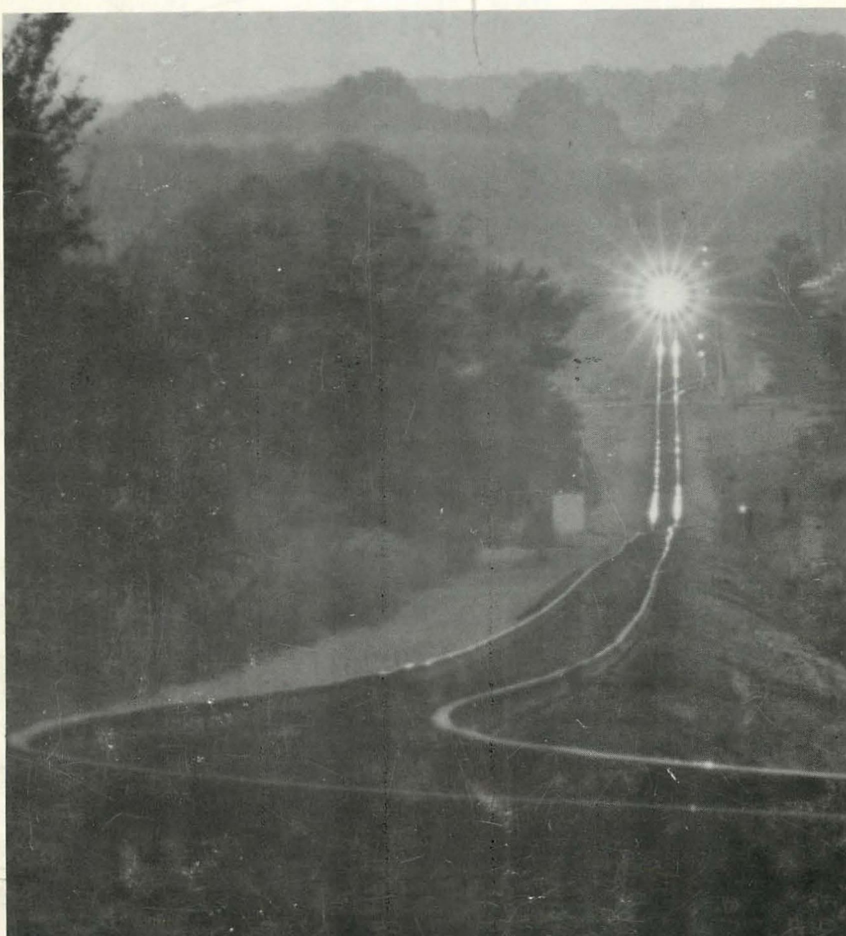
LMOA

Locomotive Maintenance Officers Association

Proceedings of the 57th Annual Meeting
Chicago, September 11-13, 1995



1995 ADVERTISERS INDEX

LOCOMOTIVE MAINTENANCE OFFICERS ASSOCIATION

COVER PHOTOGRAPHED BY:
WAYNE DEPPERMAN
COURTESY OF:
PEAKER SERVICES, INC.

LOCOMOTIVE MAINTENANCE OFFICERS APPRECIATES THESE 1995 SUPPORTING ADVERTISERS

AUTOMATIC EQUIPMENT	HUGHES RAILWAY SUPPLIES	PRECISION INDUSTRIES	TOUCHSTONE, INC.
BACH-SIMPSON	HYDRO DYNAMICS	PRIME MFG. CO.	TRIANGLE ENGINEERED PROD.
CHEVRON CHEMICAL (ORONITE DIV.)	INTERSTATE DIESEL	Q-TRON	UNOCAL 76
CITATION CHEMICAL	JBI, INCORPORATED	RAILROAD FRICTION PROD.	VMV CORPORATION
CLARK FILTER CORP.	LPI, INCORPORATED	SHELL ADDITIVES	
C & H CHEMICALS	LYONDELL LUBRICANTS	SHELL OIL CO.	
DUROX EQUIPMENT	MILLER FELLPAX CO.	SIMMONS MACHINE TOOL CORP.	
GENERAL ELECTRIC CO.	MOSEBACH MFG. CO.	SNAP-ON TOOLS CORP.	
GEN'L. ELEC.-APPAR. SVCS. DIV.	MOTOR COILS, INC.	SNYDER EQUIPMENT CORP.	
GRAHAM WHITE	PEAKER SERVICES	TAME, INC.	
GRIFFIN WHEEL	PENN LOCOMOTIVE GEAR	TECHNICAL SVCS. LABORTORIES, INC.	
G & G LOCOTRONICS	POWER PARTS	TEXACO, INC.	

ATTENTION ALL MEMBERS:
WE **DO NOT ENDORSE** ANYONE'S PRODUCT, BUT WE DO **APPRECIATE** OUR ADVERTISERS.
Listed above are the names of the ADVERTISERS whose ads appear in our ANNUAL PUBLICATION.
We appreciate the fine financial support these advertisers provide.
We hope to see **these and many more** advertisers' names displayed in this fashion at all of our future **Annual Meetings.**
We sure to read their ads in the Annual Publication.

INDEX

PAST PRESIDENTS (Con't)

1985 - D. M. WALKER, Asst. Shop Manager, Norfolk Southern Corp.,
793 Windsor St., Atlanta, GA 30315

1986 - D. H. PROPP, Gen. Supt.-Loco. Opns., Burlington Northern,
777 Main St., Ft. Worth, TX 76102

1987 - D. L. WARD, (Deceased) Coord.-Quality Safety & Tech. Trng. Burlington Northern R.R.

1988 - D.G. GOEHRING, Retired, Supt. Loco. Maint., National RR Passenger Corp.,
543 GREEN HILL LN., BERWYN, PA 19312

1989 - WILLIAM A. BROWN Mgr., Loco. Projects Montana Rail Link, Missoula, MT 59807

1990 - P. F. HOERATH, Retired Sr. Mech, Engr. Shops, Conrail,
Box 134, R.R. 4, Hollidaysburg, PA 16648

1991 - D. D. HUDGENS, (Retired) Sr. Mgr. R & D, Union Pacific, 16711 Pine St., Omaha, NE 68130

1992 - K. ALLEN KELLER, Supt. Loco. Maint., Reading, R.R., 241 E. Chestnut, Cleona, PA 17042

1993 - W. R. DOYLE, Mgr.-Maint. Control Systems
Union Pacific RR, 1416 Dodge St., Omaha NE 68179

1994 - M.A. Coles, Director Loco. Maint. Planning, Union Pacific RR,
1416 Dodge St., Omaha, NE 68179

HONORARY LIFE MEMBERS

KJELL AXELSON, Retired Superintendent Motive Power, Burlington Northern, 36-716 Bluebird Ave. Rancho Mirage, CA 92270

F. W. BUNCE, Retired Chief Mech. Officer, Milwaukee Road.

J. J. BUTLER, Retired Chief Mech. Officer, Consolidated Rail Corp., 158 Woodgate Ln., Paoli, PA 19301

OWEN CLARKE, Retired Vice-President, Chesapeake & Ohio Ry., Cleveland, Ohio

B. A. CUMBEA, Reitred Mgr. Loco. Maint.-Engr., Chessie System, 310 Cherokee Trail, Huntington, WV 25705

N. C. ECKERLE, Sales Mgr. Specialty Chem., Nalco Chem. Co., 2901 Butterfield Rd., Oak Brook, IL 60521

W. EWING, Retired, Altoona Gear Co., Calbassas, CA

W. T. FARICY, Retired Chairman of the Board, A.A.R.

J. G. GERMAN, Retired V. Pres.-Engr. Missouri Pacific Railroad Co.

J. J. GREGORY, Retired Project Mgr.-Heavy Repair Shop, Consolidated Rail Corp., 603 Ruskin Drive, Altoona PA 16602

S. GRAHAM HAMILTON, President, Global Group, Inc., P.O. Box 2024, Winter Park, FL 32790

E. R. HAFLING, Retired Engineering Assist., Santa Fe Rwy., 2711 James St., Topeka, KS 66614

W. J. HARRIS, Retired V. Pres., Research & Test Dept., Assn. of American Railroads, Washington, D.C.

H. W. HAYWARD, Retired Chief M.P. & R. S., CP Rail, Montreal 101, Quebec, Canada

D. W. HENDERSON, V.P.-Technology, Engr. & Maint. Burlington Northern RR, 9401 Indian Creek Pkwy., Overland Park, KS 66210

JOHN H. HERTOG, Retired V. Pres. Operations, Burlington Northern, Inc., St. Paul, MN 55101

JOHN W. INGRAM, Retired Pres. and Chief Executive Officer, Chicago, Rock Island and Pacific Railroad Co.

A. W. JOHNSON, Retired, V. Pres. of Opns. and Maint., Assoc. of American RR, Washington, D.C.

JOSEPH J.T. KOERNER, Sec'y-Treas. (Retired), LMOA, 3144 Brereton Cr., Huntington, WV 25705

JACK L. KUHNS, Retired Mgr. Plng. & Maint., CSX Transp., 401 Brookview Rd., Louisville, KY 40207

R. M. McDONALD, Retired Dir. of Opns., Brd. of Transport, Commissioners for Canada, Ottawa, Ont., Canada

J. F. McDONOUGH, Retired Asst. V. P.-Mechanical, Union Pacific RR, 12225 Farnum St., Omaha, NE 68154

F. K. MITCHELL, Retired Asst., V.P., New York Central Sys., Sleights Wildwood, Manitowish Waters, WI 54545

R. G. RAY BURN, Retired Executive V.P.-Operations, Chessie System, Baltimore, MD

H.P. RODES, Pres., General Motors Institute, Flint, MI 48502

F. R. RUSSELL, Retired Chief Mech. Off., Southern Pacific Co., San Francisco, CA

L. G. SALTS, Retired, AT&SF Rwy., Topeka, KS

H. L. SCOTT, JR., Retired Sr. V.P. and Chief Mech. Off. Norfolk Southern, Corp. P.O. Box 3609, Norfolk, VA 23514

C. M. SMITH, Retired Mgr-Mech. Engr.-Passenger and Loco. Consolidated Rail Corp., 3 Princeton Rd., Strafford-Wayne, PA 19087

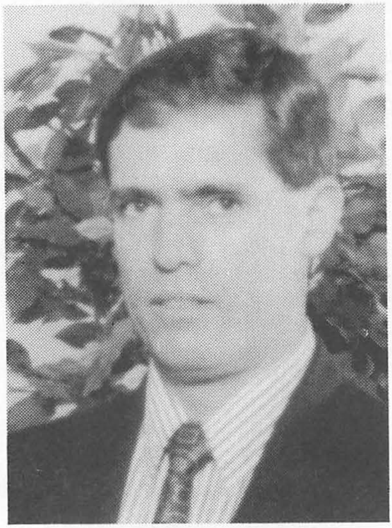
R. D. SPENCE, Retired Executive V.P.-Operations, Seaboard System RR

J. TAGGART, Retired System Mechanical Officer-Motive Power, CN Rail, 655 Richmond Road, unit 45, Ottawa, Ontario K2A 3Y3

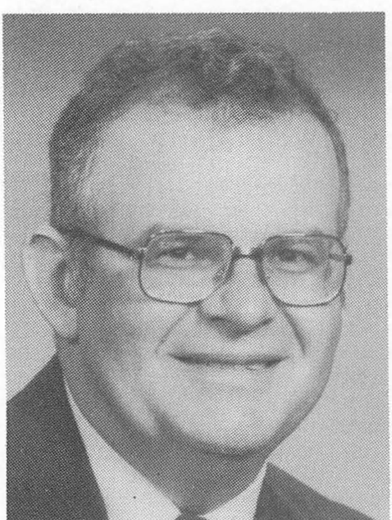
M. L. VARNS, Retired, BN RR, Nixa, MO

R. W. VITEK, National Railway Equip., Dixmoor, IL

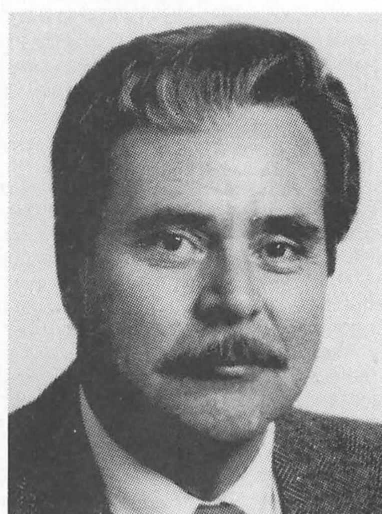
OUR PAST PRESIDENTS



MR. WEYLIN R. DOYLE
Project Manager - MCS
Union Pacific Railroad
Omaha, NE 68179



MR. ALLEN KELLER
Dir.-Loco. Projects
Reading Railroad
Cleona, PA 17042



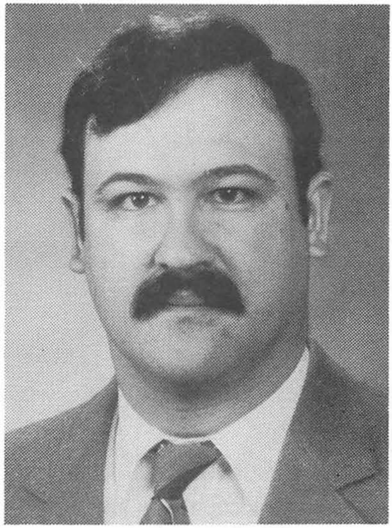
MR. WILLIAM BROWN
Manager - Loco. Projects
Montana Rail Link
Missoula, MT

OUR PAST PRESIDENTS

MR. DALE H. PROPP
Gen. Sup.-Loco. Opns.
Burlington Northern Railroad
Fort Worth, TX 76102

MR. DARRELL M. WALKER
Asst. Shop Mgr.
Norfolk Southern Corp.
Atlanta, GA 30315

OUR OFFICERS



Chairman of the Board
MR. MARK COLES
Dir. - Loco. Maint. Planning
Union Pacific Railroad
Omaha, NE 68179

OurPresident
MR. CHARLES MILLER
Dir. - Loco. Maint. Planning - Stds. & Programs
Union Pacific Railroad
Omaha, NE 68179

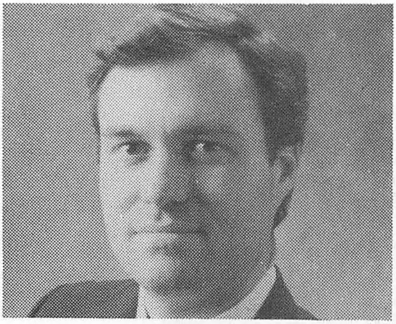
OUR OFFICERS

1st Vice President
MR. GIL BRUNO
Mgr.-Equipment - Stds. & Quality
Amtrak
Los Angeles, CA 90012

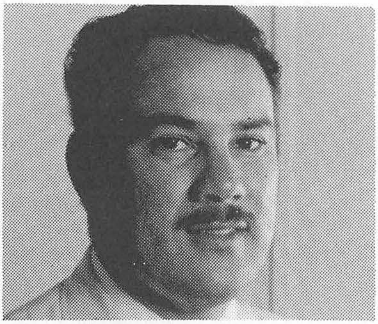
2nd Vice President
MR. DAVID M. WETMORE
Mgr.-Production
CXS Transportation
Cumberland, MD 21502

3rd Vice President
MR. MIKE PENNELL
Director-Materials
Burlington Northern Railroad
Fort Worth, TX 76180

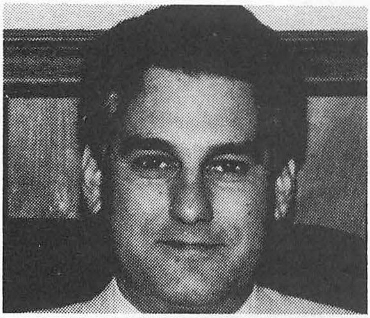
OUR REGIONAL EXECUTIVES



MR. DOUG CORBIN
Mgr. Syst. Assy. Shop
Norfolk Southern Corp.
Chattanooga, TN 37403

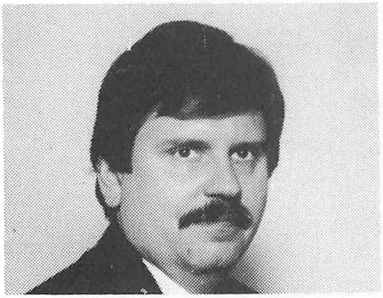


MR. JAKE VASQUEZ
Mgr. of Opns.
GWI Switching Services
Dayton, TX 77535

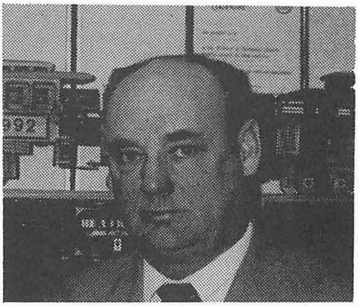


MR. LOU ÇALA
Mgr.-Reman. Components
Conrail
Altoona, PA 16603

MR. JOHN CLONTZ
Supt. -Technology Implementation
Burlington Northern
Fort Worth, TX



MR. RONALD R. LODOWSKI
Manager-Oil Congrol Labs
& Environmental Opns.
Conrail - Selkirk, NY



MR. E.L. (LEE) OVIATT
Manager-Loco. Maint.
DM& IR Rwy.
Proctor, MN

REPORT OF THE COMMITTEE ON FUEL, LUBRICANTS & ENVIRONMENTAL

MONDAY, SEPTEMBER 11, 1995
10:45 A.M.

C. KUNKEL, Chairman
Sr. Mgr.-Res. & Dev.
Union Pacific
Omaha, NE

Vice Chairman
JOHN T. JACKSON
Manager Shop-Engineering
Amtrak
Wilmington, DE

COMMITTEE MEMBERS

E. Adelman	Indus. Systm. Engr.	Amtrak	Wilmington, DE
D. Bachelder	Coord. Prod. Tech.	Caltex	Dallas, TX
Z. Bolt	Sr. Tech. Spec.	Exxon Co.	Houston, TX
T. Brown	Sr. Research Engr.	AAR	Washington, DC
K. Brinker	Sr. Mgr.-Environ.	CSX Transportation	Jacksonville, FL
G. Bowen	Mgr-Laboratory Svcs.	AT&SF	Topeka, KS
D. Carlson	Staff Engineer	Shell Development	Houston, TX
K. Davis	Mgr-Tests & Lab Svcs.	CSX Transportation	Waycross, GA
R. Dunn	Mgr.-Analy. Svcs.	CANAC International	Montreal, PQ
G. Hamilton	Sr. Staff Res. Engr.	Petro-Canada	Sheridan Pk., Ont.
L. Haley, Jr.	Chief Chemist	Norfolk Southern	Chattanooga, TN
B. Hilgenberg	Dist. Engr..	Electro Motive Div.	McCook, IL
R. Hohl	Mgr.-Equip. Plng. & Lab	CP Rail System	Minneapolis, MN
R. Iwamoto	Engr. Assoc.	Unocal 76	Brea, CA
L. Kenney	Purch. Agent	Burlington Northern	Ft. Worth, TX
C. Kunkel	Sr. Mgr.-Res. & Dev.	Union Pacific	Omaha, NE
M. Logan	Staff Engr.	Chevron Oronite	Richmond, VA
D. McAndrew	Fuels & Lub. Spec.	General Electric Co.	Erie, PA
T. Nowak	Sr. CTS Rep.	Ethyl Petroleum	Richmond, VA
S. Pearson	Product Engineer	Mobil Oil Corp.	Fairfax, VA
D. Pridemore	Mgr. Tech. Prod.	Valvoline	Lexington, KY
G. Schafer	Senior Technologist	Texaco, Incorporated	Beacon, NY
E. Shamah	Sr. Engr. Assoc.	Chevron Research	Richmond, CA
C. Tincher	Product Manager	Lyondell Petro. Co.	Houston, TX
M. Wierucki	Engineer of Test	CP Rail System	Winnipeg, MB

PERSONAL HISTORY

Chuck Kunkel

Mr. Kunkel has been with the Union Pacific for 23 years. He has held various positions in the locomotive engineering and maintenance environment. He currently is the Senior Mgr. - Research and Development. His responsibilities include lubricant, fuel and water treatment. Chuck is married with two children and his hobbies are fishing and auto mechanics.

I. MSDS'S WHAT DO THEY TELL US?

Prepared by:
Tom Pyziak
Safety Kleen Oil Recovery Co.

Introduction

Over the last several years a national effort to inform workers of potential hazards in the work place has gained a much needed priority (29 CFR part 1910 February 9, 1994).

The deaths of employees unfamiliar with chemicals or combinations of chemicals used by manufacturing has led government and industry to impose strict standards on the purchase, storage, use and disposal of these chemicals or chemical combinations.

Some of the standards imposed by the government's employee and environmental monitoring agencies such as Occupational Safety and Health Administration (OSHA) and the Environmental Protection Agency (EPA) has forced manufacturers to label products in a manner that is understandable to the common worker, while also providing detailed information regarding chemical constituents, potential health hazards and first aid (including reactivity, fire and explosion hazards), as well as, potential harm to the environment by improper use or disposal.

This paper will attempt to discuss the role of the Material Safety Data Sheet (MSDS) in satisfying these requirements. It will examine each section of information contained in its format. The discussion will attempt to put in plain understandable verbiage the who, when, where and why of the MSDS, documenting why it is a valuable tool for every employee, even an individual not in direct contact with such substances.

History

Prior to the federal enactment forming OSHA, chemical manufacturers and industries which use chemicals in their manufacturing process had little if any information regarding the potential safety and environmental hazards involved with a certain chemical. A chemical manufacturer usually provides a specification sheet indicating a chemicals use and physical properties, but a chemical's potential hazards were left to the user's knowledge.

Purchasers, supervisors, trainers and in some cases laboratory personnel were very often the only individuals in direct or indirect contact with the chemical manufacturer and had adequate knowledge of the chemical's hazards. The use of chemicals and their potential hazards were sometimes kept a secret or were often times neglected to increase production and company profits.

It was OSHA's Hazardous Communications Standards (HCS) and subsequently the "Right to Know" law that enabled any individual in direct contact with chemicals in manufacturing to have immediate access to a chemical's physical constituents, potential health and environmental hazards. MSDS's were required by law to be received by the purchaser prior to or at the time of the first shipment. It was the intent of OSHA to give ample time to train and familiarize personnel in the proper handling, use and subsequent disposal of a chemical product.

To the credit of most organizations today this procedure of MSDS supply and training is a standard one. As of this writing there is no specific format for MSDS's. OSHA has indicated what a MSDS must contain. This is called a Performance Oriented Standard. This means that MSDS's for the same or similar chemical produced by different manufacturers will contain similar information but not in the same format or order.

In 1994 the Chemical Manufacturers Association adopted a sixteen section format for use by all members based on International Standards Organization (ISO) protocol. This new format would again contain all information required by OSHA but would standardize the individual sections and its content. This in essence would make MSDS's from different manufacturers of the same or similar chemical have the same information in the same section, minimizing the potential for confusion by the user.

