	5-10	7-6	5-6	3800	16	25		4 Cycle-gas	Wisconsin	VH4D	24.7 @ 2000			20 (3)	800-900 (1)	0-200 (2)	8								Diesel-Perkins	Emergency hyd. hand pump
RAILWAY TRACK-WORK COMPANY RN RAIL VIBRATOR						25			Diesel	General Motors					20	3450 (1)			8000 lb								Turntable Roll-Off wheels

(1) Vibratory cycles per minute

(2) fpm

(3) On level track, 15 mph on 1% grade

TRACK VIBRATOR

	DIMENSION					CAPACITY			ENGINE																OPTIONS	COMMENTS
COMPANY/ MODEL	LENGTH	WIDTH	HEIGHT	BASE	WEIGHT	FUEL	HYDRAULIC	OIL	TYPE	MAKE	MODEL	H.P. @ RPM	NO. CYL.	COOLING	TRAVEL-SPEED	GOVERNED SP'D	DRIVE	HIGH SPEED	LOW SPEED					BASE-PRICE		
SAFETRAN MODEL C POWER TRACK WRENCH									4 Cycle			9 @ 3600	1			2900 RPM	Shaft	185 @ 112 (1)	800 @ 26 (1)						Vertical Chuck Traverse Carrier	Model C Carrier Balanced Weight
RMC/PORTEC* BOLT MASTER	16-6	8-0	8-8		12,300																				Auto. Oiler Cent. lift & Turntable Enclosed Cab Joint Straightener	4 or 6 hyd. wrenchs

*Railway Maintenance Corporation (Portec, Inc. - RMC division)

(1) Foot-pounds of torque @ RPM

TRACK WRENCH

APPENDIX F - DEFINITIONS FOR PROPOSED MANUFACTURERS' PUBLISHED DATA

These definitions are guidelines for equipment manufacturers in publishing standardized equipment specification data needed by a purchaser to make a preliminary selection. To constitute a sound basis for decision, it is imperative that data for all machines of the same type be generated in a manner which is constant in both substance and application. Data so derived enable the prospective purchaser to make a valid selection.

All values for published data should be in the following units where applicable:

ITEM	UNIT OF MEASUREMENT	
	English	Metric
Length, Width, Height	Feet - Inches	Meters
Capacity	U.S. Gallons	Liters
Weight	Pounds	Kilograms
Travel Speed	Miles per hour	Kilometers per hour
Vibration Frequency	Hertz	Hertz
Dynamic Force	Pounds-force/foot^2	Kilopascal (kPa)
Static Force	Pounds-force/foot^2	Kilopascal (kPa)
Amplitude	Inches	Millimeter

<u>Length</u>

- Travel Length - maximum distance from the most frontal point to the most rearward point when machine is in transporting mode.
- Work Length - maximum distance from the most frontal point to the most rearward point when all machine facilities are fully extended in the direction designated and at their maximum design extension.

<u>Width</u>

- Travel Width - maximum distance measured from the farthest point on the left to the farthest on the right when machine is in transporting mode.

- Work Width - maximum distance measured from farthest point on the left to farthest on the right when all machine facilities are fully extended in the direction designated and at maximum design extension.

Height

- Travel Height - distance between top of rail and highest point on machine when machine is in transporting mode.
- Work Height - distance between top of rail and highest point on machine when machine facilities are fully extended in the direction designated and at maximum design extension.

Base

- Distance between axle centers or truck center, whichever is applicable.

Clearance

- The distance from the center of track to the farthest point on the side opposite the point of activity, i.e., the immediate area being subjected to the design function of the machine (e.g., the tail-swing of a crane).

Weight

- The total weight of the basic machine as delivered to the purchaser, excluding optional extras and including:
  1. Full fuel tank,
  2. Oil, hydraulic oil, and cooling fluid required for operation,
  3. Supplied accessories, e.g., tools and tool boxes.

Number of Operators

- Total number of personnel necessary by classification to operate a machine through a complete working shift at its designated rate, excluding those personnel required only by railroad operating rules. Information should be expressed in man-loading by classification and percent of shift required.

Hourly Operating Cost

- Estimated hourly operating cost with the assumptions and the calculation technique stated. Hourly operating cost is to be a function of:
  1. Fuel consumption,
  2. Costs of lubricants and filters,
  3. Maintenance costs,
  4. Major repair costs.

Performance

- See criteria for Determination of Equipment Production Rates and Performance Levels (Appendix G).

Hours Per Full Tank

- Total hours machine can operate under typical conditions on a full tank of a fuel.

Noise Level - Inside

- Decibel reading taken according to SAE recommended practice J919b, "Operator Sound Level Measurement Procedure for Powered Mobile Construction Machinery - Singular Type Test."

Engine

- Type - includes the following:
  1. Number of cycles,
  2. Fuel type, e.g., gasoline, diesel, gas-oil mix.
- Make - manufacturer's name.
- Model - as designated by engine manufacturer.
- H.P. @ RPM
  1. Spark ignition (refer to SAE standard J245, "Engine Rating Code - Spark Ignition)
  2. Diesel (refer to SAE standard J270, "Engine Rating Code - Diesel")
  3. Small spark ignition (refer to SAE standard J607a, "Small Spark Ignition Engine Test Code").
- Number of cylinders - total number of combustion cylinders contributing to engine power.

- Cooling - method by which engine is maintained at designed operating temperature. State whether cooled by fluid or air.

Drive

- A - Method of power conversion from engine crankshaft to drive wheels in conjunction with numbers of driven wheels.
- B - Method of power conversion from engine crankshaft to machine's tool chuck.

Suspension System

- Machine's suspension system type (e.g., leaf spring, coil spring, rubber mount).

Transmission

- Type and number of speed selections forward and reverse.

Fuel

- Maximum holding volume of the engine fuel supply tank.

Hydraulic

- Maximum holding volume of the hydraulic oil reservoir tank.

Oil

- Engine manufacturer's recommended crankcase operating volume.

Traveling Speed

- Maximum safe velocity attainable by basic machine under its own power on tangent level track. Also state maximum safe-travel speed of the consist, if applicable.

Working Speed

- Rate or range of speed at which machine is able to operate when in working mode.