Although this standard was adopted by the Chemical Manufacturers Association it has been slow to be implemented and various formats continue to be produced.

Understanding a Material Safety Data Sheet will make your working environment safer as well as those working around you. Instructing colleagues properly can save many lives.

There are eight (8) basic sections and one (1) optional section found in an MSDS today. This discussion will follow an order typical of most of MSDS's.

*** Section 1- Product Identification**

• This first section indicates the name, address and telephone number of the company which produced the material.
• The most recent revision date for that MSDS and a contact with phone number for product information.
• The **exact** name of the material which must exactly match that which is on the label of the container or shipping document if delivered in bulk.
• Additional names by which this material is identified, which may be a common name.
• The recommended use of this material.

This first section is most important. It is a quick reference to match up an MSDS with the actual product or container. If the names on the container and MSDS do not match **exactly,** it is recommended that the material not be used until a MSDS is received matching the container label.

It is also recommended in the USA and required in Canada that information on an MSDS be reviewed by the manufacturer every (3) years. If a recent revision is not indicated in this section, request a new MSDS from the manufacturer.

This section may also contain emergency information including medical phone numbers, as well as, information on the chemicals flammability, reactivity and health hazard. This may take the form of the National Fire Protection Association (NFPA) hazardous-rating fire diamond.

*** Section 2 - Hazardous Ingredients/ Identify Information**

• This section is directed to individuals in your organization who have the responsibility to instruct and/or monitor the work place environment such as Environmental Health and Safety, Industrial Hygienists and Engineering.
• It is required by law that a manufacturer identify ingredients that are defined as hazardous and their relative percentage in the material. If ingredients are termed "trade secrets", suppliers are still required to provide health hazard data on the MSDS and additional information to safety personnel on a need-to-know basis.
• Some abbreviations and simple definitions from this section follows:

Name - The actual name of the component.

Synonym - Other trade names for the component

CAS No. - Chemical Abstract

Services number. A specifically-assigned number used to identify a component as designated by the American Chemical Society.

Wt % - A range or actual percentage of the component found in the material.

TWA or TLV - Time Weighted Average or Threshold Limit Value. A term to express an airborne concentration value to which nearly all workers can be exposed on a daily basis. The weighted average accounts for an eight (8) hour workday and forty (40) hour work week.

STEL - Short Term Exposure Limit. The maximum concentration for continuous exposure in a fifteen (15) minute period followed by (60) minutes of non-exposure.

LD - Lethal Dose. Sometimes characterized by a number (ex. LD_1, LD_{50}, LD_{99}) but indicates the dose from exposure to the substances by any route other than inhalation where the substance causes death. The number identifies the percentage of animals that died at this concentration.

LC - Lethal Concentration. Again sometimes characterized by a number as indicated above but indicates inhalation concentration leading to death.

To those involved in the health and safety of others at the work place it is important to realize that this section of the MSDS and hazardous levels indicated were set up for most healthy adult workers. Lesser exposure limits can be fatal for those at higher risk (ie, elderly, pregnant etc.).

If you are concerned about your exposure, contact Environmental Health and Safety departments. It is important when reviewing the MSDS Section 2 to realize that if information on exposure is listed in this section that there is cause for concern and that proper hygiene, respiratory equipment, ventilation or proper attire is required.

*** Section 3 - Physical/Chemical Characteristics**

• As the title indicates, this section provides information on the physical characteristics of the chemical or mixture.

• Information such as vapor density are important to note because if a chemical's vapor density is greater than 1 (which is air) the vapor is likely to seek the lowest point of a work area. If work is being performed in the low lying area, a respirator may be appropriate. A high vapor density chemical may be more prone to ignite because pilot lights are very often near the floor.

• This section informs you of how a chemical or its vapor will react. It also provides information on its odor, freezing point and evaporation rate.

*** Section 4 - Fire and Explosion Hazard Data**

• If you are involved in fire response, this section details most importantly information pertinent to extinguishing the fire such as protective clothing and extinguishing chemicals such as water, CO_2 and Halon.

• This section, along with the physical data section, will give an indication of the chemical's flash point and auto ignition temperature. These indicate at which temperature a chemical vapor will ignite by spark and when a chemical vapor will set itself on fire.

• Finally, this section covers all toxic or hazardous by-products caused by the combustion of the chemical.

• This information should be reviewed and planned for prior to use. It has much less usefulness if read once the fire has begun.

• If one is not trained in the extinguishing of a fire, it is recommended that in the event of a fire one should notify the proper personnel and vacate the area immediately.

*** Section 5 - Reactivity Data**

• This is the most variable section because of the many different ways chemicals may react with one another in changing environments or use situations. In most circumstances, this section deals with the most hazardous reactions which may occur.
• In reading this section, note if the chemical is sensitive to such things as temperature, pressure, acid, caustics and/or sparks. This information should be used to reduce chances in the work place where these reactions can occur.
• The preferred choices of storage containers often is listed in this section (ie. glass, metal, plastic).

*** Section 6 - Health Hazard Data**

• As will be indicated in Section 8 of this discussion, the most important information an MSDS can provide is that one should know how to handle and know how to provide first aid **before** you work with a chemical.
• This section describes all possible routes of entry for the chemical and its acute (immediate) and chronic (long-term) health effects. Statements of chemical carcinogenic characteristics as well as other potential health hazards will also be found in this section.
• It is always best to secure professional medical treatment as soon as possible with any exposure, but one can significantly reduce the short or long term effects of a chemical by reacting quickly. An example would be caustic in the eyes. The more quickly the eyes are flushed the less long term damage which may occur.
• This section discusses immediate symptoms as well as long term.
• Inhalation is the most common form of entry. Since many hazardous chemicals have a minimal odor or quickly desensitize the sense of smell, individuals are often unaware of the toxic exposure they have just encountered.
• Second to inhalation the most common route of entry is by direct contact with the skin. Some chemicals are absorbed directly through the skin and can have immediate and sometimes severe internal damage.
• Ingestion by contact and subsequent transfer through eating, drinking, smoking or rubbing an eye can cause severe reaction. Contact lenses are rarely if ever allowed in the workplace because of this type of transfer.

Chemicals such as arsenic, mercury, lead and cyanide must be handled with increased sensitivity to contact and ingestion due to the body's sensitivity to even minuscule amounts.

*** Section 7 - Precautions for Safe Handling and Use**

• In the event a spill or leak has occurred this section will advise you on how to remedy the situation, contain the spill and minimize your health risk and the risk to the environment, both in the clean up and eventual disposal of the material.
• This section will also refer the user to Federal, State and Local laws or regulations which need to be followed either by notifying the proper authority of the incident or proper clean up steps to prevent future environmental contamination.
• It is recommended that spills be dealt with by a trained emergency response team and that an adequate place for containment be present in the working area.

*** Section 8 - Control Measures**

• This section deals with instructions for the care of an individual who has been exposed to excessive quantities of this chemical. In any emergency situation professional medical treatment should be immediately sought. Once help is secured this section will provide some common sense, first aid procedures such as providing ventilation, removing apparel, inducing vomiting or flushing the affected area. An understanding of each contamination should be clear to all involved in the use of the chemical. The delay in administrating First Aid while searching for an MSDS can be life threatening.
• This section covers exposure to the eyes, skin, inhalation or ingestion.
• It is also important to the employer and employee that instructions given to reduce potential contamination (ie, respirators, gloves, etc.) are required by law to be available to the handler. It is also the employees responsibility to utilize equipment or refuse work if safe working conditions do not exist.

*** Optional**

Section 9 - Other Regulatory Information

• This section may or may not appear.
• This section deals with storage and non-OSHA policies such as Department of Transportation, rules in the proper handling of the chemical.
• This section also will contain assorted information which does not fit the content of the previously reviewed sections such as state-specific warnings.

CMA - ANSI

The most recent effort begun in 1988 by the Chemical Manufacturers Association and the American National Standards Institute to revamp MSDS's and make them less complex and user friendly is making progress.

Responders to a poll in 1990 indicated that current MSDS's were too long, too complicated, too hard to read and too technical. In addition respondents also wanted environmental information, disposal information and how the chemical was regulated by Federal and State laws.

With the proposed standard format individuals will not have to page through multiple sheets to find out how to respond from first aid to disposal when an emergency occurs.

The proposed standard employs sixteen sections that will always appear in a known order. This order is designed to list in descending order what an individual needs to know **first.** They are as follows;

- **Section 1: Chemical Product and Company Identification**
- **Section 2: Composition and Information on Ingredients**
- **Section 3: Hazards Identification**
- **Section 4: First Aid Measures**
- **Section 5: Fire-Fighting Measures**
- **Section 6: Accidental Release Measures**
- **Section 7: Handling and Storage**
- **Section 8: Exposure Controls-Personal Protection**
- **Section 9: Physical and Chemical Properties**
- **Section 10: Stability and Reactivity**
- **Section 11: Toxicological Information**
- **Section 12: Ecological Information**
- **Section 13: Disposal Consideration**
- **Section 14: Transportation Information**
- **Section 15: Regulatory Information**
- **Section 16: Other Information**

In addition to listing items in a standard order, writers of MSDS's are asked to identify the primary target reader of the section and write for that audience. So the first section should be written for the lay person whereas instructions to the physician will be in technical language.

One of the problems in promoting this revised MSDS format is the time and cost. Companies such as 3M, with over 40,000 MSDS's, can't perform the changes overnight. The internal costs involved to replace all old MSDS's can be very substantial for both large and small producers. But the change is coming internationally so that no matter where chemicals are moved only one format will exist.

We would recommend you ask your supplier to provide an MSDS conforming to the 16 part CMA/ANSI standard form.

Conclusion

MSDS's contain a great deal of information about a product or chemical and how it relates to the work place and environment. The intent, although sometimes confusing, is to supply the worker and purchasing company all the information needed to maintain a safe working environment and in the event of an accident provide immediate first aid instructions. An MSDS is a company's first line of defense in emergency situations and the first indication of a chemicals' potential hazards.

An MSDS is your first "Right to Know" and can save your life or those around you. It is the law to be trained to read and understand them. We recommend this publication and associated brochure be posted in the work place as a easy reference to understanding an MSDS.

Disclaimer

This paper does not purport to cover all issues involved in an MSDS or how it should be taught or what legal recourse an individual exposed to a chemical may have. Contact your local government official for clarification or contact your Environmental Health and Safety office.

II. APPLYING SATELLITE COMMUNICATIONS TECHNOLOGY TO ON-LINE OIL ANALYSIS OF CRANKCASE DIESEL ENGINE LUBRICANTS

Prepared by:
James C. Fitch and
Stuart D. Bents
Diagnetics, Inc.
Tulsa, OK USA

Abstract

The advent of unattended senor technologies has placed a particular challenge on data communication for machine surveillance monitoring. This challenge is magnified when mobile equipment and large geographic territories are involved. The use of satellite communications has been recently applied in an extensive condition-based maintenance program for a large fleet of railroad maintenance equipment. The satellite communications are a part of an integrated system of sensor, software and communications technologies. This paper describes the selection and application of sensors for the real-time monitoring of oil analysis parameters of diesel engine lubricants. Also discussed will be the onboard data collection electronics, onboard satellite transmission hardware and knowledge-based data analysis and exception reporting. The paper will be presented as a case study and is believed to be the first of its kind for condition-based maintenance and employing satellite communications technology.

1.0 Introduction

In the business realm today, an enterprise must achieve optimum efficiency in every area in order to survive in the marketplace. One area that concerns many is the area of maintenance. "Maintenance has been described as a business's largest controllable expenditure."

If the expenditure of maintenance is controllable, how can it be controlled? The answer is very simple: root problem discovery and correction. If the source of the maintenance expense is found, the root problem can be investigated and corrected. In order to locate the root causes of equipment failures, equipment incurring maintenance cost must be monitored frequently. Monitoring root problem parameters allows the operator not only to monitor and predict **failure,** but also enables him to extend and estimate equipment **life.** This type of condition-based maintenance combines the life-extension features of proactive maintenance with the failure prediction features of predictive maintenance. To actualize this type of maintenance program at a high level of effectiveness, a tremendous amount of data collection is required. This data must be collected, reported and stored quickly and easily. The most efficient method to accomplish this is the use of computer controlled sensors, coupled with data storage and trending capabilities.

In the case of mobile equipment, there is a barrage of added environmental and operational variables. Because of this, the need to monitor equipment health is more critical. However, monitoring mobile equipment can be very cumbersome. Imagine monitoring a fleet of mobile equipment operating in an area covering one half of North America. In this scenario, the use of satellite transmission for the transfer of sensor data is appealing. In the event that an integrated satellite communications system is economically justifiable and beneficial to reduce maintenance cost, countless additional data transfer opportunities are presented. These opportunities include monitoring, messaging and mapping.

2.0 The Effect of the Environment and Workload on Equipment Longevity and Performance

There are two main elements that affect the longevity and performance of fluid dependent systems. They are workload and environment. Any failure or performance problem associated with a piece of equipment, aside from poor manufacturing, design and installation, can normally be traced to workload and environment. From a design standpoint, equipment should be constructed to withstand the workload it experiences in the environment that it operates.

Environment and workload reduce equipment life with the help of two common deficiencies. These inadequacies can be described as the lack of knowledge and the lack of discipline. The lack of knowledge is a deficiency of maintenance knowledge and condition knowledge. In other words, not knowing how to maintain your equipment in the environment it operates and not knowing what condition your equipment is in or what situation it may be experiencing. Lack of discipline is the failure to act or respond when the condition would direct to do so. This lack of knowledge and discipline may not only be shared by the operator and maintenance manager, but also the design engineer.

The environment and workload parameters can be broken down into several items. These items include:

1. Atmospheric Hard Particle Contaminant Level
2. Internal System Contaminant Generation Level
3. Contaminant Abrasivity
4. Water Exposure Level
5. System Operating Pressure
6. Pressure/Flow Duty Cycle Severity

The most damaging environmental influence on a fluid-dependent system is hard particle contamination. According to Caterpillar, "dirt and contamination are by far the number one cause of hydraulic system failures." It has been estimated to be the source of over 80% of wear-related equipment failures. Since hard particles are the cause of such a high percentage of failure, the knowledge of these contaminant levels is of utmost importance in equipment maintenance. If contaminant target levels are defined, current contaminant level information can be used to determine maintenance actions and responses.

2.1 Equipment and Environment Specific Contaminant Ingestion

Contaminant ingestion is the migration of hard particle contaminants from the environment into a fluid dependent system, such as a hydraulic system or power train. The level of ingression that a specific piece of equipment experiences depends upon three items:

1. The environment in which it is placed
2. The condition that it creates in this environment
3. The protection that it retains against its environment

Equipment operating inside of an enclosed area (such as a factory) is protected from the outside elements such as rain, snow, extreme temperature and to some extent, exterior atmospheric hard particle contaminant (this will vary with the type of air filtration used in the ventilation system). In these situations, the focus can be placed on particle levels generated in the plant and on the internal igression of the equipment.

In dealing with mobile equipment, there are several additional variables.

These variables include the type of environment that the equipment is working in and the nature of work that it is performing. The type of environment will vary not only with region, but also with climate and weather. For example, if a piece of railroad work equipment is working in a region that contains sandy soil, it may experience more dust ingestion than a similar piece of equipment in a region where the soil contains a high amount of clay. However, identical pieces of equipment may experience less ingestion in a sandy region characterized by a humid climate than in a sandy region characterized by a dry climate. Additionally, the ingestion level is affected by the weather on that particular day. For example, if the weather was overcast and the rainfall totals three inches, less ingestion will be expected.

Not only is the amount of ingestion important, but also the type of ingestion. Airborne particulate will vary in size, shape, hardness, angularity and abrasivity. These variables will affect the amount of damage done to critical component surfaces. For example, railroad work equipment operating on a rock ballast with a high granite content may risk more internal damage from ingestion than equipment operating on a rock ballast composed mainly of limestone.

Another variable to be considered is the condition that the equipment creates in its environment while it operates. This depends on the type of work that the equipment is designed to perform and also the particular task that it is performing at any given time. For example, a ballast regulator, which is designed to plow and dress railway ballast, may generate a large cloud of dust composed of granite, limestone and/or soil particulate. All other things equal, this cloud will vary in size and shape depending on the nature and speed of the task being performed. A tamper, on the other hand, which is designed to align rail, does not usually stir up a visible cloud of dust. A dust cloud creates an additional environmental variable. This environmental variable will cause the engines on these two machines, although performing under similar workloads and conditions, to vary in performance and longevity. This variance, therefore, is dependent on the nature of the task being performed and is caused by differing levels of contamination generated during the operation. In the case described above, the ratio of the diesel engine life expectancy of the tamper to that of the ballast regulator can be as high as 4:1.

We can now see that longevity and performance can vary highly with environment, task and workload. If the knowledge of the variables and conditions affecting the performance and longevity of the equipment does not exist, proper action in terms of maintenance and upkeep cannot be performed.

3.0 A Proactive Maintenance Approach to Lubricant Oil Analysis

The primary objective of a new contamination control program must be to extend a machine's operating life (mean time between failure/overhaul). This activity is most commonly referred to as proactive maintenance. It has been stated that, "Proactive maintenance is not an activity that reacts to material and/or performance type failure conditions of a system. Rather, it has been developed to prevent such system degradation from occurring in the first place." Furthermore, "proactive maintenance reflects a life extension mode capability of extending the service life of the machine because it addresses both the detection and correction of root cause aberrations." This is illustrated below in figure 1.

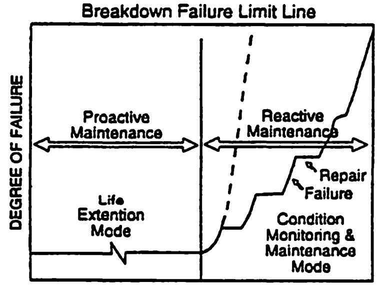


Figure 1

While extending machine life leads to many benefits, the most important is usually greater machine availability and utilization. Additionally, the best way to view life extension opportunities is in multiples of current life expectancy. While, on the surface, multiples may seem optimistic, field studies have shown achievement of life extensions in excess of **ten times!**

In implementing a proactive contamination control program, three steps must be vigorously observed:

1. Set appropriate target cleanliness levels for each field system that will achieve considerable life extension.
2. Upgrade or adjust filtration, breathers, etc., to achieve the cleanliness target with an adequate margin.
3. Implement an onboard or routine contaminant monitoring program serving as feedback to frequently confirm that targets are achieved and contaminant levels are stabilized.

Success depends greatly on setting appropriate life-extension targets (step one) and a maintenance discipline associated with active monitoring (step three). Surprisingly, fully implemented follow-up maintenance activities are relatively low in relation to pre-implementation levels, and depending on environmental ingestion rates, cost of filtration may not be adversely affected.

3.1 The Application of Real-Time Contaminant Monitoring

The application of real-time contaminant monitoring, using on-line unattended sensors, has been successfully applied to railroad track maintenance equipment. The sensors receive a continuous sample stream from the hydraulic system and engine compartment. At frequent intervals, particle levels are assessed and transmitted to an on-board computer. The computer can be programmed to store and transmit the data at predetermined times of the day or work cycle. This can be accomplished by remote programming with satellite communication using the maintenance software. Alternatively, only exception levels are transmitted, i.e., contaminant levels and data trends that are above the target level.

The addition to the proactive "life extension" benefit of controlling and monitoring contamination in fluids, predictive maintenance benefits also exist. Since nearly all types of internal machine failures result in particle generation (through the process of wear and corrosion), abnormal particle contamination levels may be the simplest test of impending machine failure. When real-time contaminant monitors are located upstream of system filters, the combined effects of contaminant ingestion, wear debris generation and filter performance can be assessed.

3.1.1 Real-Time Data Transfer

Real-time data can be defined as a constant stream of information stemming from its source. In our case, the source is a sensor or a monitor. Shown in figure 3.2 is the method used to transfer data from a piece of mobile equipment to various types of monitors. Figure 2 is an example of real-time data transfer with mobile equipment.

This method combines existing satellite technology with real-time condition monitors. As shown above, data that is produced by the condition monitor(s) is stored in a data acquisition and control computer. This computer also controls the operation of the condition monitors and conditions the data produced. As frequently as desired, the data is reconfigured, stored and sent in a single burst by a transceiver to a satellite. The satellite bounces the data down to a satellite receiving station (hub). This station reconfigures the code again and sends it by land lines to the end user's host computer. Once the code is received, the fluid condition diagnostic software interprets it, reconfigures it, reports it and stores it for future reference and trending.

3.1.2 Data Storage and manipulation

Machine specific data received via satellite is stored for future reference. This is done so that the data can be called up at any time for graphing and trending. This may be useful in tracing the development of a failure or a simple equipment performance problem, or, as the data base grows, to perform in-depth studies concerning component life and reliability. All data received is stored for future use until it is erased by the end user. Figure 3 is an example of an actual data trend from a Union Pacific ballast regulator. This trend demonstrates the usefulness of the graphing capability.

3.1.3 Exception Reporting

Since the amount of data required for real-time monitoring is high, it is better to let the software in the system sift through the data that is not immediately urgent. While this data is valuable information for trending, "stable" equipment conditions pose no immediate threat for the operators or managers. Therefore, exception reporting, which pulls only critical information from the incoming data, is a more efficient method of monitoring.

In the exception reporting used with the railroad equipment gang, the software alerts the user if adverse conditions exist within any of the hydraulic or engine lubrication systems. If no exceptionally poor conditions exist, no alarms are activated, and adequate machine health is assumed.

The fluid monitoring software program used divides fluid system conditions into five categories. These categories are referred to as "status levels." A status level "1" is good, a status "5" is hazardous, etc. Equipment operating at a status "1" do not trigger an exception report. However, any piece of equipment operating at a status "2" or higher is reported. The ISO contaminant level is listed on a screen and cannot be erased until a corrective action is reported on that particular machine. This action is typed into the computer and saved in the memory. Once this action is saved, the contaminant reading can be erased from the exception reporting screen. However, this data has already been stored in the data base for future viewing and trending.

The exception reporting system incorporates the use of function keys to trigger a listing of status dependent responses and possible actions. The possible actions given are based on the severity of the contaminant level in the system being monitored and are based on historical and technical information from similar equipment types. Once a specific system data base is enlarged, additional environmental and performance characteristics can be evaluated and additional suggested actions can be added to the system.

4.0 Real-Time Monitoring of Moisture, Viscosity, and Wear Debris

Once a two-way satellite communications system is in place, many applications for its use become apparent. The integration of these applications should be cost/benefit driven. If the cost of any additional condition monitor is justified by a positive cost/benefit equation, it becomes a necessary expense. If the cost/benefit research for additional monitors and sensors is not completed or inconclusive, these additions may become, or may be viewed as, unneeded expensive gadgetry.

4.1 Moisture, Viscosity and Wear Debris Monitoring

The use of additional on-line sensors for monitoring other symptoms or root cause conditions can be more easily justified once the onboard computer and satellite communications equipment is in place. There are many options, and the use of sensors to monitor moisture, viscosity and ferrous debris are important to condition-based maintenance strategies. All of this real-time data can be linked to an expert system for on-board assessment of complex internal-state machine parameters.

4.2 Production Data, Temperature, Pressure and RPM

Many types of diagnostic information are easily and inexpensively monitored. The monitors used to obtain this data are normally found off-the-shelf and can be easily installed and integrated depending on priority and customer requirements. Data such as production information, that may be already transferred by other slower and more inefficient methods, can be transmitted quickly using satellite transmission, upgrading performance and asset utilization.

4.3 Messaging

If communication between manager and operator is important, text messaging systems can easily be installed. These systems are already prevalent in the trucking industry. The messaging systems not only provide a method of improving inspection capabilities and arrival time estimation, but also provide a communication link which can be used to alert operators of bad weather or of incipient problems if a contamination monitoring program is in use.

5.0 Mapping Capabilities and Real-Time Equipment Management

The trucking industry provides a good example of the use of real-time equipment management, plus the application of constant position monitoring. The result has been significant improvements in "just in time" delivery performance. As with a fleet of trucks employing satellite receivers, the railway work equipment referred to in this paper is constantly monitored for position using a software computer mapping system. This map can display individual pieces of mobile equipment as well as complete fleets. Movement histories show progression for a requested time period and also highly precise position coordinates.

This data enables the manager to attain high precision and efficiency in fleet scheduling and utilization. Because the position of the equipment can actually be seen, there is no longer a need to wait on word of mouth or telephone confirmation of position. There is also an elimination of doubt and/or miscommunication that may accompany a verbal confirmation of position.

6.0 Summary

As we progress rapidly into the communication and information age, we are faced with a burgeoning need for continuous feedback of information from the systems that we operate and the projects we undertake. As this paper demonstrates, an efficient condition-based maintenance program is clearly needed on fluid-dependent systems, including mobile equipment. The challenge of integrating the use of unattended sensor technology on mobile equipment has been met by the application of high-tech satellite communication systems used in conjunction with modern condition-based maintenance software programs.

References:

1. Editor. "Early Warning Helps Avoid Costly Repairs." **Heavy Equipment Maintenance.** April, 1989

2. Fitch, E.C. **Fluid Contamination Control.** Stillwater: FES, Inc., 1988

3. Fitch, James C. "Proactive Maintenance Can Yield More Than a 10-Fold Savings Over Conventional Predictive/Preventative Maintenance Programs." **Technical Article #1.** Tulsa, OK. Diagnetics, Inc.

4. Fitch, James C. "Step-By-Step Cost-Benefit Analysis and Worksheets for Contamination Control Investments." **Product Bulletin #6.** Tulsa, OK. Diagnetics, Inc.

James C. Fitch

Creator of the widely acclaimed proactive maintenance philosophy, James C. Fitch is a recognized authority on oil analysis and condition monitoring. His keen interest in education is reflected in the more than 250 lectures and seminars he has given on the subject in some 20 countries. Known for his controversial views, Mr. Fitch is also a frequently invited conference speaker where he has given keynote addresses and numerous technical papers.

Mr. Fitch is founder and president of Diagnetics, Inc., a leading company involved in the advancement of condition-based maintenance for mechanical machinery. Previously, his industry experience included technical positions at Monsanto, Cessna, and the Fluid Power Research Center (Oklahoma State University). At Diagnetics, Mr. Fitch's creative pursuits have led to several patented instruments currently used by leading labs and maintenance organizations worldwide. As a consultant, he has assisted numerous companies in setting up oil analysis programs, including 3M, Martin Marietta, NASA and Eli Lilly.

Mr. Fitch is a registered professional engineer and holds degrees from Georgia Institute of Technology and the University of Tulsa. He currently has authored more than 40 publications on maintenance-related subjects including the seminar text. For several years, Mr. Fitch was a member of the editorial board of *Condition Monitor Journal* where he was a contributing author and lecturer.

In the 1980's, Mr. Fitch advanced the original concept of proactive maintenance, a philosophy which now forms the cornerstone of his presentations. He presents the subject as it is applied to oil analysis, giving many case studies of its important benefits. His high-energy, unconventional presentation style consistently gets top scores from audiences.

Stuart D. Bents

Project Engineer for Diagnetics, Stuart D. Bents is responsible for

design of new products, sales/engineering communication, project engineering, project management and engineering/installation consulting for current and prospective customers. Mr. Bents has been involved in development of new instrumentation as a co-inventor and design engineer. He has also co-authored several technical articles. Previously, his experience included marketing and engineering positions at Dowell Schlumberger, an oil field pumping services company.

Stuart Bents holds a Mechanical Engineering degree from Oral Roberts University with minors in Business and Mathematics.

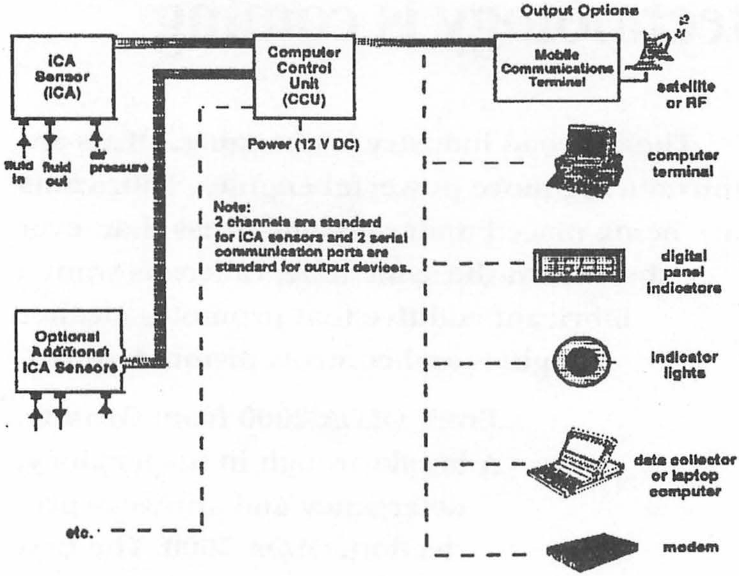


Figure 2

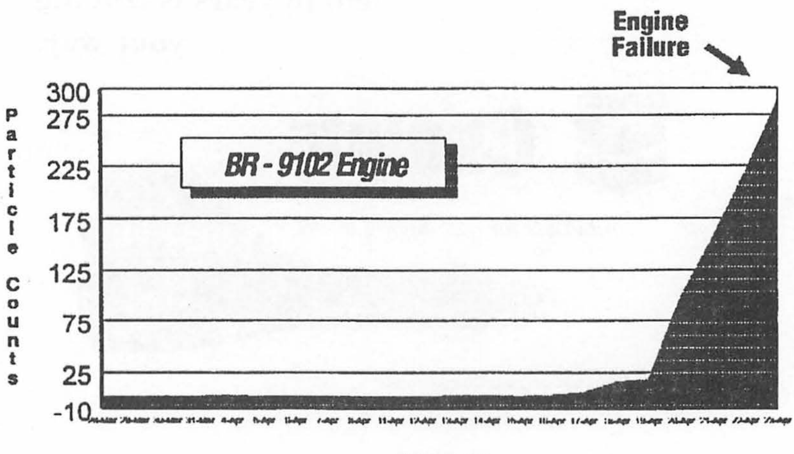


Figure 3

III. STANDARDIZED TEST PROCEDURES PAST, PRESENT & FUTURE DEVELOPMENTS

Prepared by:
Ron Lodowski, Conrail

A 1993 LMOA fuel, Lubricants, and Environmental (F, L & E) Committee paper, INSOLUBLES DETERMINATION WITH THE ADVENT OF MULTIGRADE DIESEL ENGINE OILS, dealt with a new standardized reference method that was developed to determine insolubles in diesel locomotive engine oils. The insolubles are carbon based particulate (e.g. soot) which are produced during diesel engine operation. The particulate is formed during the normal combustion of diesel fuel oil but an elevated soot level can be a further indication of a mechanical abnormality (e.g. broken rings, worn liners, improper timing). Left unchecked insoluble levels can result in plugged filters; engine sludging; and premature component replacement. The total base number (TBN or pH is a measurement of the acid neutralizing capability of the diesel engine oil additives. Extended over exposure to an engine oil with minimal to no neutralizing capabilities will result in the accelerated corrosion of soft metal surfaces. Consequently; most major North American railroads monitor insolubles and/or acid levels on a predetermined timely basis.

New pentane insolubility and acid level determination procedures were judged to be essential when a preponderance of North American railroads switched from SAE 40 single grade diesel engine oils to SAE 20W-40 multigrade diesel engine oils. The use of multigrade diesel engine oils have virtually eliminated oil drains for high viscosity, since the parafinic (HVI) base oil stocks and viscosity Index improvers (VII) limit viscosmetric increase. The down side of extending oil drain cycles has been increased soot and acid levels in the lubricating oil. Insolubles and TBN/pH measurements, more than in earlier years, must be used to determine when the diesel engine oil has reached its serviceable life span.

The annual lubricating oil round robin survey conducted by the National Association of Railroad and Environmental Testing (NARET) reveals the sample test procedures being used to measure these properties vary greatly from laboratory to laboratory, and not surprisingly so did test results. In an effort to produce uniformed industry data that could be used in addressing potential problems, the F, L & E Committee developed a standardized insolubles test method in 1993 and is currently analyzing its correlation to screening test procedures. In addition, a study of current alkalinity measurements and metal corrosion has been initiated. This paper will highlight past and outline current and future efforts by the committee in these regards.

1993 LMOA Insolubles Test Procedure

The first section of this paper covers the implementation and benefits of the 1993 LMOA Insolubles Test Procedure (ITP). The test procedure has been adopted by the General Electric Transportation Services Group as their standard and is listed in MI-00128C. For a new method to become an industry standard, it must offer some advantage (e.g. be faster, cheaper, or provide diagnostic benefits). After development of the 1993 LMOA ITP a survey was sent to eleven major railroads, two diesel engine manufacturers, and four lubricating oil additive suppliers in order to determine its acceptance in field applications. A satisfactory cross section of eight railroads, one diesel engine manufacturer, and three additive suppliers replied.

Comments in the survey stated that use of the test procedure would require most railroads to purchase additional equipment and to add analytical staff. The laboratories that had performed the 1993 LMOA ITP found that it took from four minutes to forty minutes per sample. Therefore, most of the respondents concluded that the 1993 LMOA ITP might be too time consuming to be run on a routine basis. Additionally, the method does produce a low flash point waste that requires disposal. Most of the survey respondents who have worked with the 1993 LMOA ITP did state that the results showed less variability than their current methods. This conclusion, by itself, more than justified the time and effort which committee members expended in the development of the 1993 LMOA ITP. For the first time in decades, the industry has a standardized reference test procedure that has exhibited acceptable repeatability.

Many of the railroads are using GE's general guideline located in GEK-76417C based on Type of Service to regulate oil the useful diesel engine lubricating oil life. Based upon GE's type of service guideline oil life is in the range of three to six months and appears to have virtually eliminated all oil changes for elevated insoluble levels.

One major western railroad's experience since adopting the 1993 LMOA ITP method indicates benefits of sufficient magnitude to justify the additional time, effort, and expense to use the procedure on a routine basis. The railroad reported that it cost approximately $2,000 per laboratory for the additional equipment necessary to run the 1993 LMOA ITP and that one technician can run 54 samples in eight hours. They began utilizing the method on May 1, 1994 on their fleet of 800 GE locomotives. Inspection of these GE locomotives revealed that approximately 35% had various mechanical problems including scored liners and broken rings. These varied mechanical problems were the root cause of a significant majority of the elevated insoluble readings. Subsequent to this change, the railroad used a centrifuge method with 3.5% pentane insolubles as their condemning limit. The fact that a 35% mechanical defect situation was detected by the 1993 LMOA ITP indicates that the previously used centrifuge method was incapable of removing the extremely small particulate present in used lubricating oil and actually not an accurate method to monitor field conditions. Another major benefit of the 1993 LMOA ITP method is to catch the problem before it causes a catastrophic failure. Considering GE's general guideline found in GEK-76417C, and with the help of an F, L & E subcommittee, the major western railroad is currently involved in finding a quick insolubles screening test and determining a correlation to the 1993 LMOA ITP. Until such time that a screening test is chosen the major western railroad is planning to not perform insoluble testing monthly and to wait at least 30 days after an oil change before running the insolubles procedure.

In summary, use of the 1993 LMOA ITP has improved one railroad's ability to detect mechanical defects prior to their causing extreme wear and/or catastrophic failures. The 1993 LMOA ITP is encouraged to be utilized during projects, such as locomotive lubricating oil field approval tests and railroad product approval procedures, where repeatable standardized pentane insoluble test results are critical. Additional costs for equipment and labor may be required to fully implement this method; however the results obtained by the major western railroad appear that the pentane insolubles test method is a cost effective ingredient in a regularly scheduled preventative maintenance program.

TBN/pH versus Soft Metal Corrosion

The STANDARD TEST METHOD FOR BASE NUMBER DETERMINATION BY POTENTIONMETRIC TITRATION ANSI/ASTM D4739-87, standard test methods ANSI/ASTM D664 and ANSI/ASTM D2896 are accepted industry procedures for the determination of basic constituents in petroleum products and lubricants. By its own admission in Section 1. **Scope** Subsection 1.2. ANSI/ASTM D4739-87 in particular states; "No overall relationship is known between bearing corrosion or control of corrosive wear in the engine and base number".. What this simply means is as an industry we have no definitive idea what effect, concerning concentrations or time, the organic and inorganic acids present in lubricating oils have on medium speed diesel engine bearing surfaces. We are governed by manufacturer recommendations based upon best accepted practices. Practices which if followed faithfully should prevent a vast majority of catastrophic diesel engine failures. Are the current methods acceptable? Absolutely. Is there a better way to do things? Possibly. Considering this "possibility" the F, L, & E Committee has initiated a three step procedure to address the statement in ANSI/ASTM D4739-87.

1. An analysis of current, accepted methods of TBN/pH determination. Which procedures are being used? How do they relate to corrosion on metal surfaces; that is, actual metallic weight loss on bearing surfaces? How does one measure bearing loss? Which is the most acceptable method of oxidizing diesel engine lubricating oil in order to enhance the acids present in used oils? Do any of the current procedures indicate an acceptable correlation between method of measurement and bearing corrosion? Is the procedure quick? Is the procedure inexpensive? and,

2. Is a "new" test procedure necessary? If the conclusion is reached that a "new" test procedure is necessary because no current methods provide adequate correlation a standarized test procedure will be developed and,

3. How does the "new" test procedure correlate to actual metallic weight loss on bearing surfaces? Is the procedure quick? Is the procedure inexpensive?

A subcommittee is currently progressing with Step 1. Lubricating oil samples have been collected, current alkalinity tests are being reviewed, and each of the tests is being analyzed to determine if the procedures reveal any promise of showing the corrosiveness of an oil. Questions have been raised if the oil samples are corrosive enough and if an inert atmosphere should be used during corrosion testing. At this moment there is no definitive correlation between results given by current test methods and corrosive bearing wear.

Conclusion

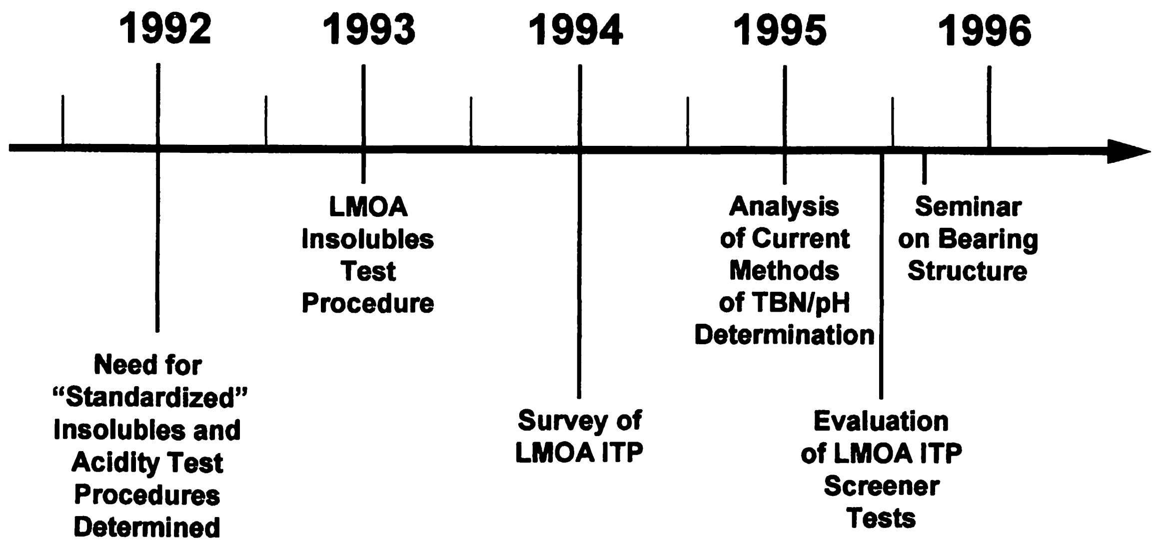
If the subcommittee continues to meet on a regular basis a functional correlation between corrosion and a current or new procedure will be determined. Likewise, the pentane insoluble screening test will be developed or chosen from current candidates.

However; since other committee members normally work on distinct papers it will take many years. In the meantime; numerous preventable catastrophic diesel engine failures might occur. Therefore, what is being proposed is to fully utilize the total efforts of the F, L & E Committee in addressing this question. A concerted "team" effort to address these undertakings. To change the direction of the F, L & E Committee to one of research and development at this time from its usual path of dissemination of information. Consequently, the LMOA will not afforded the luxury of the numerous papers created by the F, L & E Committee; except for writings developed by non-committee members addressing lubrication or environmental topics. An annual *committee update* will be presented outlining the projects' accomplishments, pitfalls, and current direction. What the railroad sector will have for its endurance is a definitive study on the relationship between corrosion and bearing wear and a quick and easily pentane insolubles screening test. We sincerely believe that it will be worth the effort.

Acknowledgement

The committee would like to express its appreciation to Mr. Ronald Schmisseur for his diligent effort in preparation of the outline relating to insolubles testing.

F, L & E Committee Project Status



IV. LOCOMOTIVE EXHAUST EMISSIONS REGULATIONS

G.R. CATALDI
ASSOCIATION OF AMERICAN RAILROADS

The federal Clean Air Act requires the U.S. Environmental Protection Agency (EPA) to regulate new locomotive engine emissions and preempt state regulations of such emissions. The law requires EPA to complete its rulemaking by November 1995, but it will be late by at least half a year. They have not yet published a notice of proposed rulemaking (NPRM) with a complete draft regulation for public comment.

Because EPA has been working with the railroads and engine manufacturers since 1992, we have a very good idea of what will be in the NPRM. This update to the LMOA covers the main points that we expect in the EPA proposal and provides some comments on how the regulations will impact railroads.

Legislative and Regulatory Review

Congress revised the federal Clean Air Act in 1990. The amendments gave EPA much broader authority to regulate emissions from industries of all kinds. Congress decided to put railroad locomotives into a special class by themselves. There are two principle differences between locomotives and other off-highway mobile emissions sources: EPA was given five years (instead of two for all other mobile sources) to promulgate locomotive regulations and new locomotive engines are preempted from state regulation.

EPA seems to be perpetually behind in regulatory rulemaking, and is late with the locomotive rules. In 1994, EPA outlined proposed locomotive regulations as part of a Federal Implementation Plan (FIP) for three areas of California. The outline, plus more recent interaction between the railroads, manufacturers, and EPA, provides the basis for this paper. A key part of the FIP, which largely followed a proposal by the Class I railroads serving California, was a requirement that the locomotive fleets used in the Los Angeles basin by the year 2010 have average emissions equal to the regulatory limits for engines manufactured from 2005 onward. In other words, unless older locomotives could be made to meet the 2005 standards, only locomotive engines manufactured after 2004 would be usable in Southern California.

EPA's Expected Proposal

Probably the most important feature of the EPA proposal, and the most difficult feature to get all EPA officers to sign off on, is the idea of classifying the currently fleet of engines as "new" when those engines are remanufactured. Those resulting "new" engines will have to meet emissions limits, but those limits will be less restrictive than those that will be in place for "freshly manufactured" engines. At this time, EPA is planning on three groupings of engines starting in 2000. First, those engines originally manufactured from January 1, 1973 through December 31, 1999 will have to be remanufactured starting in 2000 (it isn't clear whether EPA will require the remanufacturing to be completed on all of those engines by any specific date) to meet the retrofit emissions limits. Those engines freshly manufactured from 2000 through 2004 will be "phase I engines" and will have to meet somewhat more stringent standards than the retrofit engines. Those engines freshly manufactured starting 2005 will be "phase 2 engines" and will have to meet more

stringent emissions limits. Whenever any of these engines is remanufactured in the future, they will have to meet the standards in place at the time of original manufacture or remanufacture.

EPA's idea of "remanufacture" is different than what we normally think of as remanufacture. For engines originally built to 2000, this term will simply mean that some change is made to the engine which results in changed emissions levels and those levels can be expected to continue for a long period of time. Most EPA remanufacturing will probably be done during engine overhauls, which may be heavy or light. 1973 through 1999 engines will probably not receive components that are not already on the engines. Instead, there will probably be replacement parts for those already in the engines, such as higher capacity aftercoolers, different fuel injectors, and possibly changes in power assembly components like piston rings.

Engines that are "freshly manufactured" starting in 2000 will eventually have to be remanufactured, which will require bringing those engines back to as-new emissions levels. Again, there probably will not be any requirement for changing the engine configuration.

EPA will regulate oxides of nitrogen (NOx), hydrocarbons (HC), carbon dioxide (CO), particulate matter (PM), and smoke opacity. A simplified summary of the expected EPA proposed standards is contained in Table 1. EPA proposed duty cycles are contained in Table 2. Besides establishing a limit for a weighted duty cycle, EPA will propose limits at every throttle notch. This would be a new level of regulation that EPA does not require of other industry sectors.

All freshly manufactured engines as well as "kits" for remanufacturing engines must meet EPA certification procedures. EPA will propose a specific test sequence using specified instruments and require that sample engines produce less than the emissions limit of every emittant at every throttle position and on the weighted duty cycle. The certification process is very involved for sectors that EPA regulates and EPA's enforcement staff are not planning to make significant exceptions in the process for locomotive engine and kit manufacturers.

A single failure to pass the emissions test will not be catastrophic, but will lead to a requirement for testing a larger sample of engines until the manufacturer can show that the engines or kits really do meet EPA standards. If there are more failures during this effort, the manufacturer may lose his certificate. That will put him out of the locomotive engine manufacturing business until he can get recertified. The railroads have asked EPA to include a "grace period" in which non-compliant engines can be sold to the railroads and upgraded later. EPA is taking this under advisement. EPA is inclined to allow railroads to continue installing kits that they have on hand even though the manufacturer of the kit may have lost his certification.