Working Curve

- Minimum degree of curvature at which machine can perform at its designed rate.

Travel Curve

- Minimum degree of curvature that can be safely negotiated during rail travel whether under self-propulsion or in consist. Also state corresponding speed restriction.

Buffing Force

- Designed maximum force in tons.

Change to Cleaning

- Amount of time necessary to switch from excavating to cleaning, stated in seconds.

Conveyor Direction

- All possible directions in which spoil disposal can be achieved: front, rear, adjacent track, across adjacent track. Include maximum distance to dumping center measured from center of track.

Swing Speed

- Cab rotational speed with engine at operating speed and no load on hoist line with boom center line at 45 degrees to the horizontal plane stated in revolutions per minute.

Grip Method

- Method by which machine is secured when adjusting ties.

Rail Weight Limit

- Any restrictions as to rail size whether minimum or maximum.

Boom Length

- Distance measured from cab pivot point to extreme end of boom.

Hydraulic Power

- Hydraulic power determined by SAE recommended practices J745C, "Hydraulic Power Pump Test Procedure", and J7456, "Hydraulic Motor Test Procedure" (if machine has a hydraulic motor).

Minimum Cutting Depth

- Minimum possible depth measured from bottom of ties to excavation surface without lifting track.

Maximum Cutting Depth

- Maximum depth of cut measured from the top of rail to excavation surface.

Maximum Reach

- A - The distance extending from the track center to the most extreme point at which the cutting operation can be performed, measured in the horizontal plane of the track.
- B - The relation of boom length and boom angle to capacity shown on a capacity graph with notes stating restrictions.
- C - The distance extending from the track center to the maximum distance at which a tie can be grasped. State angle of line from horizontal plane in which measurement is taken.

Maximum Spoil Size

- Type and size of material which may not pass through machine. Include any material which, when passed through, would require the machine to cease operations from any time period.

Cribbing Depth

- Maximum depth to which the cribbing tools can penetrate the ballast, measured from top of the rail.

Broom Diameter

- Diameter of broom with new hoses or bristles.

Broom Velocity

- Designed operating rpm of broom.

Vibration Frequency

- The work head frequency (hertz) at its designed continuous work rate.

Amplitude

- The extent of vibratory movement of the work heads.

Blade Energy

- Available power at the cutting edge. State method used for determination.

Cribbing Force

- Maximum possible lateral forces exerted by the cribbing tools on the ballast.

Carrying Capacity

- The total amount of materials which the machine is designed to carry, stated in the appropriate units.
  1. Spikes - kegs,
  2. Plugs - bundles,
  3. Anchors - number,
  4. Ballast - cubic yards (yd^3),
  5. Heater fuel - gallons,
  6. Creosote - gallons.

Nipper Force

- Approximate available force to apply anchors. The available force is the product of hydraulic pressure, area of the hydraulic cylinder, and the mechanical leverage. The resultant is to be expressed in pounds and kilograms.

Boxing Pressure

- Approximate available force to be applied to the anchors for boxing. Its maximum value is the product of hydraulic pressure, area of the hydraulic cylinder, and the mechanical leverage. The resultant is to be expressed in pounds and kilograms.

Extraction Force

- Maximum possible force exerted upon the removed component in the longitudinal direction during removal.

Insertion Force

- Maximum force exerted upon the installed component in the longitudinal direction during insertion.

Hydraulic Pump Capacity

- SAE theoretical delivery derived in accordance with SAE recommended practice J745C, "Hydraulic Power Pump Test Procedure".

Tractive Effort

- The starting tractive effort computed with the following assumptions:
  1. Tangent, level track,
  2. Dry rail,
  3. No sand.

Hoist Line Speed

- Speed determined according to SAE recommended practice J820, "Crane Hoist Line Speed and Power Test Code."

Hoist Line Power

- Power determined according to SAE recommended practice J820, "Crane Hoist Line Speed and Power Test Code."

Lift Capacity

- A - Refer to "Maximum Reach" category, definition B.
- B - State the designed lifting power in terms of horse-power.

Dynamic Force

- Crib Dynamic Force - the vibratory force applied by the crib compactor heads to the ballast cribs.
- Shoulder Dynamic Force - the vibratory force applied by the shoulder compactor to the ballast shoulder.

Static Force

- Crib Static Force - the force applied by the crib compactor heads to the ballast cribs.
- Shoulder Static Force - the force applied by the shoulder compactor to the ballast shoulder due to its weight and applied pressure.

Optional Extras

- Those items or components which are standard accessories but result in additional cost, beyond the base price, to the purchaser.

Three-Dimensional Machine Sketch

- View of machine front, side, and rear with overall dimensions and other pertinent dimensions or information.

Turntable

- Any mechanism which allows the machine's direction of forward travel to be reversed by one man. State whether or not a turntable is available as an option or standard equipment.

Insulated

- A machine which does not affect the signal system. State whether or not insulation is available as an option or standard equipment.

Set-Off

- Any mechanism which enables the machine to be removed from the track by the operator. State whether or not a set-off is available as an option or as standard equipment.

Material Tolerance

- Dimensional tolerances of the materials which pass through the machine's application system.

Lift Envelope

- A diagram which shows the relationship between boom angle, boom extension, and lift capacity.

Maximum Toe Line

- The distance from centerline of track to the maximum reach of the ballast boxes.

Feed

- The method by which the work head is advanced.

Gear Reduction

- The ratio of crankshaft gear size to spindle-shaft gear size.

Fuel Type

- Combustible material used to create the heat for rail heating.

Blow Force

- The force applied to the spike for driving.

Blow Per Minute

- The number of strikes against the spike head with engine at normal operating rpm and compressor at typical operating pressure.

Lift Weight

- The weight that the machine operator is physically required to lift during normal operation cycles.

Number of Tools

- The number of tines inserted in the ballast during normal operation.

Maximum Shift

- The maximum distance that the ties can be adjusted in inches.

Spindle Speed

- The rotational velocity of work head in rpm's.

Number of Stones

- The maximum number of grinding stones which can be used at any given time on a machine to accomplish a rail reprofiling task.

Pull Range

- The distance that the rail end may be moved longitudinally by machine.