While the OEMs are expected to develop and sell retrofit kits for their post-1972 engines, it is not clear yet whether anyone else will develop retrofit kits for those engines. Any entity that wants to become a kit supplier can get into the game. It is possible that one or more railroads may develop kits for their own use and possible sale to other railroads. Some aftermarket suppliers may form partnerships to develop, certify, and market retrofit kits. There have been some discussions along these lines and will probably be more in the future.

An important consideration for manufacturers is the fact that if EPA sticks to its year 2000 target for startup of the emissions regulations, there is very little time to design, test, develop prototypes, work the bugs out, certify new engines and kits, retool, and stock up to be ready for January 2000. Unfortunately, any manufacturer that waits for EPA to finalize their regulations before starting the R & D effort needed to meet those regulations may not be ready in time.

We expect the manufacturers to ask EPA to push back the startup date for the regulations by one or two years because of the delay in getting EPA's NPRM published. Although the manufacturers have an excellent case, EPA is up against political pressure from the state of California and some environmental advocacy groups to move ahead on this regulation.

First, the Good News

There are some things that will alleviate the impact of EPA's locomotive emissions regulations. If the federal preemption proposal stays in the regulation, railroads will be able to operate their locomotives everywhere in the United States without restriction, except in the Los Angeles Basin. And the Los Angeles fleet average requirements would not go into effect until 2007 or later. Except for Los Angeles, pre-1973 locomotives would be allowed to operate freely.

Another helpful feature of the EPA proposal will be the ability of manufacturers to "Average-Bank-Trade" (ABT) emissions credits. Any engine family that produces less than the EPA emissions limits would gain "credits". Credit holders could then use those credits to offset any engine family that could not meet the EPA emissions limits by averaging the fleets. Therefore, no "failing" engine family will be automatically barred from use as long as the certificate holder can obtain credits from other engines. A certifying company can average within its own engine lines in a single year or put credits in the "bank" for future production needs. Companies may also "trade" credits. A "trade" probably will be a cash sale, but could be some other arrangement. EPA doesn't care how the traders renumerate each other. They want to do their job and clean up the air.

EPA recognizes that railroads remanufacture engines on a schedule that is made up well in advance and locomotive assets cannot sit around waiting for EPA and the kit manufacturer to work out problems with certification. Railroads usually have parts on hand well in advance of heavy overhauls. EPA will let railroads install retrofit kits even if EPA has withdrawn certification for those kits. Any problems will have to be corrected, but EPA will allow the railroad to continue operating the locomotive. Typically, the correction will not have to be done until the locomotive is in the shop for scheduled inspection and maintenance.

Emissions Measurement Requirements

EPA requires new engines to be tested by the manufacturer on a sample basis as the engines come off the production line. EPA will propose that a sample of remanufactured engines be tested to assure that kits continue to meet certification limits. Further, EPA plans to require retesting of sample engines through the engines' lives to assure that there is not excessive deterioration of the emissions.

So far, EPA insists that these "field tests" of engines mounted in locomotives be as stringent as production line tests. Even the production line testing is difficult to do, especially on large engines. In the field, the tests will be very expensive and the results more variable than that done in well-controlled factory settings. Emissions levels are affected by humidity, ambient temperature, and barometric pressure. These are hard to control in a factory and nearly impossible in the field. Worse, the "correction factors" EPA uses to compensate for these variables are known by EPA and engine manufacturers to be incorrect. Manufacturers simply get around the problem by conducting certification tests at standard EPA reference conditions. It will not be possible to hold locomotives until such conditions exist at the shop.

AAR has worked with Southwest Research Institute on measuring locomotive engine emissions since 1987 and the results of field testing are highly variable and difficult to obtain. A complete testing laboratory that will meet EPA requirements will probably cost at least $500,000 to assemble and debug. A qualified scientist will have to manage the laboratory and the technicians who will run it will have to be trained. It isn't clear yet that the railroads will want to take on the responsibility of conducting emissions tests at their shops. One or several commercial labs may end up doing the work for the manufacturers and railroads. Unfortunately, that would take the sample locomotives out of service for extra days to be in transit and standing by at the laboratory.

EPA has proposed that a sample of 2% or less of freshly manufactured and remanufactured engines be tested at the time of manufacturer/remanufacture and annually during a "useful life" period. But at the end of that useful life, if a railroad wants to keep running the locomotive without remanufacturing it and bringing it back to original condition, the railroad would have to conduct a full certification test on that engine and repeat the test annually to show that is is still in compliance. This would not be a sample, but would be required on every engine. EPA is proposing a fairly long useful life period, such as 900,000 miles. For some railroads, this could someday become rather costly as a significant fraction of their fleets may exceed that mileage without showing enough signs of deterioration to justify overhaul.

Impact on Engine Overhauls and Maintenance

All engines built after 1972 will eventually have to be remanufactured, probably several times. These vents will probably occur when heavy overhauls would happen anyway. That won't be true for all engines, especially switchers and the lightest road switchers that may currently go for 10 or 15 years between overhauls. The initial remanufacturing period for 1973-1999 engines might cause a speedup in the schedule for these engines. The railroads have not figured yet how many switchers/light road switchers would have to be remanufactured ahead of normal schedule if EPA mandates a complete fleet remanufacture by some deadline date.

Of perhaps greater concern is the fact that all remanufacturing of these 1973-1999 engines, as well as 2000 and later engines, is the fact that all kits used at the time of overhaul-remanufacture must be certified by somebody. The railroads must buy whole kits or they must buy components and parts that someone certifies in some way. Parts will probably be more expensive. Also, in the first years of the remanufacturing period, there may not be retrofit kits available for some engine models.

The railroads have never been forced by regulators to overhaul diesel engines on a scheduled basis. While engines in line-haul locomotives normally receive heavy overhauls at least

every seven years, railroads have been free to postpone overhauls if they wish. Evidently, this will change.

As with overhauls, railroads will have to replace parts and components with certified parts and components after the remanufacture or fresh manufacture starting in 2000. Railroad shops will not be allowed to change the engine setup (injection timing, etc.) from the requirements of the manufacturer. Such changes would be "tampering" and against the law.

The manufacturer will specify maintenance schedules and parts replacement schedules that railroads will have to follow. Failure to follow such schedules could result in a loss of EPA warranty and make the railroad responsible for the emissions levels.

Impact on Railroad Operations

EPA is considering a requirement that railroads use low-sulfur fuel like the requirement for on-highway diesel engines. If this requirement gets into the regulations, the American Petroleum Institute estimates that the cost of locomotive fuel will be about 3 to 5 cents per gallon higher. That isn't the same as the price to the railroads. Some of that cost would probably be swallowed by the refiners and passed on to other customers. Still, the railroads would pay some penalty. Since the railroads contribute only about one-tenth of one percent of all particulates going into the atmosphere, any fuel specification requirement would be hard to justify. The railroads plan to object strongly to a low-sulfur fuel requirement.

While EPA is likely to preempt the states from regulating engine emissions limits, they are so far refusing to consider preempting the states from establishing operating restrictions. Therefore, a state could impose idling restrictions or speed limits if the state thinks that such regulations would reduce emissions from railroads.

Who's Looking Out for the Railroads?

The railroad CEOs instructed AAR to establish a high-level policy group to steer railroad policy with EPA and California air quality agencies, which AAR calls the Emissions Lead Representatives. Most of these Lead Representatives have representatives of their Mechanical Departments assigned to help understand the technical issues. All AAR departments have staffers assigned to this problem, led by Michael Rush in the Law Department. The Research & Test Department's Dick Cataldi manages research to provide the Lead Representatives with timely technical input to the regulatory process. The other departments contribute expertise as needed.

TABLE 1.
SUMMARY OF EPA PROPOSED LOCOMOTIVE EMISSIONS LIMITS
(Units are grams per brake horsepower-hour)

Type of Service:	Freight/Passenger Duty Cycles			Switcher Duty Cycle		
Year Originally Built:	1973-99	2000-04	2005-??	1973-99	2000-04	2005-??
Emittant						
Hydrocarbons HC	0.9	0.55	0.3	1.8	0.75	0.3
Carbon Monoxide CO	4.8	2.2	1.5	6.1	2.5	1.5
Oxides of Nitrogen Nox	9.5	7.4	5.5	14.1	8.5	5.5
Particulate Matter PM	0.6	0.45	0.2	1.0	0.6	0.2

Notes:
1. these are the limits for engines operating on diesel fuel oil. Different limits are proposed for CO from natural gas engines. Aldehyde limits are proposed for alcohol-fueled engines.
2. EPA has proposed individual throttle position limits for each emittant in addition to the duty cycle weighted limits.
3. EPA has proposed smoke opacity limits for each throttle position, including the time in transition from the next lower throttle position and averaged over a period of time not yet determined.

TABLE 2.
EPA PROPOSED ENGINE DUTY CYCLES FOR CERTIFICATION

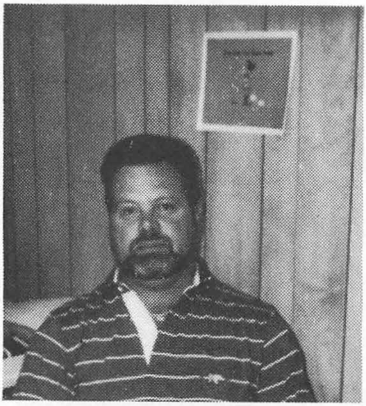
Throttle Notch	Freight	Passenger	Switcher
Low Idle (1)	19.0%	24.9%	28.3%
Idle (1)	19.0	24.9	28.4
1	6.4	7.2	13.1
2	6.4	4.7	13.1
3	5.2	5.0	6.3
4	4.5	4.3	3.9
5	3.9	3.9	4.0
6	3.9	2.7	1.7
7	3.0	1.4	0.3
8	16.2	15.0	0.9
Dynamic Brake	12.5	6.0	0.0

Note:
(1) If the engine is not equipped with "low idle", combine low idle with idle, eg. freight idle weighting would be 38.0%.

REPORT OF THE COMMITTEE ON DIESEL MATERIAL CONTROL

MONDAY, SEPTEMBER 11, 1995
1:45 P.M.

Pre-Convention Presentation Canadian Pacific



June 8, 1995 Palliser Hotel Calgary, AB Canada

WILLIAM LECHNER, Chairman
Mgr. - Material Control
Conrail
Altoona, PA

Vice Chairman
BOB CORDER
Director-Material
VMV
Paducah, KY

COMMITTEE MEMBERS

A. Chapman	Asst. Mgr. Inv. Cont.	CSX Trans	Waycross, GA
A. Chermak	Asst. Dir. Mat. Mgmt.	Wisconsin Central	Fond Du Lac, WI
M. Dinius	Mgr. of Material	Montana Rail	Missoula, MT
R. Faulconbridge	Manager-Materials	CP Rail	Montreal, PQ
R. Florczyk	Mgr-Loco. Parts Sales	General Electric	Philadelphia, PA
J. Minnie	Manager-Material	Burlington Northern	West Burlington, IA
L. Murphy	Mgr-Supply Opns.	Union Pacific	N. Platte, NE
H. Nash	Director-Mktg.	Montana Rail Link	Missoula, MT
D. Rhyne	Matls. Analyst	Electro Motive	La Grange, Il
R. Swenson	Managing Div.	Gen. West	Pueblo, Co
R. Tobin	ACMO-Admin.	Long Island	Hollis, NY
W. Wewers	Equipment Supvr.	AT&SF Rwy. Co.	Topeka, KS

PERSONAL HISTORY

William Lechner

Bill Lechner began his railroad career in 1977 as a clerk with Conrail in the Transportation Department at Trainmaster's Office in Hollidaysburg, PA. Later he transferred to Mechanical Division and held several positions in Stores Department and promotions followed: Supervisor Production Control (1980); Manager of Material and Production Control (1992); General Foreman of Air Brake Shop (1993).

Bill graduated from Altoona Area High School (1966), and is also a graduate of Penn State University (1972). Attended many schools for computer training throughout career, and many technical schools for railroad training.

Bill and his wife Debbie have two children: Wendy Jo, 21, and Todd William, 19, and both are currently attending Penn State University. They currently live in Altoona where Bill is Manager Material and Production Control and also General Foreman of Air Brake Shop for Conrail.

LMOA wishes to express its thanks to the Canadian Pacific for hosting and participating in the Pre-Convention Presentation of our Material Control Committee in Calgary, Alberta.

The interest exhibited was gratifying.

I. WARRANTY AND RELIABILITY MANAGEMENT

Prepared by:
Alan Chapman, CSX

Our Materials Control committee has presented various themes on the importance of warranty and reliability control for the last three years. The reason for this is very simple. Warranty and its equally important cohort, reliability is just that crucial to your railroad's overall operations and subsequent profitability. With today's emphasis on more effective maintenance control and Purchasing's interest in choosing the best vendors, effective warranty and reliability management is a must. In fact, the National Association of Purchasing Managers (NAPM) Rail Industry Group presently has a committee dealing with the issues of warranty, part and component marking, vendor notification, etc. and the standards are now being finalized.

But do not think the railroad industry is being singled out here today. The airline industry, through its Air Transport Association, has already completed a very sophisticated set of standards for its members. ATA has also tied in the aircraft components that have to be tracked by certain FAA standards.

By definition, a warranty is a written guarantee and contract as to the integrity of a product and contains a clear definition of the manufacturer's responsibility for the repair, including both labor and materials, or the replacement of a defective item or parts thereof.

One railroad in particular has done a significant amount of work to successfully address the issue of warranty control and I would like to talk about the CSX program today. While the program does require a full commitment to assigning various personnel to handle the program full time, it has more than paid for itself in warranty capture dollars and other related savings.

The program was implemented by the CSX Mechanical Operations department, and comprehensive inhouse training programs were designed to familiarize all employees with the process as well as to define the duties of each individual involved with the warranty process.

A major key to the success of any warranty and reliability program is the method of determining whether or not the component is still covered under warranty. The warranty committee of the NAPM spent considerable time addressing this important issue and has developed specific standards as to marking various designated parts on locomotives and freight cars. A final design was made on a tag type of system to be affixed to these parts. In fact, space on these tags will be available to utilize automated identification technology when a railroad decides on a more automated process of warranty tracking and obtaining reliability history information.

Warranty period identification can be accomplished by a number of methods including:

(1) metal information plate

(2) label or tag made of plastic, composite material, or even laminated paper

(3) etching, laser engraving, stamping, printing, painting, baking soda blasting, etc.

(4) bar code (one or two dimension) or microcircuit transponders (also called a memory button or tag).

CSX utilized a warranty tag approach, and to simplify the process further each supplier is required to display the vendor name, CSX classification, item number, date of manufacture, and expiration date of warranty on each part or component. By requiring this type of identification, it is easy to determine which parts and components are under warranty, and the CSX employee removing the part can make a quick and easy disposition of the part.

CSX employees specifically assigned and dedicated to the warranty process are responsible for processing and resolving each warranty claim. In order to initiate this warranty claim a three part tag is being used. It is the shop mechanic's responsibility to start the warranty claim by properly tagging the part. This portion of the process is most crucial to the program's overall success, and the mechanic must be properly trained to initiate the process. The variety of data required on the tag includes the following information:

1. date of removal
2. car or locomotive unit number
3. component description
4. shop location
5. serial number, if any
6. reason for removal
7. position of part
8. class and item number.

Once the mechanic completes the warranty tag and attaches it to the part, it is then placed in the designated holding area for warranted items.

At each of the major CSX shops, a full-time warranty officer is responsible for processing and resolving each warranty claim. The tasks completed by a warranty officer include:

(1) process all warranty claims initiated by the mechanics
(2) obtain an authority for adjustment (AFA) from vendor
(3) participate in joint user/vendor part inspections
(4) assign warranty purchase order numbers
(5) complete Part Two of warranty tag and notify stores that part is ready for packaging and shipment to vendor
(6) maintain a file on all warranty claims by purchase order number
(7) follow up with stores to finalize and close all claims as well as verify that all credits on part replacements are properly received.

Warranty Claim Status Feedback

Feedback on each CSX warranty claim is currently input manually into the tracking system by the warranty officers. Manual data input consists of the following:

(1) date of warranty claim disposition
(2) warranty claim acceptance or denial or N.T.F. (no trouble found)
(3) the determined course of failure
(4) receipt of credit or part replacement
(5) preparation of monthly warranty status reports and any follow up reports to the plant manager.

Summary of CSX Warranty Process

(1) The Mechanical department has completed work with both the Supply department and Services Management department to improve on-line capability for improved data retrieval and in a manner to allow a wide variety of cross references.

(2) The CSX warranty program is now being used by all departments of CSX to route non-conforming material back to the appropriate supplier.

(3) The feedback from the process will provide CSX objective measurement of supplier performance and ensure that the railroad will make efficient use of both purchasing and inventory control.

(4) The CSX process assists both CSX and suppliers in determining the cause of failure and the corrective actions taken on non-conforming material.

This will result in improved part performance and reduced part usage.
(5) The only limitations to the success of the program could come from failure to have all applicable employees comply with the warranty guidelines as set forth in the program manuals, or from a lack of proper administration of the program.

One added feature of the CSX program is that the successfully completed warranty claims once approved by the vendor will be credited back to each shop and be deducted from the original purchase order expense.

How Reliability History or Life Cycle Analysis Fits into Warranty Management

While a good organized warranty management program should be a top priority for any railroad, whether it be a Class I, regional, or shortline, even more important is a comprehensive "life cycle analysis" program which, of course, includes warranty management. In other words, warranty management is but one slice of the larger pie called life cycle history and analysis. Many industries including the airline industry, U.S. Department of Defense, and others address their parts and components from three interrelated categories:

(1) reliability
(2) availability
(3) maintainability.

In other words, just like the railroad industry, the Department of Defense wants its equipment to be highly reliable, to be available for service where and when wanted, and to have a high degree of maintainability at a low cost. By utilizing a data base information system and providing it with timely and accurate maintenance and repair information, a reliability data base can be easily developed. However, it is important to indicate that the data must be complete and accurate and the system must be easy to use and fulfill the user's needs. By using such a program, the DoD is able to achieve a higher degree of reliability improvement of existing equipment.

New computer data base development techniques and more sophisticated software tools have allowed the creation of a new, popular process called reliability centered maintenance (RCM) which optimizes a preventive maintenance program by matching a component's failure characteristics to an effective maintenance technique. A reliability centered maintenance program begins with an RCM analysis where one of the things reviewed is to determine whether performing or not performing a preventive task is actually justified with analytical evidence.

In order for any industry, ours included, to attain a high degree of high reliability, improved availability, and maintainability at a lower cost, a number of elements are necessary. These include:

(1) high quality parts and components
(2) a robust and sturdy design of parts and components
(3) good manufacturing and assembly practices by the vendor
(4) a suitable inventory of spare parts and components
(5) a good maintenance infrastructure along with good policies and procedures.

By having a good maintenance database with accurate and reliable information, a variety of features can be realized, including:

• accurate warranty claims
• data for reliability improvement
• a reliability baseline for better vendor selection
• data for spare parts inventory optimization

- data for improved design optimization by identification of failure modes
- a baseline for preventive maintenance optimization
- statistical information to estimate availability and reliability of both existing and future parts and equipment.

Equally important to being able to obtain and maintain good reliability information on a railroad's locomotives and other pieces of equipment by the methods and business processes mentioned earlier, are two other business process methods originally developed by the U.S. Department of Defense.

First is a process called a failure mode and effect analysis or FMEA in DoD terms. Basically, this is design evaluation procedure used to identify all conceivable and potential failure modes and to determine the effect of each on system performance, i.e. for example, the effect of an armature failure in a traction motor or a clogged injector in the locomotive engine. A criticality rating is then developed for each failure mode and the resulting effect. Once the FMEA is completed several other processes can take place in order to achieve the reliability centered maintenance process.

- determine if a failure pattern exists through statistical analysis of failure histories
- match applicable and effective maintenance task types to preventable failure modes
- use a conservative default logic approach if any uncertainty exists
- continue to collect failure data to remove uncertainties in the RCM process.

The other DoD program is a failure reporting, analysis, and corrective action system, or FRACAS. This program is seen by many as one of the most effective reliability improvement techniques, especially for vendors and manufacturers. It is considered as an essential element in the early and sustained achievement of the reliability and maintainability potential inherent in equipment, systems, and even any software that drives them. The essence of a closed loop FRACAS is that failures and faults of both hardware, and any related software, are formally reported, analysis is performed to the extent that the failure cause is understood, and positive corrective actions are identified, implemented, and verified to prevent further recurrence of the failure.

A well run FRACAS program has been identified as a hallmark of Malcolm Baldridge award winners and a corrective action tracking program is a key element to obtaining ISO 9000 certification.

Railroads can use a FRACAS program in conjunction with their vendors in that the railroad can use the program for field return tracking and the manufacturers can use it for that purpose as well as for manufacturing defect tracking.

Benefits of FRACAS include:

- an efficient process to systematically identify and analyze failures and defects
- an estimate of product reliability, manufacturing yield statistics, or other quality metrics
- development, management, and verification of all corrective actions.

Specific analysis and reporting features include:

- correct calculation of statistics, such as field reliability estimates
- Pareto analysis of select data fields to identify "heavy" contributors to failures, defects, returns, etc.
- failure mode and corrective action status reports
- vendor quality reports
- returned items reports.

In summary, by instituting a number of proven and established processes, i.e. by utilizing some business process, re-engineering steps in the areas of warranty and reliability information through your already existing maintenance data program, a significant return in value can be achieved by any railroad, regardless of size.

As just two examples, one major Class I railroad has said that within two to three years of instituting a warranty and reliability management program, it conservatively estimates that it can have an additional availability of 15 locomotives per day, or 1/2 or 1% of their fleet size.

Another Class I rail system has indicated that it can obtain an estimated $750,000 per year in warranty claims it is not presently claiming because the claims "fall through the cracks" of the present system.

The NAPM standards are expected to be set soon and these will go a long way in promoting good warranty management for every railroad adopting such standards. By adding reliability tracking management through such processes as FMEA, FRACAS, and others, complete life cycle history analysis, i.e. "the total pie," can ultimately be achieved.

II. RIG EXCHANGE STANDARD FOR PARTS CATALOG INFORMATION

For the past two years the Diesel Material Control committee has highlighted the benefits of "electronic catalogs" in its presentations. Momentum to implement electronic catalogs is continuing to build. In October of 1994 a Railroad Industry Group (RIG) task team issued a RFQ to develop a standard for the exchange of parts catalog information. This standard will make possible the efficient implementation of electronic parts catalogs (EPC's) as well as make it possible to directly disseminate OEM parts information to other rail applications such as inventory and purchasing. This paper will briefly juxtapose electronic parts catalogs (EPC's) with traditional paper parts catalogs to help position one of the main benefits of the standard: the deployment of EPC's. It will also describe the elements that comprise the standard and the functionality supported by the standard.

A paper or "hardcopy" parts catalog has two categories of problems, or at least disadvantages, when compared to electronic versions. The first category is its users and the abuse paper documents endure at their hands. For instance, what assurance do you have that documents are correctly re-filed once used? If a particular piece of documentation is deemed valuable is it likely to disappear into someone's private library? Every time a publisher issues a revision, are revised pages inserted and old pages removed - in every copy? How do you make documentation readily accessible and yet protect it from neglect and abuse?

The second category is the difficulty of extracting and communicating information contained in a paper document. Assuming that the tradesman can find the required documentation, he must next search the documentation for the parts information and write the numbers on a piece of paper or key them into a system, which is the first occasion for the numbers to be incorrectly recorded. This information is then given to a maintenance planner or to a parts crib attendant to translate the OEM numbers into the supplier's part numbers and key these numbers into a work order or inventory application.If the parts need to be ordered, the purchasing department now has a turn at massaging the information with additional part number lookups. Finally the order is sent to the supplier. And because the railroad company is dealing with "hard copy" it may not have the latest parts information and the supplier must further massage the order before sending out the part(s). The bottom line is that this is all very costly in time and manpower.

An electronic parts catalog makes it possible to solve all of the limitations associated with a paper catalog. Briefly, users cannot abuse an electronic parts catalog. Electronically viewing a document will never result in its being misfiled or becoming worn. Images of its pages are always available to as many as want to view them - even simultaneously. Updating catalog information is done electronically - updating one file updates every copy in your library. Part numbers need not be re-keyed from one system to the next. The electronic parts requisition list can electronically flow through the entire order process. The functionality provided by an EPC is much greater than that provided by a hard copy version. Typical functionality allows a user to "click" on an image of a part and have information about that part appear (typically the part number, description, quantity required). A parts requisition list is thereby generated and fed electronically into other maintenance management functions such as work orders, inventory management or purchasing.

As much as you may support the arguments of the advantages of an EPC over a hard copy parts catalog, the time and expense involved in converting your documentation to an electronic format may have prevented you from pursuing the implementation of EPC's. Without a standard, each railroad wishing to deploy EPC's is individually responsible for this conversion. And since rail suppliers have no single specification for disseminating their documentation electronically it is unfeasible for them to offer an electronic version even though to do so could save them the added expense of publishing paper documents. The bottom line is that without a standard, EPC implementation is more costly both for the user and supplier.

These obstacles motivated the RIG task team to issue the RFQ for the development of the electronic parts catalog exchange standard (EPCES). Applied image technology (AIT), an EPC supplier, with its sub-contractor, SoftQuad Inc, a standard generalized markup language (SGML) software provider, won the bid to develop the EPCES. the purpose of the EPCES is to define specifications of the components of parts catalog information so that suppliers may provide a single electronic version and know that any rail Industry EPC or application will be able to directly import the electronic information. Thus, the EPCES will enable suppliers and railroads to take advantage of the cost savings of EPC technology and reduce the costs of importing OEM parts information into other railroad applications.

AIT and SoftQuad worked with the task team in the first phase of the development of the EPCES to define the functionality and standards specifications that would support the rail Industry's requirements. A variety of standards and their implementations in industry were considered. Two industry standard initiatives turned out to be the most applicable, the Defense department's continuous acquisition & life-cycle support (CALS), and a CALS implementation by the Airline Traffic Association (ATA). CALS and as a result the ATA, both adhere to specifications endorsed by the International Standards Organization (ISO). As the world's largest publisher, the Defense department has wrestled with and solved many of the issues related to the transmission of published material utilizing the standards specified in CALS. While reviewing other industry initiatives for part catalog specifications, it is apparent that the ATA has the most mature specification for parts catalogs. The ATA specification is currently being tested and applied by several companies. This specification includes capabilities for most major information elements identified by the task team, including part effectivity and document/data revision.

The task team identified four classes of information that comprise a parts catalog and therefore must be supported by EPCES: text, data, drawings, and images. Also, the task team specified that the EPCES provide full "point and click" functionality. In other words, the EPCES must transfer the information necessary to support a user pointing and clicking on an image of a part and thereby have the part number displayed. Each of the four classes of information (or "objects") and the "point and click" functionality are specifically addressed in the EPCES.

Discussion of the particular standards comprising the EPCES - the standard generalized markup language (SGML). SGML will in effect be an envelope for the transfer of parts catalog information. A key word in the acronym, SGML which explains how SGML works, is "markup". Most are familiar with word processors today. Word processors "markup" text. When, for example, you wish to bold a word you invoke a command that makes it appear bolded. What has occurred is your word processor marked up that word or words with code before and after the word or words you wish bolded, telling the computer to start bolding after the first piece of code and stop bolding after the second. SGML works the same way. Markup is often called tagging in SGML because SGML does not require the use of ambiguous control characters but rather user defined meaningful descriptors. For instance a part number's SGML tag might be "<part num>". SGML, you may notice, is tagging text or data or graphics with information about the information's content - not just its appearance. SGML allows you to mark a warning as a warning - a part number as a part number, a drawing as a locomotive, etc. The computer receiving an SGML document is thereby able to "understand" how to deal with the information being transferred.

Two of the four objects, text and data, will not have any treatment other than SGML. As state above, SGML provides the capability of transferring text and data without loss of any of their attributes. However, SGML cannot describe a drawing so that it redrawn or an image so that it may be reproduced. The standard selected for drawings is computer graphics metafile (CGM). CGM represents an international standard growing in popularity and support. The CGM specification today provides for the transfer of two dimensional drawings. Tagged image file format (TIFF) has been selected for the transfer of images - bitonal, grayscale and color. TIFF is readily supported by nearly all suppliers and end users, as well as the fact that other industries have successfully applied TIFF for the exchange of faster information.

One of the key advantages to electronic transmission and delivery of information is the ability to quickly and effectively navigate between physically separated but logically related information. And so, EPCES is designed to take advantage of this "hypertext" capability in allowing the publisher of parts catalogs to specify these linkages. For the consumer of catalog information, these links provide excellent traversal. SGML has such powerful linking capability that it was used as the underlying technology for defining an ISO approved standard for defining linkages between completely disparate and non-congruous SGML objects. This standard is called hytime, and will be utilized by EPCES.

The EPCES project is due for completion in January, 1996. Once the EPCES is published it will be incumbent upon the railroads to drive its implementation. In organizations with existing maintenance systems, EPCES might be used strictly as an exchange medium. When EPCES catalog information arrives at the target destination, the information would be broken down, translated and forwarded to existing maintenance systems, potentially several different systems. Other organizations may desire to use EPCES to insert documentation directly into an EPC system. Typically, in this mode, commercial software package(s) would be configured to allow an EPCES catalog to easily flow into a presentation and access environment. In either case, railroads will be the driving force, demanding that suppliers provide their EPC information according to the specifications in the EPCES.

REPORT OF THE COMMITTEE ON SHOP EQUIPMENT

MONDAY, SEPTEMBER 11, 1995
3:45 P.M.

Pre-Convention Presentation NS

June 21, 1995
Marriott Hotel
Airport
Roanoke, VA

BILL PETERMAN, Chairman
Mgr-Facilities Engineering
Canadian Pacific
Montreal, PQ

Vice Chairman
J. MUENCH
Industrial Engineer
CSX Transportation
Jacksonville, FL

COMMITTEE MEMBERS

S. Fuzail	Dir. Opns Res. & IE	C&NW Trans.	Chicago, IL
J. Gamble	Dir. Leasing	Mk Rail	Leawood, KS
J. Hunt	General Foreman	Illinois Central	Homewood, IL
D. Kisko	Cont. Mgr.	General Electric	Erie, PA
R. Lynch	Sr. Gen. Foreman	Norfolk Southern	Roanoke, VA
D. Nott	Mgr. Oper. Maint.	MK	Boise, ID
M. Scaringe	Mgr-Loco. Overhaul	Amtrak	Beech Gove, IN
T. Stefanski	Mgr.-Loco. Maint.	EMD	Alliance, NE
J. Wiesch	Gen. Mech, Frmn.	Mont. Rail Link	Livingston, MT
R. Yartin	Shop Mgr.	Conrail	Cleveland, OH

LMOA wishes to express its thanks to the Norfolk Southern Corporation for hosting the Pre-Convention Presentation in Roanoke, VA.

Our Shop Equipment Committee was well received in what we trust was a mutually beneficial experience.

I. PRE-MAINTENANCE INSPECTION

Prepared by: Joe Muench, CSXT

Inefficiencies in shop operation often occur because all work requirements for a locomotive are not known before maintenance and/or repairs begin. There are obvious benefits to knowing as much as possible about the work content before work is actually initiated so as to prevent wasted effort. Waste may include extra switching, repairs progressed on components that are subsequently disqualified from service, increased detention time of locomotives and inefficient or wasted shop labor.

One strategy that maintenance forces have utilized to effectively identify the work requirements is to incorporate a pre-maintenance inspection into their process. The pre-maintenance inspection serves a similar function to the medical strategy of triage. Triage is a process that serves to sort injured people into groups based on their need for medical attention. Pre-maintenance inspection allows early identification of locomotive requirements so that they best be matched to the facility's resources. The pre-maintenance inspection is especially beneficial to a large facility that features several dedicated work stations like wheel truing machines, traction motor drop tables and filter change stations.

Inspection procedures include dynamic or running inspections like load testing and static inspections including most FRA required inspections. Some noteworthy inspection strategies include: the qualification of components based on their vibrational signatures, water pressure test methods that incorporate treated water recycling systems, electronic gauging of locomotive wheel dimensions and other specialized tools.

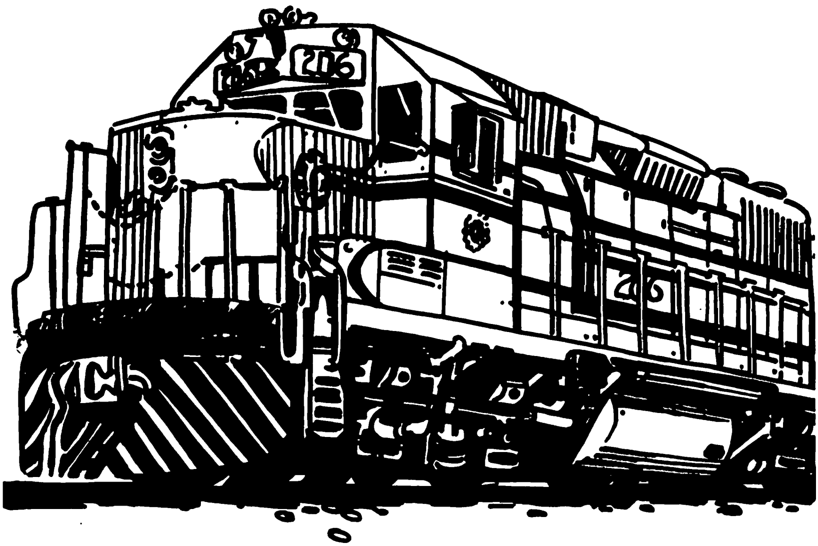
Vibration Analysis

Vibration analysis of basic locomotive components establishes vibrational parameters associated with certain faults. It is included in a predictive or conditional maintenance program that locates defective parts before catastrophic failure occurs, decreases maintenance costs and the potential for line of road failure. In addition, saving core parts from destruction prevents additional charges from being incurred in purchases or reclamation of replacements. Typical locomotive components chosen for vibration analysis include air compressors, turbochargers, main generators/alternators, and EMD camshaft drive gear trains. Defective conditions identified include misalignment, imbalance, excessive bushing clearances, gear and bearing defects or wear.

Devices used in making the analyses include a portable machinery analyzer, an accelerometer to measure movement and a photo tachometer. Simply put, the analyzer evaluates the vibration in relationship to the revolutions per minute of the component. If a component is found to be out of specification, a decision grid may be employed to determine if the component is to be repaired or replaced based on it's time in service and/or the locomotive class of power.

Treated Water Recovery

Often in pressure testing locomotive cooling systems water must be added to flood radiators and other reservoirs to verify system integrity. When the test is completed the excess water must be drained. If untreated water was used for add in water, it is now contaminated with the water treatment that was



contained in the locomotive cooling system and conversely, the locomotives water treatment concentration has now become diluted and may require additional water treatment to restore it to proper strength. Another constraint is that water discharge regulations of certain municipalities will not allow disposal of waste water that contains certain chemicals that are used in water treatment products commonly in use in locomotive cooling systems.

A solution to this problem can be a self contained, treated water recycling system, deployed so that the treated water used during the pressure testing procedures may be contained and returned to a reservoir for reuse. The need is then reduced for additional locomotive water treatment added to the locomotives processed and environmental concerns are substantially alleviated. The main components of the recycling system include the reservoir, positive pressure pump, pressure regulation and control components.

Electronic Wheel Gauge

The electronic wheel gauge is a computerized instrument designed to take the same readings as the steel wheel gauge. Unlike the steel gauge, the electronic gauge takes the flange thickness, flange height and rim thickness at the same time. Another measurement secures the reference groove dimension. The electronic gauge checks the accuracy of the wheel readings and stores them electronically. Upon completion of the wheel measurement process, the readings are transferred to a wheel reading data base on the mainframe computer system and a standard wheel report is produced.

Electronic Pyrometer

Electronic pryometers are available that offer portable, battery powered, non-contact monitoring of temperatures as generated by mechanical and electrical equipment. Some even offer the ability to provide print outs of measurements. By using electronic pyrometers, technicians can identify over heating conditions in electrical wiring, panels, switchgear, motors and mechanical equipment. Temperature differential may also be observed, as an example, by monitoring exhaust manifold temperatures at the cylinder exhaust discharge to determine which cylinder is not receiving proper fuel distribution.

Miscellaneous

Other devices employed in a Pre-Maintenance Inspection facility may include:

• A test stand to qualify the pressure cap for the engine cooling system.

• A electrical train line circuit continuity tester.

• A electronic manometer to measure various pressures can replace liquid filled versions that are cumbersome and confusing to read.

• A blacklight used for checking for fuel leakage as seen in fuels milky white reflection.

• An air dryer analyzer used in the dryers circuitry verifies continuity and cycles the dryer to verify proper operation.

• Trams for measuring and qualifying locomotive features.

Summary

The intent of a pre-maintenance inspection is to determine what repairs and resources are required in locomotive maintenance and repair, then to facilitate the planning process of how it will be processed through the shop. It includes the inspection and qualification of the locomotive, its parts and systems with specialized tooling.

With the locomotives true work requirements determined, efficiencies in work sequencing and progression may be achieved. Benefits include the ability to return the locomotive to service with increased quality of repairs and a minimum of detention.

II. RAILROAD TURNTABLE MODIFICATION

Prepared by:John Wiesch
Montana Rail Link

For well over a century, locomotive turntables have evolved to meet changing weight requirements and technological advances. The late 1800's were the most significant changes to turntable design with electrification. Only within the last decade has the electric motor power supply been improved on.

Fortunately, most turntables in use today were structurally over engineered when built. With fifty plus years of service, many of the turntable components such as gears and motors are beginning to wear. Since very few turntables were built exactly alike, locating repair components can be very difficult as well as costly. If, for instance, a main drive gear fails, it may require the gear to be reverse engineered before manufacturing. In some cases, main drive motors can no longer be rebuilt and must be made new. Lengthy out of service times severely hamper shop operations and train dispatching.

As turntables required extensive repair or overhauls, several railroads looked at alternatives to the old electric drive design. The Burlington Northern Railroad decided on using hydraulic drive power units on their table conversions. Some of these applications have been in service for almost ten years and have proven to be reliable.

There are several different design locations for placement of the drive and power unit. One design is housed in the enclosure previously used to contain the controls and switch gear of the electric motor drive. This design would probably be more advantageous in geographical locations that experience severe cold weather conditions during winter months. It would allow the unit to remain heated to a constant temperature and thus avoid hydraulic failures associated with sub-zero conditions.

Another design for power unit placement is at the location where the main drive motors were previously located. This application is slightly less costly and may be better suited for more temperate winter locations. Regardless of the design chosen for the particular table being converted, there are many similarities to the design, and repair parts are easily obtained.

There have also been numerous designs of braking mechanisms fabricated for turntable use. Although effective, they would no longer be required with the ability to incorporate a disk brake into the hydraulic control mechanism. Again, the advantage here is standardization of repair components.

Once the design application has been chosen for the conversion, removal of the old system begins. First, the old electrical system and related wiring comes off. Removal of the main drive motor and drive gears and shaft is then completed to accommodate the new skid mounted hydraulic power drive unit. As this particular hydraulic drive system requires no gear drives, the main wheel drive shaft gear is also taken off. The turntable wheel and shaft are then removed for application of the coupling to the new hydraulic drive motor. Minor modifications are performed to the old motor and drive area to securely mount the new hydraulic power unit.

With the old drive system and components removed, construction of the new system starts. Hydraulic piping is applied. Care should be taken to closely follow manufacturers specifications to avoid contamination to the internal walls of the piping and hoses. This could cause premature failure of the

new system when put in service. Mounting brackets are fabricated to secure the drive motor to the main member of the table, allowing it to be coupled to the shaft. Once in place the remaining hoses and piping are applied.

Simultaneously, new electric service is installed. New cable is run from the control enclosure to the new power unit. This is done through the existing conduit. New controls and breaker boxes are placed and wired in the previously gutted control enclosure. Once completed the table is ready for service.

As previously noted, there are several different designs for the placement of the power units. There are also several different designs for the applications of the hydraulic drive motor as a result of different table configurations. Some tables have been converted retaining a portion of the gearing of the original drive line. When considering the hydraulic conversion, thought should be given to eliminating as much as possible of the existing gear drive. With the high torque low speed motors available, it can be accomplished. This will not only reduce scheduled maintenance on the table, but also diminish the need for future gear replacement.

The hydraulic conversion should not immediately be considered for every turntable. Many tables in service today have recently had major upgrades performed on the electrical as well as mechanical components. Where sufficient repair components are on hand, these tables may give decades of service. The cost effectiveness of each circumstance should be examined.

When the decision has been made for a particular table conversion, it may be prudent to perform an evaluation on recent maintenance and repair performed on the device. Since it will be out of service for one or two weeks, advantage can be taken of the existing down time. It is recommended the table be jacked and the center casting and bearing be inspected or repaired if needed. Wheel bearings should be inspected and replaced as required. Once the main mechanical components have been brought back to specifications, the table may well produce another half century of reliable service.

The hydraulic conversion is not limited to turntable applications. With some minor structural changes, it could very well be adopted to transfer table use. Again, these assessments would have to be based on examination of each individual unit.

This paper has deliberately omitted exact specifications for these modifications. As duty requirements and environments vary from one location to another, one power unit design may not be practical. Anyone wishing more information on these conversions may contact this committee.

III. MOBILE LOCOMOTIVE SERVICE VEHICLE

Prepared by:
Bill Peterman, CP Rail Systems
and Bob Lynch, Norfolk Southern

There is a constant requirement to improve locomotive availability.

One area that is being addressed as a means to increasing locomotive availability is locomotive servicing and the time and costs associated with present locomotive service operations. To a large extent most railways move their locomotives to fixed servicing facilities. This is effective if the servicing facility interfaces effectively with the train yard operations such as main line fuelling and servicing; however in a lot of cases the servicing facilities are located adjacent and interfaced with a diesel maintenance facility. This can cause congestion and lost time when missing servicing movements with shop operations.

Locomotive availability begins to drop when you first start to move the locomotive to a facility for servicing and then the resultant lost time in the queing at the shop. In some cases locomotives are sent up to 25 miles to get serviced and have been removed from a train or made a trip from a terminal where a faster turnaround could have been achieved using the same locomotive. Between 40 and 80 per cent of locomotives visiting a diesel facility are there for repairs. The volume of traffic, track layout, inadequate facilities, lack of storage space and the mixing of service power with locomotives at the facility for scheduled and unscheduled work can result in a locomotive requiring 12 hrs. to be processed with the actual servicing activities requiring only 2 to 4 hours.

Therefore it is essential that this area be addressed as a means for improving availability and have a strategy in place. The servicing of locomotives must be part of an overall strategy for improving availability which includes not only mechanical operations but transportation as well. A solution requires a strategy that is:

1. Mobile
2. Flexible
3. Efficient
4. Cost Effective

There are 4 objectives in the strategy for improving availability through better servicing:

1. Reduce servicing time
2. Eliminate excess servicing
3. Improve servicing process and facilities
4. Eliminate locomotive movement to servicing sites where possible

The solution to addressing most of these problems was the concept of implementing mobile locomotive servicing whereby instead of bringing the locomotive to a fixed site for servicing the servicing is taken to the locomotive. This is accomplished by putting a complete line of services, equipment and supplies on specially designed super service trucks that can travel over a wide area to service locomotives in the field either at intermodal terminals, customer sites, mainline or any location that is more convenient than moving a locomotive to a specific fixed service site.

What are the advantages

- Locomotives do not have to be removed from trains for servicing.
- Locomotives being serviced away from existing servicing facilities eliminates a transportation move. New areas available for servicing are on the main line, terminals, customer sites and more effective accessible areas within present yards.

- Save time in transporting and costs to move locomotives.
- Faster turnaround times.
- Reduces need for additional locomotives normally required to replace locomotives involved in the servicing process.
- Reduces number of locomotives being serviced at existing facilities and therefore reduces congestion at existing servicing and repair locations resulting in faster turnaround.

These vehicles will be 53 foot trailers hauled by tractors. They will be stationed in strategic locations and will be radio dispatched to the appropriate service sites. Also there will be regular schedules for servicing of assigned power throughout the region being served. These trucks will not be typical of existing mobile servicing but will carry a complete inventory of supplies and services for locomotive. The service is to match or exceed what is presently being performed at fixed site.

The vehicle construction will be as follows:

a. Diesel Truck Tractor
b. 53 foot trailer with the following services

- 120 cubic feet of sand
- tanks for waste oil
- tank for waste water
- tanks for engine coolant
- tank for fresh oil
- generator
- air compressor
- vacuum
- hose reels and cabinets for above
- aerial platform and fall protection
- electrical supply and lighting

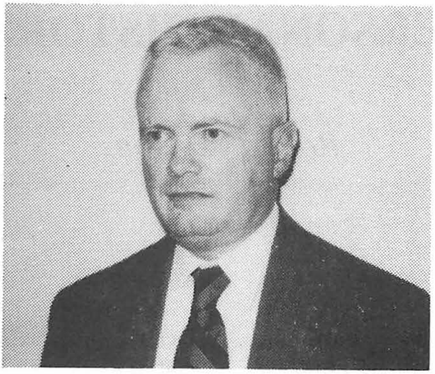
This strategy has to be maintained in order to work and must be part of any train scheduling. The vehicles must be maintained and be a structured part of the servicing process. Also included in the strategy is mobile fuelling which goes hand in hand with the servicing. In some instances the fuelling and servicing can be performed at different locations but in conjunction with other activities.

The concept of mobile servicing meets the four criteria of being mobile, flexible, efficient and cost effective. The major effect will be the faster turnaround time for locomotives plus increased availability.