Pull Force

- The designated available pulling force that can be applied to the rail.

APPENDIX G - DETERMINATION OF EQUIPMENT PRODUCTION RATES AND PERFORMANCE LEVELS

The following criteria are to be applied in the determination of machine production rates and performance levels. This information is to be incorporated into the published literature where relevant for each individual machine. For the purpose of establishing a uniform basis for all data, machine performance is to be determined under the conditions of a reference MOW track.

Reference MOW track is defined by the criteria below. Adherence is required in determining the performance of those machines bearing the reference MOW track, except as noted.

- Tangent
- Level
- Single Track Territory
- Class 3 by FRA Standards
- Tie spacing: 19 1/2-inch
- Level shoulder at subgrade elevator
- CWR, 132-RE
- Alternate ties, box-anchored
- AREA size 4 granite ballast
- Spikes, 6 in., four per tie
- Ballast: min. 6 in. below ties
- Ballast shoulder: 12 in., 2:1 slope
- Subballast: min. 8 in., 1/4 in. per foot slope
- Double-shoulder tie plates, 14 in., 1:40 cant, AREA standard
- Ties: 9"x7"x8'-6"
- Tie condition: in accordance with FRA track safety standard 213.109 Section a and b
- Traffic: 20 MGT

The MOW machines have been categorized into three groups:

- Group I - Production rate and performance level not required.
- Group II - Production rate and performance level to be determined analytically.
- Group III - Production rate and performance level to be determined by field performance.

GROUP I

The setting of performance criteria or production rates is impractical and/or unjustified for the machines in Group I, because of one or more of the following factors:

- Large variation in operation
- Low cost
- Limited number of manufacturers
- Insignificant relationship to overall maintenance project production.

The following machines are included in this group:

- Ballast Regulator
- Brush Cutter
- Cleaner, track/yard
- Cranes, on-track only
- Rail Slotter
- Gauging Machine
- Motor Car, small
- Motor Car, large
- Rail Grinder
- Rail Joint Straightener
- Rail Lifter
- Rail Puller
- Rail Threader
- Tie Boring Machine
- Tie Handler
- Tie Plug Setter/Driver
- Tie Sprayer
- Track Fastening Wrench
- Track Liner
- Track Wrench
- Track Vibrator

Group II

The machine types in this group are those for which the operator or the environment is a major factor in the determination of production rate. Additionally, included in this group are machines for which it would be uneconomical to determine production rate through a practical test.

Although the theoretical production rate will probably not be attained under actual operating conditions, it is a valid means of comparison, if all these production rates are determined by the same method.

The production rates for the following machines are to be determined analytically under the conditions and assumptions described.

Ballast Compactor

Assume operation on the reference MOW track and calculate cycle time of the work head with a three-second compaction time. Production rate is to be expressed in feet/hour.

Ballast Shoulder Cleaner

Capacity is dependent on two interrelated limiting factors. Performance should therefore be stated in terms of each of the two factors:

- The maximum capacity of the ballast elevating device.
- The maximum cleaning capacity of the screen with dry approximately 20% fouled AREA No. 4 ballast.

Production rates are to be expressed in cubic yards/hour.

Ballast Undercutter

Maximum capacity based on the maximum cutting speed of the chain with ballast of negligible resistance. This measurement should be independent of the elevating mechanism. Production rate is to be expressed in cubic yards/hour.

Ballast Undercutter/Cleaner

Capacity is dependent on three interrelated limiting factors. Performance should therefore be stated in terms of each of the three factors:

- Maximum capacity based on the maximum cutting speed of the chain with ballast of negligible resistance.
- Maximum capacity of the ballast elevating device.
- Maximum cleaning capacity of the screen with dry approximately 20% fouled AREA No. 4 ballast.

Production rate is to be expressed in cubic yards/hour.

Crib Ballast Remover

Assume operation on the reference MOW track and calculate the cycle time of the work head with non-frozen ballast and cribbing to bottom of tie depth. Production rate is to be expressed in feet/hour.

Rail Anchor Adjuster

Assume operation on the reference MOW track and calculate cycle time for adjusting all anchors. Production rate is to be expressed in feet/hour.

Rail Heater

Calculate the designed maximum available heat which can be supplied for rail heating. Production rate is to be expressed in btu's/hour.

Tampers (all)

Assume operation on the reference MOW track and calculate the cycle time of the work head, tamping every tie with three insertions. Production rate is to be expressed in feet tamped/hour.

Tie-End Remover

Calculate the cycle time to remove one pair of tie ends from the reference MOW track. Production rate is to be expressed in seconds/tie.

Tie Spacer

Calculate the cycle time to adjust every third tie six inches on the reference MOW track without crib ballast or rail anchors. Production is to be expressed in feet/hour.

GROUP III

Production rates are to be determined by observation of each of the following machines under the conditions prescribed. Machines are to be as described in the manufacturers' published data. All machines in this group are to be evaluated on the reference MOW track. Any criteria which do not affect the operation of the machine may be disregarded. To expedite publication of data, production rates can be initially determined analytically; although ultimately it is anticipated that all machines should be field tested.

Rail Anchor Applicator, Manual Set

Machine is to be operated through its cycle for a distance of one-quarter mile on the reference MOW track, box anchoring every other tie. Production rate is to be expressed in feet anchored/hour.

Rail Anchor Applicator, Semi-Automatic

Machine is to be operated through its cycle for a distance of one-quarter mile on the reference MOW track, box anchoring every other tie. Production rate is to be expressed in feet anchored/hour.

Rail Drill

This performance evaluation requires the drilling of the six holes of the joint of two 132-lb. rails. The procedure is to be performed on the reference MOW track and timed. Timing will commence with the drilling of the first hole and will end with the completion of the sixth hole. Production rate is to be expressed in minutes/joint.

Rail Saw or Abrasive Cutter

Machine is to be secured to 132-lb. rail as designed. Commence timing of cutting operation from start of cut through completion. Production rate is to be expressed in minutes/cut.

Spike Drive, Automatic

Operate machine through its designed cycle for a distance of one-quarter mile under the following conditions:

- Reference MOW track
- New 6-inch spikes
- Non-bored ties
- Hopper loaded

Production is to be expressed in feet/hour with the number of operators stated.

Spike Driver Pneumatic

Operate machine through its designed cycle for a distance of one- quarter mile under the following conditions:

- Reference MOW track
- New 6-inch spikes
- Non-bored ties
- Spikes pre-set at 1/2" maximum depth

Production rate is to be expressed in feet/hour with the number of operators stated.

Spike Puller

Operate machine through its designed cycle for a distance of one-quarter mile on the reference MOW track, pulling spikes from one rail only. Production rate is to be expressed in feet/hour.

Tie Adzer

Operate machine, on rail set as necessary, for a distance of one-quarter mile on the reference MOW track. Set machine to adze a one-half-inch deep cut in all ties for a 14-inch tie plate. Production rate is to be expressed in feet/hour.

Tie Bed Scarifier/Inserter

Operate machine over the reference MOW track with a tie replacement rate of 800 ties/mile. Cycle machine as designed for scarifying and insertion. Production rate is to be expressed in ties/hour.

Tie Cribber

Operate machine over the reference MOW track with rail set as necessary. Crib for 132-lb. rail anchors. Production rate is to be expressed in feet/hour.

Tie Destroyer

Operate machine to destroy defective ties, all of which are in one- third sections. The term defective is defined in Section 213.109b of FRA track standards. Removal rate is approximately 800 ties/mile. Production rate is to be expressed in ties/hour.

Tie Injector/Inserter

Operate machine over reference MOW track with a tie replacement rate of approximately 800 ties/mile with replacement ties having been placed on track where necessary. Production rate is to be expressed in ties/hour.

Tie Remover

Operate machine over the reference MOW track with a tie replacement rate of 800 ties/mile, with ties to be removed having been premarked. Production rate is to be expressed in ties/hour.

Tie Saw or Shear

Operate machine over the reference MOW track with a tie replacement rate of 800 ties/mile. Cycle machine as designed for tie sawing or shearing. Production rate is to be expressed in ties/hour.

AREA COMMITTEE NO. 22

J. A. Naylor - (CH) CN
R. W. Bailey - C&NW
C. D. Barton - MP
G. R. Beetle
H. B. Berkshire - SP
A. Bornhoft - BN
J. W. Brent - CHESSIE
R. G. Brohaugh - BN
A. W. Carlson - WP
J. A. Caywood - DCO
W. H. Clark - AT&SF
J. R. Clark - CONRAIL
P. A. Cosgrove - IGC
H. R. Davis - FRA
M. H. Dick
H. B. Durant - UP
P. Patula - CONRAIL
J. Fox - CP
W. Glavin - GTW
C. R. Harrell - SCL
W. A. Hoar
B. G. Hudson
J. C. Hunsberger
J. T. Hunter
C. Johnson
R. D. Johnson - AMTRAK
G. Liljeblad - DM&I
M. J. Marlow - EJ&E
T. D. Mason - AT&SF
A. L. Maynard - CHESSIE
R. T. Meyer - DM&I
E. T. Myers
J. R. Miller - IGC
G. A. Nelson
K. A. Olson
M. E. Paisley - CV
R. W. Pember
G. G. Phillips - IGC
J. A. Randles - N&W
F. L. Rees - AT&SF
M. S. Reid - C&NW
C. L. Robinson - CHESSIE
M. Rougas - B&LE
G. E. Scholz - BN
A. E. Shaw, Jr. - AMTRAK
R. W. Simmons
E. H. Stang
E. H. Steel - AMTRAK
N. E. Smith - CMSP&P
W. B. Stackhouse - SCL
J. T. Sullivan - CONRAIL
J. E. Sunderland
W. A. Swartz - CONRAIL
S. W. Sweet - UR
H. J. Umberger - PB&NE
J. D. Vaughn, Jr. - L&N
G. E. Warfel - SL&SF
J. T. Ward - SCL
H. G. Webb - AT&SF
G. H. Winter - LI
T. P. Woll - FRA
B. J. Worley - CMSP&P

MEMBERS RETIRED

A. S. Barr
S. A. Cooper
L. C. Gilbert
W. J. Jones
H. W. Kellogg
W. E. Laird
L. A. Loggins
J. M. Lowry
G. M. O'Rourke
H. W. Seeley
F. R. Woolford
H. C. Minteer

APPENDIX H - INDUSTRY COMMITTEES

AREA COMMITTEE NO. 27

D.E. Crawford	- (CH) Chessie
Dave Schultz	- CN
S. Slobidsky	-C&NW
F.H. Smith	- S&FE
B.F. Riegel	-EJ&E
J.P. Zollman	-ICG
V.R. Erquiaga	-SP
R.L. Matthews	-P&LE
R.P. Drew	-Milw.
M.L. Stone	-AMTRAK
P.V.Divine	-MOP
W.J. Gottsabend	-CONRAIL
R.L. Bolginoni	-C&NW
L.J. Calloway	-L&N
J.C. Crook	-S&FE
E.T. Daley	-CONRAIL
J.M. Dreihuis	-ONT N
H.F. Dully	-SP
E.J. Fisher	-CN
E.E. Fliess	-CHESSIE
W.D. Gilbert	-CHESSIE
C.T. Harmon	-SOU
W.H. Holt	-WP
S.R. Horn	-GTW
C.Q. Jeffords	-SCL
D.C. Johnson	-S&FE
R.M. Johnson	-AMTRAK
C.F. King	-CP
H.F Longhelt	-AMTRAK
W.A. MacDonald	-AMTRAK
R.E. Murdock	-B&LE
T.J. O'Donnell	-WMATA
C.H. Olds	-CONRAIL
C.A. Peebles	- SL-SF
J.A. Pollard, Jr.	-SCL
R.S. Radspinner	-CHESSIE
D.F. Richardson	-SL-SF
T.R. Rigsby	-ICG
R.T. Ruckman	-D&RGW
W.C. Scott	-Union
J.R. Smith,Jr.	-WP
C.R. Turner	-D&RGW
J.W. Winger	-CHESSIE