REPORT OF THE COMMITTEE ON NEW DEVELOPMENTS

TUESDAY, SEPTEMBER 12, 1995
9:15 A.M.

Pre-Convention Presentation Conrail



June 6, 1995 Ramada Altoona, PA

ROBERT RUNYON, Chairman
Engineer-Loco. Design
Norfolk Southern Corp.
Roanoke, VA

Vice Chairman
GEORGE HSU
Sr. Research Engr.
Burlington Northern
Fort Worth, TX

COMMITTEE MEMBERS

B. Begole		General Electric	Erie, PA
J.S. Biln	Mgr-Mech. Engr & Admin.	BC Rail	Vancouver, BC
R. Brewer	General Foreman	Illinois Central	Southaven, MS
T. Brunner	Gen. Mech. Supt.-Loco.	Amtrak	Philadelphia, PA
T. Frederick	Mgr. Loco. Mech. Sys.	Conrail	Philadelphia, PA
D. Hamilton	Mgr.-M.P. Maint.	C anadian National	Montreal, PQ
J. Hogan	Natl. Accts. Mgr-Loco.	Caterpillar	Mossville, IL
W. Jacobs	Mgr-Locomotive	Union Pacific	North Little Rock, AR
J. Larkin		MK Rail	Boise, ID
C. Prudian	Tech. Mgr.	Electro-Motive	La Grange, IL
B. Smith	Dir. Tech. Supt. & Equip Engr.	New Jersey Transit	Kearny, NJ
C. Wills	Sr. Engr.-Maint. Support	Santa Fe	Topeka, KS

PERSONAL HISTORY

Robert Runyon

Bob Runyon was born in Williamson, W. VA on June 13, 1939, and resided in Belfry, KY throughout his early years. After graduating from high school, he attended Virginia Polytechnic Institute in Blacksburg, VA., graduating in 1961 with a BS degree in electrical engineering. He continued with post-graduate studies for another year and while on active duty in the Army, earning an MS degree in nuclear science and engineering in 1966.

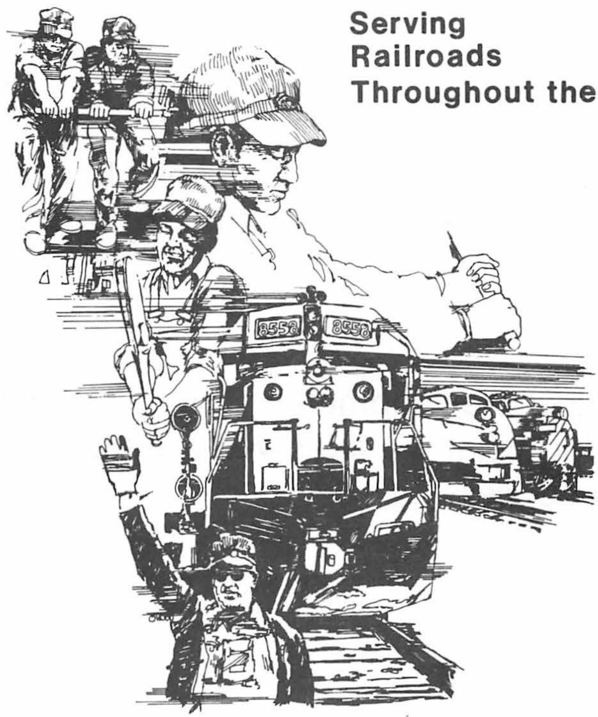
For five years starting in 1962, Mr. Runyon served in the U.S. Army Artillery, assigned to various positions including a three-year stay in Germany and a year in Pittsburgh, eventually holding the rank of Captain. Upon leaving the Army in 1967, he moved to Roanoke, VA and joined ITT in an engineering capacity.

Mr. Runyon's railroad career began on April 16, 1970, when he joined Norfolk & Western Railway Co. as an assistant engineer in Roanoke, VA, with subsequent promotion to gang foreman in 1972. During most of this time he supervised the design and construction of a SEARCH locomotive test facility, which he operated through the end of 1974, and participated in the design of a fleet of slug locomotives to be used in yard and hump service. After spending a year as assistant foreman supervising one shift at Roanoke Shops, he was transferred to the Locomotive department staff to take on the electrical design phase of a new slug locomotive.

In 1977, Mr. Runyon was promoted to mechanical supervisor, replacing the retiring incumbent, and in 1982 was promoted to his present title of engineer locomotive design. During the years that followed, he has continued with responsibility for various projects to include repowered locomotives and additional slugs, fuel efficiency testing, and the continuing effort to computerize drawings and other records. He is presently active in his church, has served in the International Management Council from 1972, and is licensed to practice engineering in Virginia.

Bob has been married since 1962 and lives in Roanoke with his wife, Nancy. They have two daughters, both married, and one granddaughter.

800-861
9280



LMOA wishes to express its thanks to Conrail for hosting the Pre-Convention Presentation in Altoona, PA.

Our New Developments Committee was well received in what we trust was a mutually beneficial experience.

I. BELTPACK® LOCOMOTIVE CONTROL SYSTEM

Prepared by: Don Hamilton
CN North America

Introduction

In 1987, the development of the BELTPACK®(LCS) system was started by the CN Rail Technical Research Centre with application geared to improved productivity in hump yard operations. In 1990 this type of technology was implemented successfully at Canadian National's Symington yard, in single employee hump operation. This operating advantage is now being extended to a flat-yard switching version of the locomotive control system (LCS), a continuing evolution of the technology.

This product encompasses the necessary attributes of enhanced safety of operations and increased labor productivity leading to significant return on capital investment.

While systems such as this are typically referred to as remote control locomotives, it is important to note that this LCS system, is *not* remote control but rather computer controlled.

Typically, competitive systems simply duplicate the features of the locomotive control stand at a location remote from the locomotive itself; the operator must then judge speed and close the feedback loop between the speedometer and the throttle or brake control. In contrast, the CN system turns control of the locomotive over to an on-board microprocessor-based computer which, in response to a radio-transmitted operator speed request, makes the command and control decisions regarding brake and/or throttle application.

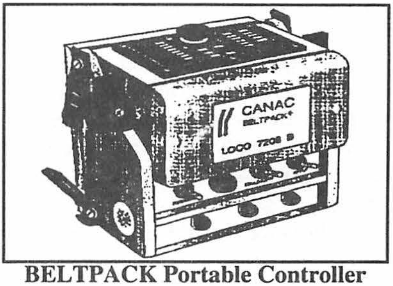
Development of the computer controlled system has simplified the Beltpack® operator's work to such an extent that following two weeks of training, an employee not familiar with locomotive operation, is qualified to operate an LCS-equipped locomotive.

The impetus for implementation of the locomotive control system is two-fold: enhanced safety and significant economic benefits. Safety is significantly enhanced by virtue of the ability to transfer control of the locomotive between operators ensuring that the employee on the leading end of the movement is in control regardless of the direction of travel. Precise speed control selection ensures proper couplings and reduces damage to lading and equipment. The potential for inadvertent movement of a consist is eliminated.

The installation of LCS on a given locomotive results in the permanent abolishment of the locomotive engineer's position on that assignment. If we consider a locomotive assigned to yard service operating three shifts per day, seven days per week, the installation of a single Beltpack system reduces a total of four locomotive engineers' positions.

The Beltpack system has three major elements: the Beltpack portable controller, the ground based equipment, and the locomotive on-board equipment. Following is a description of the controls and features of these three elements.

Beltpack



BELTPACK Portable Controller

The Beltpack is the primary control interface within LCS. It is compact, light-weight (6.5 lbs.), portable, battery powered and is worn on the operator's abdomen by a harness. It is the device by which operator command requests are translated into a data stream and transmitted over an RF link to a receiver on board the locomotive.

Speed Control
(Operator's right-hand side)

As mentioned previously, what is unique to the CN Beltpack system is the introduction of the on-board microprocessor-based computer which is designed to make decisions regarding throttle and brake settings in response to an operator request for a specific speed.

The system applies or reduces power on independent brakes so that the selected speed is maintained within ±1.0 mph for speeds of 4 mph and above, and within ±0.5 mph at speeds below 4 mph.

Speed settings selections, used by CN, (mph) are 15, 10, 7, 4, Couple (1 mph), Coast (no tractive effort), Coast B (no tractive effort and 15 psi on independent brake) and Stop. Other values can be implemented simply as they are software programmable. When the Stop command is selected, power is removed and an independent brake applied until the movement comes to a complete stop.

Brake Override Lever
(Operator's left-hand side)

Not required for normal starts and stops, the brake override lever is used when the Beltpack operator desires to override and apply more brake pressure than the computer selected brake application.

For instance, should the locomotive consist and a number of cars be stopped on an ascending grade, the operator would apply a light or medium independent brake to prevent rollback while tractive effort is applied in response to a speed request. In addition, another switch controls the application of train brakes if requested.

Independent brake settings are Release, Light, Medium, Full, and Emergency. Train brake settings are programmable and normally are: Release, Minimum (7psi reduction), Light (10 psi), Medium (15 psi), Full (30 psi) and Charge, which allows charging of the air-brake system under condition of train-line make up. Charge operates while protecting main reservoir pressure against depletion if air hoses are open to atmosphere somewhere down the train being made-up. As well the engine is fast idled during the train-line charging.

Reverser (Front)

A three setting switch with Forward, Neutral, and Reverse positions.

As a safety precaution, if the operator attempts to change the requested direction while the locomotive is moving, a service brake application is made and the reverser changed only after the locomotive has come to a complete stop.

Bell And Horn (Front)

A three-position switch allows the operator to activate the bell alone or the bell and horn together as prescribed by operating rules.

The third (bell+horn) position is spring-loaded and will return to the "bell only" position when released. The bell position is latched in order that the operator might cause the bell to be rung as long as required without having to hold on this control. In addition, the

bell will ring automatically whenever the locomotive is requested by the operator to move from a stopped position.

Reset Safety Control (RSC) Top

This feature is similar to the RSC found on conventionally controlled locomotives. The Beltpack monitors operator command requests while the engine is in motion. If a 50-second period elapses between operator commands (e.g. independent brake application or speed selection) the controller activates an audible warning for ten seconds. If no further operator action is detected during this ten-second audible alarm period, a full service train brake application is applied.

The Reset Safety Control is reset by the manipulation of any control setting, as on a locomotive, or by depressing the large red button on the top of the Beltpack controller.

Tilt (Internal)

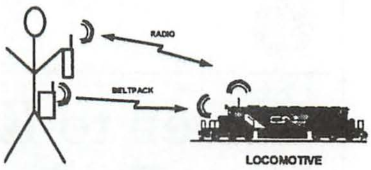
If the Beltpack is tilted off the vertical more than 45° for more than one second, an audible warning commences. When the Beltpack is not returned to the upright position prior to the expiration of a further three seconds, the Emergency Stop command is automatically transmitted to the locomotive.

Time Extender (Front)

Operates in conjunction with the tilt detector safety feature. If the operator is required to bend to line a switch, etc., depression of the time extender button allows a 60-second delay before the audible warning and emergency brake countdown commences.

The time extender function is not cumulative. Pressing the button five times will not result in five minutes of extension but rather only 60 seconds from the last time the button is pressed.

Status (Talker) (Front)



Pressing this button causes the system to transmit a voice message over the operator's yard radio, in order that the status of the locomotive can be determined as required. The message can be re-transmitted as necessary by repeatedly pressing the button. Prior to transmitting, the system monitors the yard radio to ensure the channel is clear. Should the channel be in use, the message will be held, then transmitted when voice traffic has ceased.

This feature is similar to the hot box detector voice synthesizer which relays train journal bearing status to operating crews. It is currently available in either the English or the French language.

Visual Indicators (Top)

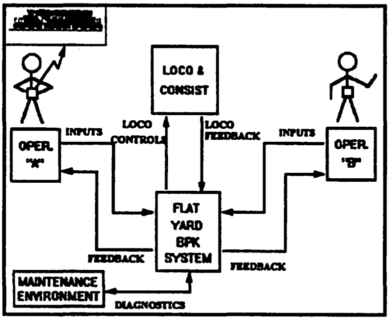
Light Emitting Diodes (LED) on the top surface of the Beltpack allow quick visual confirmation of the control settings selected. In addition to speed, brake, etc. settings, a low battery warning light illuminates when the battery has approximately 1 1/2 hours of usable power remaining.

If a condition requiring operator attention exists (tilt, reset safety) the audible alarm commences and a warning LED begins flashing. The LED extinguishes when the problem is corrected.

On/Off/Headlight Switch (Front)

The three position power switch is located on the front of the Beltpack controller. In addition to turning the portable unit on and off, the switch allows selection of the headlight between the "dim" and "bright" settings. The headlight at the end of the locomotive corresponding to the Forward/Reverse selector will be lit appropriately in the direction of motion.

Pitch And Catch (Front)



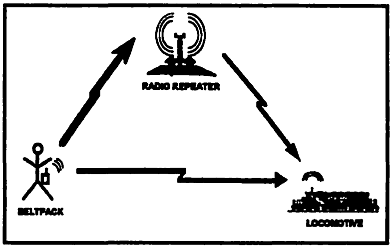
This feature is the most significant evolution from the hump yard version of LSC.

Pitch and catch allows either of the two operators normally assigned to a Beltpack equipped switching assignment to alternately have control of the locomotive.

One controller is "on line" at all times; that is, it has control of all system functions. The "off line" controller can operate only the bell, horn, status, and emergency brake functions. This second controller is designed to be in failsafe communications at all times similar to the controlling Beltpack.

Providing a series of safety steps has been satisfied, depressing the pitch button transfers control of the locomotive from the "on-line" portable to the other BELTPACK operator. Use of the pitch and catch feature ensures that the employee on the leading end of the movement is in control. That employee need not rely on signals relayed from the opposite end of the movement. This ability significantly enhances switching operations and safety while decreasing damage to lading and equipment.

Ground Equipment



The only ground based equipment for LCS is a radio repeater to extend the operating range between the operators and their LCS locomotives. In direct communications, control messages go straight from the Beltpack to the locomotive. In situations of long range (1 to 2 miles), over rough terrain, bridges, or other obstacles a radio repeater is needed.

The repeater operates through an antenna strategically positioned in the center of the LCS territory. The antenna by its height and signal gain is more accessible to radio signals from operators near ground level and to the locomotives with roof mounted antennas.

The RF messages from the portables to the repeater are rebroadcast on a different frequency to the locomotives. This requires that the locomotives have receivers for both the direct and the repeat frequencies.

Locomotive On-Board Equipment

The on-board equipment consists of four radio receiver antennas (on the roof), four radio receivers, mobile interface (electrical and pneumatic), safety detectors and the mobile controller (computer) with the voice synthesizer.

Radio Receiver

Receives operator command requests and relays those commands to the mobile controller. Two receivers are used on each of two frequencies. One frequency is for direct reception from the portable units and the other for messages from the repeater.The radio subsystem provides the highest level of message integrity and radio range through the use of space diversity antennas. Each of the four antennas feeds one receiver.

Mobile Controller

The mobile controller brings state-of-the-art control of locomotives to the operator while demanding significantly less experience and training.

The "brain" of the on-board system receives operator commands over the radio communication link as well as information from locomotive sensors (speedometer, reverser setting, pressure and flow sensors, etc.) and produces control commands to the locomotive via the mobile interface to ensure the engine properly responds to the operator's request.

Archive Memory

An archive memory in the mobile controller logs commands received, system responses and status conditions, adding their time and date, to aid in diagnostics and sequence of event reconstruction if required. The log can be downloaded into a lap-top personal computer on the locomotive much like an event recorder or remotely over a cellular modem-phone installed on the locomotive.

Talker (Voice Synthesizer).

The mobile controller contains and controls a voice synthesizer. This module generates messages to be broadcast over the LCS locomotive's assigned yard radio (VHF or UHF). These messages are triggered by requests from either operator (by use of the Status button) or by requests from the LCS software when it detects prescribed situations. These automatic messages occur especially for faults; e.g. if a Tilt condition continues due to the collapse of an operator a message is broadcast every 60 seconds as a guide to other employees that an operator is in distress.

Electric And Pneumatic Interfaces

There are interface units for controlling both the electrical and pneumatic locomotive devices from the on-board controller. These interfaces both send controls and receive feedback from speedometers, safety detectors, the air brake system, the train-line 27-pin multiple unit connector, bell and horn, reverser, generator field control relay, etc. The electrical interface incorporates the changeover switch located in the locomotive cab which permits the engine to operate either conventionally or in Beltpack mode.

Safety Detectors

Detectors are installed on the locomotive consist so LCS can recognize hazardous conditions and respond accordingly. For example, if a locomotive truck brake cylinder is cut out the system will cut power and apply a full service train brake. The same applies to conditions such as low main reservoir pressure, low brake pipe pressure, independent brake response, low engine lube oil or water, tripped ground fault relay and other train-line conditions.

In addition to these safety detectors,

numerous interlocks have been designed into the system to prevent damage to the locomotive consist as a result of inadvertent operator commands; e.g. should the operator change the reverser selector while in motion, an "illegal reverser command" message will be transmitted and the movement stopped before the reverser setting is allowed to change. Similarly the speed selector lever is interlocked so that movement out of the stop position requires a two state sequence of control operation to eliminate accidental movement of the locomotive.

Air Dryer

To prevent frosting problems in the operation of the electro-pneumatic valves, an air dryer has been fitted to the locomotive to control air frost point below -50 deg. F.

Security

CN North America's approach to development of the locomotive control system was to introduce computer-controlled switching in a manner which was as safe or safer than traditional methods. As a result, the highest levels of safety and redundancy have been incorporated into the system.

In addition to features such as reset safety control, operator interlocks, tilt protection and precise speed control, numerous other safety and monitoring systems have been designed into LCS.

Braking System Protection

LCS protects against brake faults or failures in the system. It monitors and reacts by applying an emergency brake if either low main reservoir pressure (less 90 psi) or failure of the consist to respond to operator brake requests conditions exist.

Radio Security

Communication polling is typically four and a minimum of two times per second. If radio communication is compromised, e.g.: loss of carrier (Beltpack fails, loses power or is turned off), message data errors (garbled or corrupt messages, noise), communication time out (communication is blocked, loss of seven successive polls), the system responds with a full service brake application.

Operator Alarm Notification

In addition to messages generated by the voice synthesizer and broadcast over the normal radio equipment, audible and visual warnings alert the operator to any condition that requires his or her attention.

Conclusion

In conclusion, the CN Locomotive Control System,. designed and constructed by CANAC, is not just a theoretical concept. Rather, it is a field tested fully operational system. Having successfully implemented the humpyard version of LCS almost four years ago, this system is now poised to expand its use to the flat-yard switching environment. Beltpack switching will significantly alter switching operations, by improving labor productivity in the workplace and enhancing safety.

II. THE MK1200G SWITCHING LOCOMOTIVE

Prepared by: Jim Larkin, MK Rail

The rail transportation industry is rapidly forging an era of modernization long overdue in our business. Automated systems management, electronic controls, high adhesion steering trucks, contemporary architectures, AC propulsion systems, and alternate fuels, are a few of the technologies being aggressively advanced by all serious members of the industry. A determination to advance these efforts is currently being demonstrated by the Locomotive Division of MK Rail located in Boise, Idaho, and our strategic partner, Caterpillar, Inc.

After engineering and manufacturing several new locomotives to client specifications, MK Rail is today embarking on an extended mission to market a series of brand new locomotives. The first of the series, the MK1200G, is designed primarily for yard switching operations and features a unique prime mover that is fueled exclusively by liquid natural gas (LNG). The second design is a modern, high horsepower, high speed freight locomotive designated the MK500C. This paper will dedicate its focus to the MK1200G switcher locomotive.

This is a 1200 horsepower locomotive fueled entirely by liquefied natural gas. Clean burning LNG allows the 1200G to produce the lowest No_x emissions of any locomotive in its horsepower class. The 1200G stands alone as a rail transportation product capable of delivering superior environmental performance through the use of:

☞ The Caterpillar G3516 spark ignited, turbocharged-aftercooled (SITA) V-16 engine.

☞ Modern electrical rotating machines supplied by KATO Engineering, a division of Reliance Electric.

☞ A state-of-the-art microprocessor-based locomotive control system.

☞ An advanced liquefied natural gas fuel management system of cryogenic tanks, process piping, vaporizer and controls designed and supplied by Minnesota Valley Engineering (MVE).

☞ A modern, high-visibility ergonomically designed cab.

☞ A broad array of high-tech performance and safety sensors/controls.

The cab and carbody designs optimize visibility and crew efficiency. Instrumented testing of cab sound levels yielded measurements that range from 60-75 db in normal operation. Cab appointments are complete with the provisions for a toilet in the short hood. The sub-base area below the cab is packaged with both the air brake manifold and an HVAC unit mounted on glide racks for ease of maintenance and servicing. The carbody is equipped with "gull-wing" doors for easy access to the engine for adjusting valves and changing spark plugs.

Collision posts and anticlimbers are standard and comply with the latest AAR/FRA regulations. The two-axle trucks are a standard Blomberg type design equipped with 40"-in. wheels, G-G type journal bearings, and clasp composition brakes. Traction motors are from Motor Coils with a 62.15. gear ratio.

The Caterpillar G3516 engine is a thoroughly developed natural gas engine with a performance specification that meets and exceeds proposed emissions criteria for large industrial engines for the late '90s and beyond. Several thousand of the G3516 SITA engines are in service as stationary generating plants; however, the MK1200G is the first locomotive application for this engine. However

the diesel version of the 3516 series engine, at over 2000 hp, is installed and performing successfully in hundreds of light general purpose locomotives.

The engine features are as follows:

- 16 cylinder
- Turbocharged-aftercooled
- 4-stroke cycle
- Spark ignited
- 11.1 compression ratio
- 1350 BHP@ 1500 RPM
- Lower firing pressures
- 60" "V" configuration
- 6.7" (170 mm) bore - 7.5" (190 mm) stroke
- 2-intake valves, 2-exhaust valves
- Electronic ignition system (EIS)
- Air/fuel ratio control
- Fast transient response
- Trouble shooting/maintenance capabilities.

Six-row mechanically bonded radiator cores remove heat from the separate jacket water and aftercooler circuits. The aftercooler circuit dispenses heat to the LNG vaporizer and the radiators. Two twelve blade, 48-in. fans provide forced ventilation through the radiator banks.

The engine start switch is located in the cab and auto start/stop capability is available. Use of the engine's shutdown capability increases engine life, permits longer maintenance intervals and reduces fuel consumption.

While many other engine development efforts using alternate fuels are showing promise, natural gas was selected as the fuel of choice for this application because natural gas stands alone for its good specific heat value, its substantially reduced effect on engine wear and maintenance, and its greatly reduced exhaust emissions. Table A is a detailed description of the properties of LNG. Table B shows the emissions performance of the Caterpillar G3516 SITA engine.