MEMBERS EMERITUS

N.W. Hutchison
M.E. Kerns
W.F. Kropp
J.W. Risk
S.E. Tracey

MEMBERS RETIRED

R.E. Dove

NEW MEMBERS

M.W. Adams	-SP
E.W. Buckles	-SP

APPENDIX H (CONT'D)

REMSA COMMITTEE ON TRACK MACHINERY

Chairman

R. C. Crosby, General Manager
Railway Products/Marmon Transmotive

C. L. Coy, General Sales Manager
Canron Railgroup

J. W. Neuhofer, Vice President - Sales
Plasser American Corporation

J. Knox Kershaw II, Executive Vice President
Kershaw Manufacturing Company, Inc.

O. F. Buscho, Domestic Sales Manager
Fairmont Railway Motors, Inc.

J. H. Bush, Vice President
Jackson Vibrators, Inc.

John R. Rushmer, Manager Customer Service
REXNORD, Inc., Nordberg Machinery

G. W. Christiansen, JR., Executive Vice President
Racine Railroad Products, Inc.

G. W. Barrett, President
Railway Track-Work Company

E. J. Powell, General Manager - Sales
Portec, Inc., RMC Division

J. E. Gavin, Vice President - Marketing
Loram Maintenance of Way, Inc.

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FIGURE I-1 - MAINTAINABILITY TABULATION FORM

MAKE: Manufacturer X

MODEL: A

TYPE: Track Machine

ITEMS	SERVICE REQUIRED	LOCATION	ACCESS	OPERATION	MISCELLANEOUS	SUB-TOTAL	FREQUENCY-MULTIPLER	TOTAL	COMMENTS
		CONSIDERATIONS							
Engine Oil	Check	1	4	3		8	100	800	
	Fill	8	4	1		13	2	26	
	Drain	2	1	8	4	15	10	150	
	Filter	10	1	4		15	10	150	
Derail Collar	Grease	10	1	1		12	20	240	6 Nipples
Derail Collar	Grease	10	1	1		12	20	240	6 Nipples
Hydraulic Oil	Check	1	1	1		3	100	300	
	Fill	1	15	15		31	2	62	
	Drain	10	1	6		17	1	17	
Drive Chain	Check	10	1	1		12	20	240	Tension #1
Drive Chain	Check	2	1	1		4	20	80	Tension #2
								2305	MI
MAINTENANCE MANUAL									
Type					.014				
Schedule					.02				
Directive					0				
					.034	(2305)	=	78	
TOTAL MAINTAINABILITY INDEX								2383	

FIGURE I-2 - OPERABILITY TABULATION FORM

I. INITIATION

COMMENT	CHECK FLUIDS: LOCATION	CHECK FLUIDS: METHOD	CHECK FLUIDS: ACCESS	START: PRESTART	START: METHOD	START: TYPE	COMPONENT OPERATION: LOCATION	SUBTOTAL
Fuel	1	1	1					3
Water	8	1	3					12
Hydraulic	1	1	1					3
Oil	10	3	4					17
key					1			1
Derail-rear						1	3	4
Derail-front						1	3	4
							TOTAL	44

II. INDICATORS

COMMENT	TYPE (1)	FREQUENCY (4)	(1) x (4)	LOCATION (2)	NUMBER (3)		SUBTOTAL (1)x(4)+(2)+(3)
4 - 1½" Cal	6	4	24	15	2		41
1 - 3" Cal	3	1	3	15	1		19
1 - ½" Cal	6	2	12	15	1		28
1½" Hyd.	6	2	12	15	1		28
Air Filter	3	1	3	15	1		19
						TOTAL	135

III. CONTROLS

COMMENT	METHOD (1)	TYPE (2)	PHYSICAL REQ'M (3)	SENSITIVITY (4)	LOGIC (5)	LOCATION (6)	(1)[(2)+(3)+(4)+(5)+(6)]	LABELING	COMBINATION	SUBTOTAL
Control A	7	1	0	0	0	0	7	7		14
Control B		2	0	0	0	0	14	7		21
Control C		1	0	0	0	0	7	7		14
Control D		1	0	0	0	0	7	7		14
Control E		1	0	0	0	0	7	7		14
Control E		1	0	0	0	0	7	7		14
Control D		1	0	0	0	0	7	7		14
Control C		1	0	0	0	0	7	7		14
									TOTAL	119

MAKE: Manufacturer X

MODEL: A

Track Machine — TYPE

FIGURE I-2 -(con't)

IV. STABILITY

COMMENT	DIRECTION OF OP.	DAMAGE POT.	SAFETY ENVIR.	UPSET POT.	TOTAL
	0	5	0	0	5

V. ENVIRONMENT

COMMENT	COMFORT	NOISE	EXPOSURE	VISIBILITY (WORK)	VISIBILITY (ENVIR)	MOTION	VIBRATION	SUBTOTAL
	3	8		6	3	7	15	42
Cover only			7					7

TOTAL 49

VI. TERMINATION

COMMENT	NO. OF OPERATIONS	TYPE	LOCATION -TYPE	SAFETY DEVICES	LOCATION-SAFETY	SUBTOTAL
Control 1	4	0	3			7
Control 2		0	3			3
Control 3		0	0			0
Valve A		3	10			13
Pin A				1	3	4
Pin B				1	3	4

TOTAL 31

I	II	III	IV	V	VI	OPERABILITY INDEX
44	135	119	5	49	31	(383)

FIGURE I-3 - REPAIRABILITY TABULATION FORM

MAKE: Manufacturer X

MODEL: A

TYPE: Track Machine

OPERATION(S)	SPECIAL TOOLS & EQUIPMENT	LOCATION	ACCESS	MISCELLANEOUS	TOTAL	COMMENT
Change Hydraulic Hose						Front to Rear
Remove Plate #1	2	11	1	6	20	
Remove Plate #2	2	11	1	6	20	
Remove Hose	2	11	1		14	Left
Remove Hose	2	11	1		14	Right
Replace Hose	2	11	1		14	Left
Replace Hose	2	11	1		14	Right
Replace Plate #1	2	11	1	6+9	29	Multiple manpower + hoist
Replace Plate #2	2	11	1	6+9	29	

REPAIRABILITY INDEX 154

FIGURE I-4 - RELIABILITY TABULATION FORM

MAKE: Manufacturer X

TYPE: Track Machine

MODEL: A

COMPONENT DESCRIPTION	CONSIDERATIONS: POPULATION p	INDEX RI_i	STRESS LEVEL S_i	TOTAL pRI_iS_i	COMMENT
DRIVE TRAIN					
Gear Box	3	11.7		35.1	
Friction Clutch	1	250		250	
Gears	4	0.1		0.4	
Drive Chain	2	50		100	
Roller Bearings	8	0.6		4.8	
Drive Rod	2	20		40	
					Subsystem total = 430.3
WORK HEADS					
Hydraulic Cylinders	10	53.3		533	
Hydraulic Hoses 1 1/2"	8	2.5	$\frac{2750}{5000}$	11	
1 1/4"	2	2.5	$\frac{2750}{5000}$	1.1	
1"	23	2.5	$\frac{2750}{5000}$	45.2	
Fittings, Hose	66	4		264	
Fittings, All Others	102	1		102	
Bushings	16	14		224	
Arm	10	20		200	
Coupling	4	10		40	
					Subsystem total = 1182.3
CONTROLS					
Valve, Servo (Hydraulic)	4	25		100	
Pressure Regulator (Hydraulic)	1	8.4		8.4	
Valve, Sequence (Hydraulic)	3	17		51	
Hydraulic Hose	10	2.5	$\frac{2750}{3500}$	20	
Fittings, Hose	20	4		80	
Fittings, All Others	10	1		10	
					Subsystem total = 269.4
RELIABILITY INDEX				1882.0	

APPENDIX J - A STUDY OF METHODOLOGIES FOR DETERMINING THE RELIABILITY OF MAINTENANCE-OF-WAY EQUIPMENT

Reliability is one of the most important factors to be considered in the overall evaluation of maintenance-of-way equipment. Regardless of the production rate or quality of work produced by a machine, if it is not reliable enough to perform its intended function, the effectiveness of the entire track maintenance operation is greatly compromised.

Reliability is defined as the probability that the system will operate at an agreed level of performance for a specified period, subject to specified environmental conditions. The designer and manufacturer of maintenance-of-way equipment has the initial control over the reliability of his machine and must consider each individual component used in the design and its inherent failure rate. Factors which have an impact on the failure rate of the equipment are his degree of attention to detail in each phase of design, procurement and screening of materials, properly controlled manufacturing processes, and control systems for effective corrective action. Once the equipment is in the hands of the user, there are two key elements that also affect reliability: first, the required maintenance and how conscientiously it is performed and second, the use environment. Both of these elements must have been considered by the designers; the users' adherence to maintenance recommendations, however, must be total to assure the desired reliability. The use environment is also a key factor in the design process. Severe roadbed conditions which fall outside the nominal design limits and abuse caused by poorly trained operators greatly reduce reliability.

It can be seen, therefore, that for a machine of given complexity, there are many different levels of effort that can be applied, each one yielding a vastly different level of reliability. To summarize, the achieved reliability is directly dependent upon the emphasis placed on reliability by customer and manufacturer management throughout the life cycle of the equipment.

Approach

Two basic approaches were considered to determine the reliability of a machine: a practical demonstration test and a theoretical study. The demonstration test consists of a closely monitored series of tests within a tightly controlled environment, performed by a specific sample size of the machine for a given number of operational hours. All malfunctions are recorded during the test conduct, and a judgment is made concerning the chargeability of each failure relative to predetermined failure definitions. Depending on the type of test performed, the duration can be either fixed or continue until a specific limiting number of failures occurs.

At this point the failure rate is calculated by dividing the total chargeable failures by the total operating time. This value is a point estimate of the true failure rate of the machine. A method, such as finding the true failure rate at specific confidence limits by using the chi-square or Weibull distributions, can be applied.

The theoretical approach has several options. To some extent the principal determinant of reliability is the inherent complexity of the machine, since the more complex the design, the greater is the probability that a failure will occur. Each functional component of a machine could be tabulated with the lower number being the most reliable. A predictive analysis could take this method one step further by assigning a failure rate to each part and tabulating the total failure rate. This method ranks each component relative to a failure rate data base and allows an assessment of the reliability relative to this data base.

Another theoretical method would be a thorough design review which analyzes each facet of the design including applied stresses, part usage, design approach, design and component maturity, accessibility of frequent maintenance items, degree of modularity, and manufacturing techniques and quality. This entails a detailed analysis by engineers with expertise in the disciplines related to the design. Each component is evaluated for several factors with applied and peak stress levels the major concerns.

This technique takes advantage of the fact that reliability is generally improved when a part is used properly and is operated with less stress, e.g., a hydraulic hose rated at 5,000 psi has a higher probability of failure when operated at 4,500 psi than at 2,500 psi. This approach also allows evaluation of the design technique utilized, electrical vs. hydraulic vs. pneumatic vs. a combination technique.

Intrinsic availability is an even more useful measure of a system's true usefulness in operating. It is defined as the probability that the machine operates satisfactorily at any moment when used under stated conditions, where the time considered is operating time and active repair time. Intrinsic availability refers to the built-in capability of a machine to operate satisfactorily under stated conditions. This type of analysis requires knowledge of the reliability and maintainability of the equipment. Although intrinsic availability is influenced to some degree by maintenance personnel expertise and the test equipment and documentation at their disposal, it can be a satisfactory measure of the merit of the physical system.

A more comprehensive theoretical technique involves an analysis of system effectiveness. System effectiveness is the probability that a machine can successfully meet an operational demand within a given time when operated under specific conditions. Effectiveness is obviously influenced by the way the equipment is designed and built, as well as the ways in which it is used and maintained. Specifically, system effectiveness is influenced by the design engineer, the production engineer, the operator, and the maintenance man. It is also influenced by the logistic system supporting the operation, and by the administration through personnel policy, rules governing equipment use, fiscal control, and other administrative policy decisions. System effectiveness includes operational reliability, availability, administrative and logistic times related to maintenance and spare parts acquisition, maintainability, time available for maintenance when the equipment is not needed for work, and design adequacy which involves the amount of time that the equipment is operated outside of its design limits.