LIQUID NATURAL GAS

CHEMICAL CONTENT	
Methane (CH_4)	97.0%
Other Hydrocarbons	.5%
Nitrogen (N_2)	2.5%
METHANE PROPERTIES	
Boiling Point °F	-259
Specfic Gravity	.56
Liquid Weight lbs/gal	3.5
Volume Expansion Ratio - Liquid to Gas	625:1
Heating Value BTU/ft3 - gas	950
Heating Value BTU/GAL - liquid	76,000
Heat of Vaporization - BTU/lb	2.19

TABLE A

CATERPILLAR G3516 SITA EMISSIONS PERFORMANCE

ISO 8178-1 CONDITIONS	GRAMS/BHP HR
Oxides of Nitrogen (NOx)	2.0
Carbon Monoxide (CO)	1.9
Hydrocarbons (HC)	2.8
Particulates	.08

TABLE B

Over the past two years, Caterpillar has enhanced this engine design for variable speed - variable load locomotive service. Switchers spend a good deal of time operating at idle, therefore particular attention was paid to this mode of operation.

The 1200G utilizes a low pressure (30-40 psi) gas flow to the engine through a carburetor and is spark-ignited within the cylinder. This is in contrast with the higher horsepower LNG road locomotives which are being discussed in other papers being presented this year and which were discussed by this committee last year. They use a high pressure (about 3000 psi) supply of gas to the engine which is injected with a small amount of diesel fuel and ignited in conventional diesel fashion.

The fuel management system is divided into three primary categories: the fuel tanks, the process piping and valves, and the LNG vaporizer.

The tanks are designed and constructed to carry and store a cryogenic material under low to moderate pressure. The tanks are made up of three basic assemblies not unlike large scale thermos bottles. The inner vessels are fabricated from type 304 stainless steel and will hold the LNG at approximately -260 deg. F. This inner vessel is encapsulated in a form of thermal insulation barriers. In this case the barriers are multilayers of an aerospace - developed super insulation comprised of a light layer of fiberglass material and a thin layer of aluminum foil. The fiberglass and foil laminate is then wrapped many times around the vessel until an overall blanket thickness of about 1-1/2" is achieved.

Next, the vessel and its super insulation blanket is placed within a high strength carbon steel outer vessel that gives the tanks its structural integrity and strength. Finally, after the hardened outer vessel is capped and sealed, the insulated area is pumped down to establish a high vacuum jacket between the inner vessel and the outer structural tank. The vacuum jacket adds significantly to the thermal insulation efficiency of the system.

There are three LNG tanks installed on the MK1200G to maximize on-board fuel volume; a large center tank with a capacity of 900 gal, and two small side tanks at 250 gal capacity each. All three tanks are interconnected by process piping so as to function as a single 1400 gal tank.

The tanks are supported in a reinforced steel support structure designed to bear twice the weight of the locomotive without transferring load to the fuel tanks. Incorporated into the support structure is a thick plate which shields the process piping.

The fuel system is designed with safety and simplicity in mind. The saturation pressure of 50 psi with loaded LNG tanks provides the driving potential for the fuel system. No pumps are used for fuel delivery. Excess heat and fuel pressure are removed by an economizer regulator that draws vapor from the top of the tanks when the pressure exceeds 80 psi. Below this pressure the regulator is closed and only liquid fuel is delivered to the engines vaporizer. It should be kept in mind that as the liquid fuel (a liquid at -260 deg. F and a gas above that) continues to be stored, and the locomotive is not used, it will begin to boil off which results in a pressure increase that must be slowly vented at the top of the locomotive long hood. This is a normal process and not dangerous. It is, in fact, difficult to ignite LNG. A very narrow range of air/fuel ratio is required.

A key component of the LNG fuel system is the liquid heated vaporizer which is constructed much like a cylindrical liquid - to - liquid heat exchanger. The vaporizer is the single mechanism that serves to transfer a portion of the engine coolant to the integrated LNG circuit at a rate and temperature that will vaporize the fuel to a gaseous state, for delivery to the engine.

The physical flow of natural gas throughout the entire system is the function of the stainless steel process piping and valves. Stainless steel components are required at cryogenic temperatures because of their ductility. A carbon steel at those low temperatures becomes extremely brittle and could shatter easily. There are three basic networks that make up the relatively complex set of LNG process piping: the LNG fill and offload piping; the LNG fuel supply piping; and the gaseous fuel vent piping system.

The process piping system is equipped with pressure relief valves and other safety devices to prevent any isolated overpressure conditions or fuel venting. The only two valves in the process pipe system that are rountinely manipulated during normal locomotive operations include the fuel fill valve that is operated during all refueling procedures, and the main fuel shut-off valve that is operated whenever the locomotive engine is started or stopped. All other valves serve to provide alternate operational capability such as to isolate any of the three LNG tanks. Otherwise, they remain inactive and require no adjustments of any kind during normal locomotive service.

Fueling the locomotive is simple and efficient. LNG is transferred to the locomotive tanks through a receptacle mounted on both sides of the locomotive. LNG enters each tank through a top fill spray bar and is distributed through the vapor space to immediately reduce tank pressure to the saturation pressure of the incoming liquid. Filling in this manner eliminates the need for venting. Fuel level monitoring is accomplished with capacitance tubes in each of the LNG tanks. Liquid level changes cause the measured capacitance to change. Tank capacitance is converted to an output signal by conditioning electronics to drive side sill and cab mounted fuel level indicators.

Several unique electronic safety features are designed into the MK1200G. Standard fuel cut off switches are distributed throughout the locomotive for manual shut-down. Methane detectors are installed in various locations. The detectors provide input to the MK-LOC microprocessor based control system. They are powered continuously and designed to activate a train line warning alarm if a methane leak is detected while the locomotive is operating in a consist. When methane is detected at specified levels, the engine is shut down and strobe lights and an alarm are activated.

Throughout the design and construction process MK Rail worked very closely with its suppliers and customers to insure that the finished product was not only functional but safe, reliable and easy to maintain.

Testing at our shops and on the Union Pacific Railroad in the Boise area consumed seven full months of dedicated effort. By the end of the calendar year 1994, two units were at work on the Union Pacific Railroad and two on the Santa Fe, all in the Los Angeles area.

Our experience to date has indicated good performance and acceptance. High points are excellent tractive effort and adhesion, excellent acceleration, extremely quiet cab, and extremely low emissions.

III. ADVANCED TRACTION MOTOR TESTING

Prepared by: Donald M. Schucht
American Railway Technologies, Inc.

A. Introduction

Traction motor repair and failure costs constitute a significant portion of a railroad's locomotive maintenance costs. Unfortunately, due to the nature of traction motors and their operating environment, there is no simple means to assess a motors' health once in service. Under these circumstances, it is apparent that if the railroads are to reduce costs associated with traction motors, the only means to accomplish this goal is to install more reliable motors in locomotives.

All railroads perform some type of test on a traction motor after it has been rebuilt. Although this test varies from railroad to railroad, this post-rebuild test can be defined as a "rebuild" test. When a motor is returned to the shop for reasons other than a failure, the majority of railroads subject the motor to another test, which can be defined as a "re-installation" test, before the motor is put back in service.

Since a motor cannot be tested once it is installed, the opportunity to test the motor again, when it has been removed, should be taken advantage of the fullest extent. Valuable information regarding the motor's fitness for service could be obtained if a number of modifications were to be made to the traditional testing methods. First, if the test were to be performed in a very consistent manner, discrepancies in motor performance could be evaluated. These performance discrepancies could be observed between motors and during subsequent tests on the same motor. Also, if an accurate and simple method for storing and evaluating these performance discrepancies were available, a motor's fitness for service could be determined accurately and rapidly.

These improvements in the testing methods are only achievable through the use of computer control, automated data storage and computer analysis. An added benefit of this computer control, is a significant reduction in the time it takes to perform the test and a subsequent increase in productivity.

Considering the expense associated with traction motor rebuilding and failures, it is surprising that there are no comprehensive diagnostic procedures for traction motor performance evaluation. However, since the implementation of testing procedures and documentation requirements necessary to perform the diagnosis is challenging, it is understandable that the railroads have avoided the task. The appearance of affordable computers and interfaces allows cost effective automation and data storage. Advanced motor testing, using state-of-the-art data acquisition and control systems, can perform the complex testing and data storage tasks consistently and affordably.

B. Traditional Testing

Although test routines vary from railroad to railroad, the traditional tests discussed herein are sufficiently universal and should compare favorably to the test routines of most railroads. Traction motor testing is performed using two variable power supplies, one for the field and one for the armature. There are five basic motor variables which the operator must observe. These variables are armature voltage, armature current, field voltage, field current and motor speed. Physical characteristics include bearing temperatures and vibration. Traditionally, both of these supplies are manually controlled by a single operator. During the rebuild test, the operator performs three tests segments and must continuously monitor the motor during the test and manually record test results.

The first test segment performed is the bearing run. During this test the operator applies power to the field and armature so that the motor rotates at a relatively moderate rate. The test is performed for approximately one hour in the clockwise direction and approximately one hour in the counterclockwise direction. This test is performed for a long period of time in order to provoke a bad bearing to exhibit its faults in the form of heat. If a bearing's temperature exceeds a certain level, the motor fails the test.

The second test segment performed is the over speed test. During this test the operator applies a specific voltage to the armature and lowers the field current until the motor rotates at a predetermined high rate. This test is performed for approximately one minute. The operator manually records the voltages, currents, speed and vibration levels during the test. If the armature and field currents are not within specification, the motor fails the test. Note that armature voltage and motor speed are fixed while field voltage, field current and armature current are not regulated during this test.

The final test segment performed is the maximum voltage test. During this test the operator adjusts the power supplies such that a specific voltage is applied to the armature and specific current is drawn by the field. This test is performed for approximately two minutes. The operator manually records the voltages, currents and speed during the test. Note that armature voltage and field current are fixed while armature current, field voltage and motor speed are not regulated during this test.

The parameters of the re-installation test vary greatly from railroad to railroad. Some railroads perform the rebuild test again while others perform an abbreviated test. In either case, there is no means to perform the tests consistently and store the tests results in a accurate manner. Ultimately, making comparisons between the rebuild test and re-installation test is difficult. In the case where an abbreviated test is performed, making this comparison is impossible since the two tests performed on the motor are different.

Note that the test requires over two hours and a re-installation test can require between 15 minutes and two hours.

C. Advanced Testing

The test routine performed in an advanced test is very similar to that of a traditional test. The advanced test does not require a bearing run. The over speed and maximum voltage tests are performed in the exact same manner. The use of sophisticated computer controls and software results in the acquisition of much more valuable data as well as a reduction in test time.

To take advantage of the full benefits of advanced motor testing, motors should be subjected to a test at every convenient opportunity. Ideally, a motor will be tested after it is rebuilt. Not only will this initial test allow the evaluation of the motor's health by comparing test results to accepted standards, but it will also serve as a base line for subsequent tests. When a motor is removed from a locomotive for any reason other than a severe failure, it should be tested again and the new test results compared to previous test results. Any degradation of motor performance will be an indication of imminent motor problems. An advanced warning of a motor problem not only allows for the removal of a motor before it fails, thereby averting a costly road failure, but it also prevents the motor from experiencing any significant damage which would increase the cost of returning the motor to service.

One of the most important features of an advanced motor test system is the use of a computer to control the voltage and current levels supplied to the motor under test. The elimination of the human factor ensures that every motor of the same model is tested in exactly the same manner every time a test is performed. This consistency also ensures that test voltages and currents are set and maintained at the exact levels dictated by the test specifications. Unless these test voltages and currents are set and maintained at exact levels, test results become less meaningful. These new accuracy levels, not feasible using a human operator, provide information not obtainable previously. A secondary benefit of computer control is that the operator has the ability to attend to tasks not related to controlling the motor. Note that the computer can set and adjust test levels more quickly than humanly possible. This results is a reduction of test time. Figure 1 shows the test parameters for an EMD D77 motor. Note that the system computer stores a different set of test parameters for every motor model. These test parameters can be easily modified by accessing the appropriate database function.

The use of a computer allows for the easy integration of a database in order to store test results. The operator is not required to record the test voltages, currents, speed and other values. This automatic storage ability allows for easy observation of a motor's performance over a period of time. Refer to Figure 2 to review test results of a typical motor. Note that every motor has its own file, defined by a serial number, containing test results, model, manufacture, armature number and frame number.

During the over speed test, armature voltage and motor speed are set and maintained at specific levels. Under these conditions, armature current, field voltage and field current will vary from motor to motor and from test to test. Refer to Figure 2 under the over speed heading. Note that armature voltage and motor speed are consistent from date to date. Changes in motor performance over time can be easily observed in the changes in armature current, field voltage and field current.

During the maximum voltage test, armature voltage and field current are set and maintained at specific levels. Under these conditions, armature current, field voltage and motor speed will vary from motor to motor and from test to test. Refer to Figure 2 under the Maximum Voltage heading. Note that armature voltage and field current are consistent from date to date. Changes in motor performance over time can be easily observed in the changes in armature current, field voltage and motor speed.

The availability of affordable high speed computers and advanced software techniques has allowed for the addition of a new and important feature to motor testing. This feature is wave shape analysis. This wave shape analysis, which consists of breaking a waveform into its constituent frequencies, is useful in the evaluation of bearing and electrical condition. As discussed previously, the bearing run is performed in order to provoke a bad bearing to get hot during a test. By analyzing the vibration wave of the commutator and pinion ends of the motor, valuable information on motor balance and bearing condition can be ascertained. This technique, which evaluates bearing condition in a matter of seconds, results in a significant reduction of test time. A complete motor test, which rotates the motor in both directions, will take approximately 25 minutes. If the brushes are to be seated and the armature air cured, the test will take approximately 40 minutes. Figure 3 shows the vibration wave analysis. Any vibration which occurs at a frequency other than the rotational frequency is an indication of a motor problem other than a simple imbalance. Vibrations which take place at bearing frequencies are a clear indication of imminent bearing failure. Vibration analysis takes place during the over speed test since the motor is rotating at a high rate.

The same technique used to evaluate the vibration wave can be used to evaluate armature voltage. Figure 4 shows the armature voltage analysis. The dominant frequency in the armature voltage should be a function of the motor's rotational speed and the number of commutator bars. The presence of other frequencies is an indication of commutator, brush or other electrical problems. Armature voltage analysis takes place during the maximum voltage test since armature voltage is at its greatest at that time.

The performance of a loss test, not performed in a traditional test, is possible with the use of computer control. Armature circuit, core and mechanical losses can be determined. It is not humanly possible to take the accurate time and speed measurements necessary to make such loss measurements. Field circuit losses can be determined by mathematic manipulation on field voltage and current. Refer to Figure 2 under the Losses heading.

A final area where an advanced test provides a significant improvement over traditional tests is in the area of test evaluation. Again, the use of a computer and sophisticated software allows for automatic test result evaluation and simple performance trend analysis. Traditionally, test results are represented in the familiar quantities of voltage, current, temperature, RPM and inches per second. While being informative, these characteristics can prove confusing when attempting to assess a motor's performance. In order to simplify the evaluation process, a graduated standard is utilized which allows for the instant assessment of the motor's performance during a specific test date and over a period of time. Figures 5a and 5b show a typical graduated standard which allows for the determination of the quality of a motor's performance. The graduated standard assigns a grade of A, B, C of F to key performance characteristics of the motor. The values which determine the letter grades are easily changed by accessing the appropriate database function. The grading values can be modified as motor rebuilding techniques are perfected and tighter controls are placed on motor testing. With the grading system, all that is required of the operator is to look at the letter grades the motor received during the test or test dates. The burden of quality assessment no longer falls on the operator. The result is a reduction in the time it takes to evaluate a motor's performance and a virtual elimination of assessment error. Note that variations in motor response as it rotates in opposite directions is also evaluated. Figure 2 shows the graded test results for typical motor.

Presently, there exist universally accepted values for motor performance. These values provide an upper or lower level for motor performance but do not provide values for the determination of motor performance grades. By correlating motor reliability with test results, the railroads will be able to assign accurate values to the graduated standard and therefore assign grades to motor performance. Ultimately, these grades will correspond to motor reliability.

D. Conclusion

The ability to perform tests consistently in conjunction with a complete database and performance assessment will give the railroad the ability to ensure that only reliable motors are installed on locomotives. The added benefits of automation and vibration analysis results in an improved test which requires significantly less time to perform.

A number of areas that can be identified will allow railroads to realize cost savings with the use of advanced testing and the subsequent installation of more reliable motors:

Increase the number of locomotives available for revenue service.

The use of the advanced testing will ensure that only reliable motors are put in service.

This will result in fewer failures on the road and a longer period of time before a locomotive must return to the shop for the installation of a new traction motor.

Reduce rebuilding costs

Unaware of their condition, railroads operate their motors until they fail, at which point major damage has occurred. This necessitates having motors undergo expensive rebuilds in order to be returned to service. By removing motors before catastrophic failure has occurred, thereby avoiding burning and other physical damage, relatively inexpensive rebuilds are all that will be required to restore the motors to good operating condition.

Evaluate motor rebuilding techniques and materials

The use of advanced testing will allow the railroads to evaluate the techniques and materials used in the rebuilding process. Over a period of time, materials and techniques can be improved, resulting in longer motor life.

Strategic motor placement

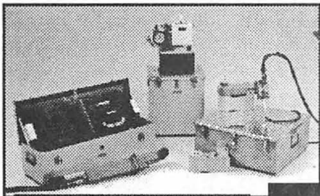
Some motors which receive a low performance grade will be unfit for service on a locomotive which performs in high-power mainline service. However this low grade motor may have a useful lifetime under less severe conditions. This strategic placement of motors will reserve the best motors for services that require maximum performance and reliability.

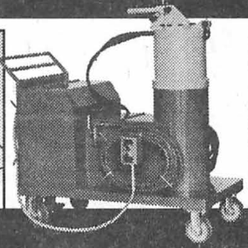
Increase Productivity

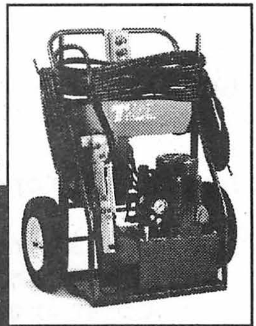
Through the use of advanced testing and its short test time, productivity will be increased due to an increase in throughput. Since the advanced testing is fully automated, the operator can perform other functions while motors are being tested. There is no need for the operator to "keep an eye on" the motor during testing. The result is a reduction in labor costs. A machine which performs an advanced test can take the place of a number of traditional machines and their associated costs.

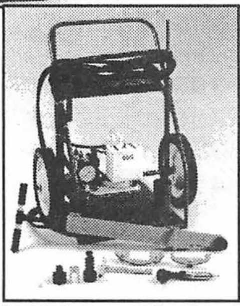
American Railway Technologies, Inc. has developed a system which performs the advanced test described herein. This system, called the Traction Motor Diagnostic System, is available for demonstration to interested parties.

TIME-SAVING Tools and Machines for Locomotive Maintenance, Parts Reclamation, and Testing









INCREASE
SHOP PRODUCTIVITY

REDUCE
LOCOMOTIVE DOWNTIME

IMPROVE
YOUR QUALITY ASSURANCE PROGRAM

MAIN BEARING WRENCHES
EMD & GE Engines

CRAB NUT TORQUE WRENCHES
EMD Engines

TRACTION MOTOR SUPPORT BEARING CAP WRENCHES
EMD & GE Traction Motors

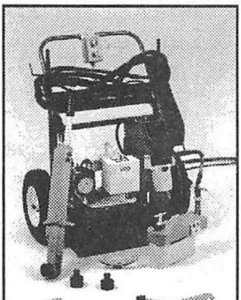
LOWER LINER INSERT PULLER/INSTALLER
EMD Engines

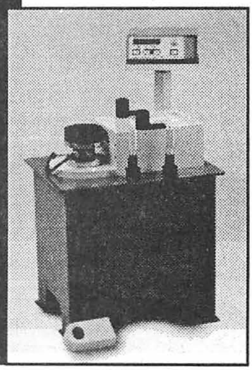
CYLINDER HEAD AND LINER WATER TEST MACHINES
EMD Engines

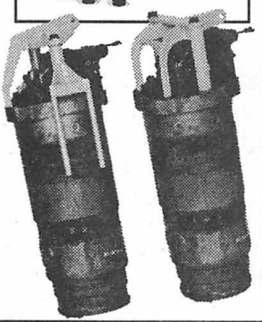
EXHAUST VALVE SPRING DEAD WEIGHT TESTER
EMD Engines

and other SPECIAL TOOLS & MACHINES designed to

SAVE YOU MONEY







TAME, INC.

TAME INC

Tools and Maintenance Equipment Co., Inc.