Evaluation of Alternatives

The alternatives available for evaluating the reliability of MOW equipment were compiled and were discussed previously.

Discussions were held with two individuals with considerable experience in reliability and associated systems assurance disciples. Mr. John Rawasia, Director of Product Assurance for Norlin Communications, and Mr. Brian Moriarty, Senior Systems Assurance Engineer, De Leuw, Cather/Parsons & Associates, were contacted and asked to comment on the various alternatives as well as suggest other methodologies. Mr. Rawasia and Mr. Moriarty indicated that a demonstration test would produce the best results. In addition, Dr. Leonard Lamberson, Associate Professor of Industrial Engineering at Wayne State University, was contacted. Dr. Lamberson has done considerable work on automobile, heavy truck, and military vehicle reliability. He suggested a thorough design review by a team of multi-disciplined engineers as the best method of obtaining an assessment of MOW reliability. Failure mode analysis, detailed circuit analysis, and stress-strength analysis would be performed for each machine. The merits and shortcomings of each would be tabulated for use during the selection process.

Both the testing and design review methods have serious drawbacks, however, as indicated in the following discussion on the advantages and disadvantages of each technique for determing reliability of MOW equipment.

Testing

As mentioned earlier, testing is the most effective technique available to evaluate the reliability of MOW equipment. If the equipment tested can be said to be reasonably representative of the total population of equipment, the test results will indicate a point estimate of the reliability of the total population. However, some MOW equipment is manufactured by the batch method which tends to degrade the probability of a test sample from one batch representing the reliability of the total population. A test of MOW equipment has many drawbacks that appear to remove it from contention as a viable evaluation technique. A large sampling from each manufacturer (between two and eight for large expensive machines), difficulty in establishing uniform track and roadbed conditions for each test, variations in operator skills, time involved to conduct the tests, and the exorbitant cost all make it a less attractive alternative. Laboratory tests of critical work heads could be done, but again the same constraints apply. For smaller machines that do not consume excessive amounts of materials, a test may be feasible.

Inherent Complexity

This method would rate the simplest machine as the most reliable. This concept can be misleading, however, because current trends are toward more complex automated machines that reduce operator activity. As the operator has been indicated as a factor contributing to machine unreliability, the more complex system may reduce some of these overstresses and improve reliability. To make this happen, the manufacturer must include maintenance aids to improve the repairability of the machine when it fails, and take more precautions during design and production to reduce failures. Another disadvantage of this method is that each different component within the machine has a different failure rate which can vary as much as four orders of magnitude. Not taking this into consideration could skew the evaluation of a machine.

Predictive Analysis

A prediction of reliability can be accomplished by applying a failure rate to each component of the machine. This process requires a valid data base of failure rates that are applicable not only generically, but that are pertinent to the particular equipment type and its typical use environment. This data base is lacking for MOW equipment and for mechanical components in general. In the Mechanical Reliability Design Evaluation Guide Status Report, (December, 1976), F.M. Hall, et. al., state that, "Meaningful failure rates for mechanical components will not be available unless components are more standardized, failure modes and failure causes more thoroughly defined, and a data base established. There is little doubt about the feasibility of accurately evaluating reliability of nonelectronic systems, but a valid data base does not yet exist."

Data compiled by individual railroads is not readily usable, because the available data is taken in varying environments, the operators and their skill levels are not consistent, the level of maintenance varies, and the measurement techniques for failures, particularly how each railroad defines a failure, are never the same. The use of a marginal data base will result in a considerable uncertainty in the final failure rate. The error or uncertainty of each component failure rate is accumulated for the entire system by the relationship, plus or minus the squareroot of "n" times the percentage of error, where "n" is the number of components. To illustrate this impact, if 25 parts were selected as a sample for MOW reliability evaluation and if there were a mere 5% uncertainty in the data base, the final result would have an uncertainty of plus or minus 25%. If 100 parts were evaluated, the result is plus or minus 50% system uncertainty.

Design Review

This method requires a detailed analysis by a team of multi-disciplined engineers. Each component is evaluated for usage, stress, quality, and maturity. The overall design approach, accessibility of frequent maintenance items, modularity, and assembly quality and techniques are also verified. Done properly, the results of this review will provide an excellent qualitative and quantitative assessment of each machine. This technique might require electrical, mechanical, and industrial engineers with expertise in control systems, hydraulics pneumatics, electronics, and diesel engines. The large railroads may have the engineering department and budget to support this type of review; however, the smaller railroads probably do not. For this reason a design review does not appear feasible.

Intrinsic Availability

Reliability is not the only factor of importance to the user of MOW equipment. A prime concern is having the equipment available to perform when needed. Intrinsic Availability considers how often a machine fails together with the amount of active repair time required to correct the problem. To implement this type of analysis, information pertinent to failure rate and mean active repair time must be available. The active repair data for MOW equipment has the same problems as failure data, in that each railroad compiles and defines differently the various aspects of maintenance. There is, however, a technique to develop indexes for what the Society of Automotive Engineers Handbook refers to as maintainability and repairability. The maintainability and repairability indexes relate the difficulty of performing preventive and corrective maintenance, respectively. These indexes cover such areas as maintainer location, access, operations to be performed, and frequency of the operation. This method may prove to be an adequate evaluation tool for the maintainability portion of availability. It is recommended that this factor be added to the list of areas to be evaluated and that the methods outlined in SAE J817a be followed.

System Effectiveness

A system effectiveness analysis takes availability one step further. This technique would allow each railroad to consider several of its own parameters that influence MOW effectiveness. System effectiveness is the product of operational reliability, the probability that the system will continue to operate satisfactorily for the period of time required; operational readiness, the probability that the system is operating satisfactorily or is ready to be placed in operation; and design adequacy, which is the probability that the system will successfully accomplish its task if it is operated within design limits. To calculate these probabilities, information must be known about the failure rate of the machine, the amount of time the machine is operated outside its design limits, the amount of storage versus operational time for the machine, and the availability which is composed of total operating time and the total down time. If all these data were available, a reasonably high level of confidence could be attached to this index. However, as stated earlier, a valid data base for failure rates and down time is not available. This and the fact that the mathematical process is somewhat tedious appear to overcome the advantages of this type of analysis.

Conclusions

In investigating the merits and disadvantage of the various techniques for evaluating MOW equipment reliability, two methods indicate superiority in producing the most valid results; however, these methods also have severely limiting features.

Testing of MOW equipment to evaluate reliability should provide a reasonable point estimate of actual machine reliability. The equipment manufacturers that have been interviewed indicate that they prefer this method. They currently demonstrate their equipment for prospective customers, which explains their willingness to submit to a test.

However, the constraints of a reliability demonstration test would require a testing environment which is quite different from the conditions under which demonstration tests are currently performed. A disadvantage of the testing method is the number of machines required from each different manufacturer. While this number would depend on the type and complexity of the machine, for larger machines the number would range from two to eight. This sample size is required to assure that the sample represents the total population and to produce test results with a reasonable confidence level.

Another key disadvantage of testing is the necessity to standardize the work environment. To conduct a true comparative test, this environment must be constant for each machine and manufacturer. Any attempt to create the required standard conditions will most probably prove to be very costly or impractical to implement. Testing of critical assemblies such as work heads is also influenced by the requirement for uniformity of environmental conditions and sample size.

The design review appears to be the most desirable alternative from the theoretical standpoint. A thorough examination of each candidate design will allow the analysts to evaluate several aspects of each design. Judgments can be made on qualitative aspects such as quality level of parts used, modularity, accessibility for maintenance, packaging and layout, and manufacturing quality. A quantitative evaluation of the stress levels on each component can also be accomplished.

However, for a design review of this type to be effective, several engineers with varying expertise must perform the review. This fact becomes the limiting consideration because of the cost of either maintaining a multi-disciplined engineering staff or hiring consultants. As discussed earlier, this factor will affect smaller railroads more than the larger ones. For this reason the design review technique can not be employed uniformly. Therefore, it is not a viable prospect for evaluating MOW reliability.

While considering alternate methodologies for determining MOW reliability, the factors contributing to unreliability were investigated. Interviews with railroads and equipment manufacturers have identified two areas that appear to compromise reliability. First, improperly trained operators can cause severe overstress which result in equipment failures. Secondly, maintenance techniques and improperly defined or observed preventive maintenance intervals can accelerate the wearout of mechanical parts. Two examples of situations contributing to premature system failure are contamination of the hydraulic system during hose replacement and neglect in tightening loose parts regularly.

Owing to the high cost and other drawbacks associated with testing and design review, an alternative method had been selected as the most feasible technique for evaluating MOW equipment. This method utilizes predictive analysis to develop a Reliability Index for MOW equipment and evaluates only those parameters inherent to the equipment design. Effects of maintenance and the operator are not considered. The process involves a truncated predictive analysis which is comprised of two key elements, the failure rate data base and the critical operational subsystems. The failure rate data base has been developed from several military data bases and, in most cases, though not directly applicable to MOW equipment, can be used for comparative analysis. It is thought that uniform application of the data base to each product being evaluated can result in machine indexes that allow meaningful comparative judgements to be made, although the actual reliability of a machine is not determined.

The data base will contain a reliability index for each type of component used in MOW equipment. The indexes are dimensionless and do not relate to actual failure rates. They do, however, maintain the proper proportionality relationship between component indexes.

The critical operational subsystems are the areas of each type of MOW equipment which are analyzed. The critical operational subsystems are those portions of a machine whose operation is either directly or indirectly critical to the performance of the work function. This relates to the portions of the machine that contact the work medium along with their control functions. Examples are the work head and leveling and lining subsystems of a production tamper; the injector-inserter head of a tie inserter (boom and hydraulic system); and spiking heads, nippers, and spiking guns with associated control subsystems of spiking machines. Those subsystems which perform ancillary functions are not analyzed because they have less critical wear and stress characteristics as a result of their use environment. Their exclusion should not have an appreciable impact on the overall index, and the simplification of the analytical process makes its implementation more practical.

Identifying the critical operational subsytems for each different machine is a task involving a considerable amount of research. This is beyond the scope of the current project and must be accomplished as additional work.

The process used to determine the reliability index entails identification of each component type in the critical operational subsystems and its population, and multiplying this population by an index from the data base. When these quantity-index products are summed for the entire critical operational subsystems, the result is the total equipment index.

A stress factor can also be introduced to enhance this index. This factor relates the applied or peak stress levels to the manufacturers' specified maximum limits. This factor is multiplied by the quantity-index product to form the component index. It is generally agreed that reliability is increased as the stress level decreases. Derating of electronic and electrical components to improve reliability is a common design practice. J.P. Silva and J.L. Hammond in their paper on "Reliability, Maintainability, and Performance in Hydraulic System Design," (June 1977), state that in helicopter designs, derating hoses to between .25 and .33 of rated burst pressure to handle the peak surges present in the system has shown increases in hose reliability. This same report focuses on the effects of vibration and how the reliability of hydraulic components deteriorates with increasing levels of vibration. A correlation was found between a 50%

reduction in vibration levels and a 50% reduction in hose and tubing failure rates.

These examples point to the value of the stress factor in evaluating the designers' adherence to engineering practices that improve reliability. A great amount of information is required to calculate this factor, however. Manufacturers' specifications for each component type must be available, and the design stresses on the component must be calculated. This will require a fairly detailed stress analysis of the machine which is time consuming and costly. For these reasons, the stress factor will be listed as an optional parameter in the evaluation process. If the analyst requires only a basic evaluation of reliability, the stress factor can be eliminated. If a more detailed evaluation is required due to similarities in reliability and other indexes, use of the stress factor may be very helpful.

The overall reliability index is the summation of the product of each individual component index, its population, and its stress factor. The lower the final index, the more reliable the equipment is, relatively speaking. The mathematical expression for the reliability index is as follows:

$$RI = \sum_{i=1}^{n} p \; RI_i \; S_i$$

Where p = population of the i^{th} component in the critical operational subsystems

RI_i = reliability index of the i^{th} component

RI = Equipment Reliability Index

n = total number of component types in the critical operational subsystems

S_i = stress factor of the i^{th} component

The procedure for evaluating maintenance-of-way equipment using the reliability index is discussed further in section 3.8 of the final report.

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