2523 Chattanooga Valley Drive • P.O. Box 250
Flintstone, Georgia 30725 • U.S.A.
Telephone: (706) 820-0397
Fax: (706) 820-9802

AMERICAN RAILWAY TECHNOLOGIES

Traction Motor Diagnostic System
TEST PARAMETERS

Model: D77

Polarization Voltage: 500 volts

Brush Seating & Air Curing
- Field Amperage : 300 amps
- Armature Voltage (1st): 250 volts
- Armature Voltage (2nd): 350 volts
- Armatire Voltage (3rd): 450 volts

Bearing Run
- Field Amperage : 500 amps
- Armature Voltage : 600 volts
- Test Time, 1st dir.: 45 Minutes
- Test Time, 2nd dir.: 45 Minutes

Over Speed
- Armature Voltage : 1060 volts
- Test Speed : 2940 RPM
- Test Time : 1 Minutes
- Observation Speed: 2100 RPM

Maximum Voltage
- Field Amperage : 600 amps
- Armature Voltage: 1200 volts
- Test Time : 2 Minutes

Losses
- Field Amperage : 300 amps
- Test Speed : 1000 RPM

Rotational Moment of Inertia : 500 $lb*ft^2$

Figure 1

AMERICAN RAILWAY TECHNOLOGIES

Motor Number: 12345
Model : D77
Manufacturer: EMD
Armature # : 23456
Frame # : 12345

Date	Polar		Bearing Run					Overspeed							Maximum Voltage				Losses			
			Pin		Com		Sur	Arm		Fld		Pin	Com									
	Ind	Ω	T	U	T	U	T	A	δA	A	δA	U	U	Vib	RPM	δRPM	acV	Gnd	F	A	M	C
10-01-94	X	A	A	A	A	A	A	B	A	B	A	A	B	C	B	A	A	A	C	A	F	B
10-02-94	X	A	A	A	A	A	A	B	A	B	A	A	B	C	B	A	A	A	C	A	F	B

BEARING RUN

Date	Dr	Am	Pinion Bearing Temp(°F)				Pinion Bearing Ultra(dB)				Commutator Bearing Temp(°F)				Commutator Bearing Ultra(dB)				Com Surf Temp(°F)			
10-01-94	CW	86	11	13	14	16	0	0	0	0	7	9	11	13	7	7	7	7	125	127	132	133
	CC	86	0	4	7	9	0	0	0	0	0	2	4	5	7	7	7	7	114	117	119	123
10-02-94	CW	90	13	14	16	22	0	0	0	0	5	7	9	11	7	7	7	7	123	125	130	131
	CC	90	0	4	7	9	0	0	0	0	-4	-2	0	2	7	7	7	7	113	115	116	122

MAXIMUM VOLTAGE

Date	Dir	FldV	FldA	ArmV	ArmA	GndA	RPM	ACVolts
10-01-94	CW	5.25	598	1198	14.4	0	1720	4.9
	CC	5.20	597	-1201	14.6	0	1725	4.9
10-02-94	CW	5.26	599	1199	14.4	0	1722	4.7
	CC	5.22	596	-1202	14.6	0	1726	4.9

POLARIZATION

Index	Final MΩ
X	OPEN
X	OPEN

OVERSPEED

Date	Dir	FldV	FldA	ArmV	ArmA	RPM	VibP	VibC	VibA	UltraPin	UltraCom
10-01-94	CW	1.72	209	1059	14.6	2948	0.28	0.00	0.00	0	14
	CC	1.69	204	-1059	15.2	2949	0.24	0.00	0.00	0	14
10-02-94	CW	1.75	210	1061	14.9	2950	0.26	0.00	0.00	0	14
	CC	1.72	205	-1061	15.1	2949	0.24	0.00	0.00	0	15

LOSSES (Watts)

Date	Clockwise				Counter Clockwise			
	FldCkt	ArmCkt	Mech	Core	FldCkt	ArmCkt	Mech	Core
10-01-94	859	143	2300	2113	841	252	2308	2114
10-02-94	825	185	2300	2117	839	179	2308	2112

Figure 2

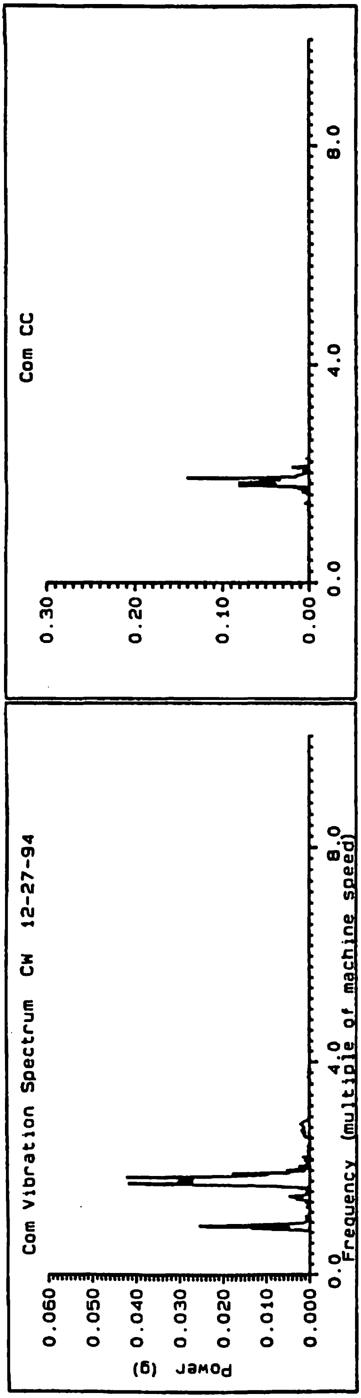

Com Vibration Spectrum CW 12-27-94
Power (g)
0.060
0.050
0.040
0.030
0.020
0.010
0.000
0.0
4.0
8.0
Frequency (multiple of machine speed)
Com CC
0.30
0.20
0.10
0.00
0.0
4.0
8.0

Figure 3

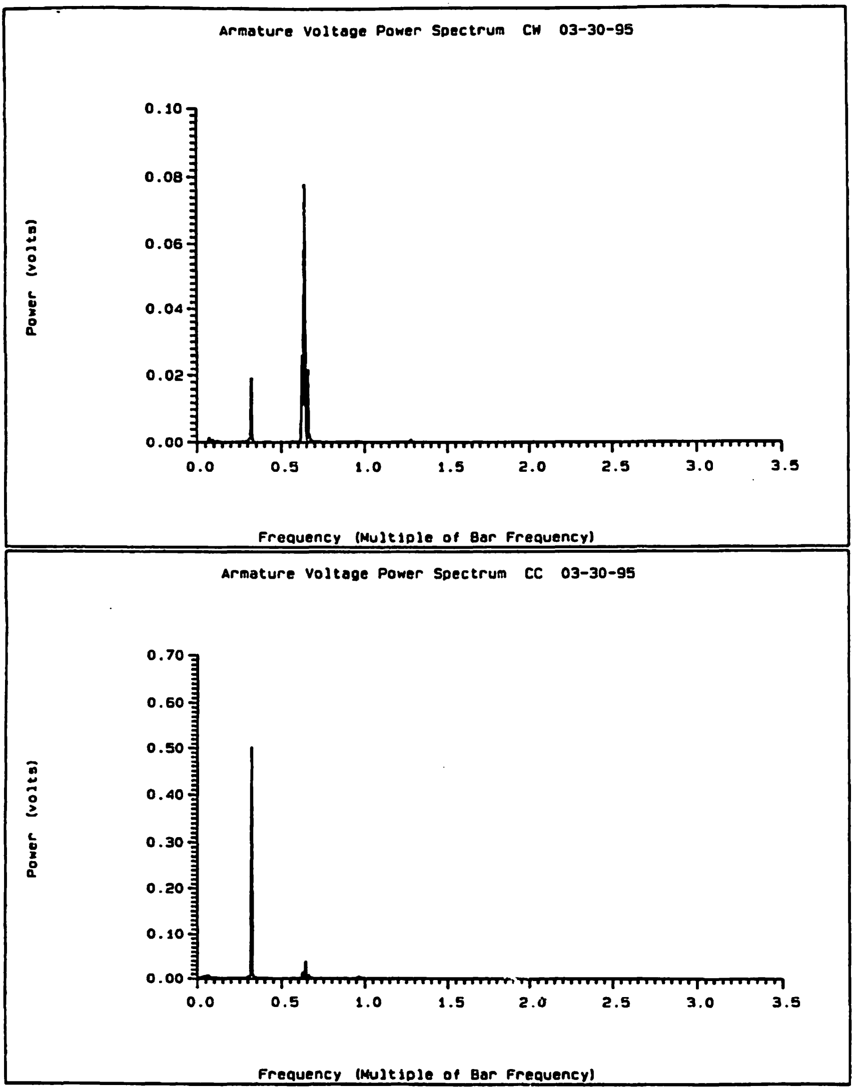

Armature Voltage Power Spectrum CW 03-30-95
Power (volts)
0.10
0.08
0.06
0.04
0.02
0.00
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Frequency (Multiple of Bar Frequency)
Armature Voltage Power Spectrum CC 03-30-95
Power (volts)
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Frequency (Multiple of Bar Frequency)

Figure 4

AMERICAN RAILWAY TECHNOLOGIES

Traction Motor Diagnostic System
GRADUATED STANDARD

Model: D77

BEARING RUN

Pinion Bearoing Temperature above ambient (F)
```
         50        60        70
<----A----|----B----|----C----|----F---->
```

Commutator Bearing Temperature above ambient (F)
```
         35        45        55
<----A----|----B----|----C----|----F---->
```

Pinion Bearing Noise (dB)
```
          6        12          30
<----A----|----B----|----C----|----F---->
```

Commutator Bearing Noise (dB)
```
          8        15          35
<----A----|----B----|----C----|----F---->
```

Commutator Surface Temperature (F)
```
         140       170       200
<----A----|----B----|----C----|----F---->
```

OVER SPEED

Armature Current (Amps)
```
         10        20        30
<----A----|----B----|----C----|----F---->
```

Directional Difference in Armature Current (Amps)
```
          1         3         6
<----A----|----B----|----C----|----F---->
```

Field Current (Amps)
```
         200       220       240
<----A----|----B----|----C----|----F---->
```

Directional Difference in Field Current (Amps)
```
          5        10        15
<----A----|----B----|----C----|----F---->
```

Vibration (in/sec)
```
         .1        .2        .3
<----A----|----B----|----C----|----F---->
```

Pinion Bearing Noise (dB)
```
          6        12         30
<----A----|----B----|----C----|----F---->
```

Commutator Bearing Noise (dB)
```
          8        15         35
<----A----|----B----|----C----|----F---->
```

Figure 5a

```
MAXIMUM VOLTAGE
   Leakage to ground (Micro Amps)
                  100       300       600
         <----A----|----B----|----C----|----F---->

   AC Armature Voltage (Volts)
                   5        7       10
         <----A----|----B----|----C----|----F---->

   Speed (RPM)
                  1700      1720      1740      1760      1780      1800
         <----F----|----C----|----B----|----A----|----B----|----C----|----F---->

   Directional Speed Difference (RPM)
                   5         10        15
         <----A----|----B----|----C----|----F---->

LOSSES
   Field Circuit (Watts)
                  500       700       900
         <----A----|----B----|----C----|----F---->

   Armature Circuit (Watts)
                  600       800      1000
         <----A----|----B----|----C----|----F---->

   Core Loss (Watts)
                  2000      2300      2600
         <----A----|----B----|----C----|----F---->

   Mechanical Loss (Watts)
                  1000      1400      1800
         <----A----|----B----|----C----|----F---->

POLARIZATION INDEX
   Polarization Index
                   5         4         3
         <----A----|----B----|----C----|----F---->

   Final Resistance (MegOhms)
                  25        20        15
         <----A----|----B----|----C----|----F---->
```

Figure 5b

REPORT OF THE COMMITTEE ON DIESEL MECHANICAL MAINTENANCE

TUESDAY, SEPTEMBER 12,1995
10:45 A.M.

Pre-Convention Presentation Union Pacific

March 24, 1995
Jenks Shop
North Little Rock, AR

T. H. VOLKMANN, Chairman
Supt. MP-GE
C&NW Transp.
Council Bluffs, IA

Vice Chairman
J. HOLLEY
Mgr.-Opns & Data Control
CSX Transportation
Jacksonville, FL

COMMITTEE MEMBERS

D. Anderson	Mgr-Mech. Engr.	Morrison Knudsen	Boise, ID
J. Baranko	Shop Supt.	Conrail	Altoona, PA
J. J. Calvey	Loco. Shop Mgr.	Wisconsin Central	Fond Du Lac, WI
F. Cowan	Asst. Mgr-Assy. Shop	Norfolk Southern	Chattanooga, TN
M. Dinius	Chief Mech. Officer	Montana Rail Link	Missoula, MT
J. Flores	Gen. Frmn. Equip. Training	Illinois Central	Memphis, TN
R. Gates	Gen. Equip. Supr.	AT&SF Rwy. Co.	Kansas City, KS
W. Hobart	Director-A.C. Tech.	Burlington Northern	Ft. Worth, TX
K. Mahalik	Mgr-North American Field Svc.	Electro-Motive	La Grange, IL
L. Olson	Mgr-Energy R&D	Burlington Northern	Overland Park, KS
F. Pantel	Asst. Supt. Engrg. Maint-MP	Canadian National	Winnipeg, MB
R. Plaugher	Maint. Proc. Spec.	Union Pacific	N. Little Rock, AR
B. Sweeley	Mgr.-Int. Locos	General Electric	Erie, PA
G. Stickler	Reg. Mgr.-Maint.	Amtrak	Wilmington, DE

PERSONAL HISTORY

Tad H. Volkmann

Tad H. Volkmann was born January 31st, 1957, in Chicago, Illinois. He was raised in Naperville, Illinois, where he acquired an early interest in railroads from his grandfather.

Tad received an associate degree in drafting and mechanical design from Morrison Institute of Technology in 1978, and a bachelor of science degree in manufacturing engineering from Milwaukee School of Engineering in 1980. He graduated with honors from both institutions, and taught classes in numerical controlled machining and robotics as a teaching assistant at M.S.O.E. He is commencing graduate studies.

Tad began his career at Chicago and North Western in 1980 as a management trainee in the Motive Power department. He was promoted to assistant diesel supervisor in 1981, and to general foreman at Marshalltown, Iowa in 1983. Tad was appointed shop manager at Marshalltown locomotive shop in 1987, where he oversaw a period of growth that resulted in doubling of maintenance activities and workforce.

Tad was appointed superintendent motive power - GE locomotives in 1994, with responsibility for the maintenance and performance of CNW's growing fleet of General Electric locomotives. He looks forward to continuing his career with the Union Pacific Railroad.

Tad lives in Council Bluffs, Iowa, with his wife Sue and three children. His hobbies include fishing, boating, and rabid support of the Chicago Bears football team.

I. GENERAL ELECTRIC NEW 7 HDL 6000 HP DIESEL ENGINE

Prepared by: Bruce Sweeley, GE and Jay Holley, CSXT

Background:

GE has been supplying high horsepower diesel electric locomotives for more than 30 years, and understands the particular requirements of engines used in locomotive applications, including reliability and maintenance. More than 10,000 engines have been produced and are powering locomotives all over the world. The single most important requirement for a diesel engine used in locomotive service is that it must be capable of withstanding high cycle thermal loads, a fact which is often misjudged by even experienced diesel engine manufacturers who try to apply general purpose diesel engines to locomotive service.

Locomotives operate under demanding climatic conditions, which include operation at altitudes to more than 3000 meters and temperatures from -40 deg F to 120 deg F. In addition, tunnel operation can cause the locomotive engine to operate at ambient air inlet temperatures which exceed 150 deg F. These requirements put unusual demands on the turbocharger. These demands were recognized years ago and led GE to develop its own turbocharger, enlisting the talent of the aircraft engine division of the company.

For the increased tractive effort capability with the new AC propulsion, the horsepower must be increased from 4400 to 6000 so that train schedules can be met using fewer locomotives. In order to maintain engine efficiency while maintaining or improving reliability, an engine with greater displacement than the current GE7FDL is necessary. For locomotives, the new engine develops this additional power without appreciably increasing engine size and weight.

Objective:

General Electric began a study in 1991 on what the railway's needs for the future truly were and what type of locomotive would be required. With AC technology increasing tractive effort over 30%, a corresponding horsepower increase should take place. GE then evaluated over 30 engine designs worldwide with four major criteria:

- Engine capability
- State of technology
- High horsepower experience in dynamic and severe environmental applications
- Compatibility with locomotive design and GETS manufacturing capability.

GE selected Deutz Motoren Werke Mannheim AC (MWM) as its partner. MWM is one of the largest engine builders in the world with more than 75 years of experience. MWM has a proven design for a diverse range of size and application requirements. MWM has vast design experience with heavy duty high horsepower engines as well as industrial engines with high horsepower/weight ratio.

The GE/MWM responsibility is as follows:

GE

- Functional Engine Specification
- Locomotive Engine Integration
- System Interface
- Engine Endurance Testing
- Turbocharger Design
- EFI Control Design
- Pre-Production Manufacturing
- Production Manufacturing

MWM

- Engine Design
- Thermal Analysis
- Mechanical Analysis
- Stress Analysis (including FEA)
- Production Drawings
- Test Engine Verification
- First 3 Prototype Engines

The GE and MWM agreement calls for a business plan for a family of engines:

I-6 2345 GHP
Manufactured by MWM in Mannheim

I-8 3125 GHP
Manufactured by MWM in Mannheim

I-9 3515 GHP
Manufactured by MWM in Mannheim

V-12 4690 GHP
Manufactured by GE in Grove City

V-16 6250 GHP
Manufactured by GE in Grove City

V-18 7030 GHP
Manufactured by GE in Grove City

The engine family design will be jointly owned. GE has exclusive locomotive rights, including parts and service. MWM has Marine and other rights, including parts and service.

GE Transportation Systems combined its locomotive engine expertise with the marine and power generation engine expertise of MWM of Germany, to develop a high horsepower diesel engine which can be suitably applied to both the locomotive and the marine markets. Deutz-MWM is a part of KHD of Cologne, Germany which produces more than 130,000 diesel engines per year, both water cooled and air cooled, and is one of the largest engine manufacturers in the world.

The water cooled medium and large bore engines developed and manufactured by Deutz-MWM have ratings up to 10,000 hp. More than 82,000 of the larger engines are in service internationally.

Deutz-MWM has been designing and building diesel engines for marine and stationary power plants for more than 90 years. Marine engines, characterized by long life and high reliability, must be capable of withstanding high sustained loading for very long periods. They must also be capable of significant overloading in emergency operation. Many of the engines operate "heavy fuel" rather than distillate, increasing the requirement for wear resistance under adverse conditions.

One of their most popular engines currently being produced, slightly bigger than the GE7FDL, is the "628" rated at 5,000 hp at 1000 rpm. Approximately 4000 of these engines are operating worldwide.

The new engine under development comprises a family of engines consisting of in-line 6, 8 and 9 cylinder engines, to be manufactured by MWM and Vee engines of 12, 16 and 18 cylinders to be manufactured by GE. Initial testing was performed on an inline 8-cylinder test engine, and the V-16, the first fully developed member of the engine family for locomotive service is being tested.

A comprehensive engine specification for locomotive and marine applications was formulated for the design of the new diesel engine. Although a common engine is being developed, there are some differences between the locomotive and marine engines which are necessary to satisfy their unique application requirements. However, any engine designed to accept the most demanding requirements of both applications will be even more fitting for either application.

The new engine is designed to meet the demands for higher horsepower, improved fuel consumption and reduced emissions, along with longer life expectancy and greater reliability.

Certain principles of the current 7FDL engine are retained for the new engine design. It will operate on the 4-

stroke cycle principle rather than the 2-stroke cycle principle. Among the 4-stroke advantages are, a longer period for the gas exchange process, lower thermal loading since the pistons, rings, liners heads, etc., are exposed to the high temperatures only every other revolution, and more favorable running conditions for pistons, liners and rings due to the absence of liner ports.

The new 7HDL engine will be turbocharged and aftercooled with 4 valves per cylinder. Because of the lower fuel consumption, it will use direct injection, with shallow bowl, quiescent combustion chambers, as opposed to indirect injection systems. This type of combustion chamber, formed by the piston and the head, is the simplest in design and has the least heat loss because of the low ratio of surface to volume.

Engine speed of 1050 RPM is retained. It is now generally believed that the parameter affecting piston, ring and liner life is the number of "ring reversals" the number of times per minute that the rings change direction. Therefore the engine speed should be as low as possible. In the past, mean piston speed was mistakenly accepted as the major parameter.

The 45 degree bank angle minimizes the width of the engine and is an excellent design parameter for the 12 and 16 cylinder engines as well as the 18 cylinder marine engine.

Other features that will be retained include the cast frame, steel crown aluminum pistons, cam location at the outside of the engine, and unitized power cylinder assembly for ease of maintenance.

The new, higher horsepower diesel engine for locomotive applications is designated as the GE7HDL (Deutz-MWM designation is "632"). A comparison of its basic parameters to the current GE7FDL shows that the bore and stroke have increased so that the displacement increases by 43%. Thus, at the same RPM, the BMEP (brake mean effective pressure) has not increased. The compression ratio increases to 15.7 and the gross horsepower increases from 4500 to 6250.

The main structure of the new GE7HDL engine is a one piece casting made from nodular (ductile) iron. The main frame is still a casting, which provides inherent vibration damping, maximum strength, and minimal weight. A welded structure was not considered for these reasons and also because its manufacturing process quality is too dependent upon hard to control weld processes.

The new GE7HDL engine is more of a "block" in that the liners are supported closer to the top where the loads are the highest. This increases the stiffness of the entire assembly. The nodular iron material itself is about 60% stronger and 34% stiffer than the current GE7FDL crankcase material which is alloyed cast iron.

The upper part of the liner is supported by a separate "strongback" which not only provides liner strength, but also forms the jacket for the liner coolant. Also incorporated in the strongback are the fuel injection pump and the roller tappets for the valve train. A cylinder head with a thin steel head gasket sets on top of the liner and the entire assembly is through-bolted to the engine block. High strength steel bolts are used as the reaction to the firing. The steel head gasket is vented to the atmosphere and is completely separated from the coolant passages, avoiding any chance of coolant leaking into the cylinder, or combustion products leaking into the cooling system.

The liner of the new engine is made of cast iron. Steel is not required since the liner will not be welded to the head.

The new engine oil pan is a combined cast/weld structure that adds to the rigidity of the engine. The sump capacity has been increased approximately 30%, to accommodate the 30% increase in engine horsepower so that the time between oil changes will be similar to today's.

All of the head studs and main bearing cap bolts which handle the main forces within the engine are hydraulically tightened for assurance and uniformity. This also minimizes distortion of the bearings and cylinder liners. The number of other different tools required is minimized.

The intake manifold of the new GE7HDL engine is located in the vee. This reduces the width of the engine. There are only about four parts to the inlet manifold for the 16 cylinder model. The cylinder head or power assembly can be removed without upsetting the inlet manifold. This will increase the reliability as well as improve maintainability.

The new GE7HDL engine employs a simple, one tube per bank, dual exhaust system. It is used on the current GE7FDL as well as the special "PEARL" system developed by Deutz-MWM and is located in the engine vee. There is one section with one bellows per cylinder. The thermodynamic performance of this type of manifolding is well tried and proven.

As on the current GE7FDL engine, an individual cylinder assembly, called the power assembly, which includes the head, liner, piston, connection rod and fuel pumps of the new GE7HDL engine, can still be removed separately as a unit without disturbing the other cylinders. Or, the head can be removed separately, if desired.

The new engine's larger crankshaft is designed for optimized mass balancing, low bearing load and low torsional vibration. It is continuously forged from high strength steel with welded counterweights, as used on the 7FDL engine. It is fitted with a one piece camshaft drive gear. A viscous damper is also fitted to the engine.

The main bearings and the connecting rod bearings of the new GE7HDL engine will be steel backed aluminum or micro grooved bearings. The micro grooves are filled with the bearing overlay which can tolerate more of the fine wear particles which are generated within the engine, without danger of seizure. The calculated oil film thickness for the bearings at maximum oil temperature meets the acceptable value for locomotive applications (tunnel operation) per GE experience. These bearings can be expected to have longer life and higher reliability than the trimetal type bearings.

The steel crown aluminum skirt piston design is retained for the new engine. The piston crown has hardened ring grooves and is oil cooled, with the oil supplied from drilled passages in the connecting rod.

The new engine's connecting rods are side-by-side design rather than the articulated design currently used in the GE7FDL. Although the articulated rod concept has the ability to increase oil film thickness at the crankpin for any given load, the output and performance of the engine varies from bank to bank. With increased desire for "fine tuning" and improved engine performance with respect to fuel consumption and emissions, and the increased mechanical loading on the rods themselves due to increased output, the side-by-side rod concept is more desirable. However, the new engine's bearing proportions have been established such that the bearing loads and oil film thickness requirements for long life have not been compromised by using the side-by-side concept. The number of parts and the number of bolted joints required have been reduced; thus, the

reliability of the engine will increase.

The connecting rods are split diagonally so that they can be removed through the cylinder, if desired. The split is serrated to eliminate any bending on the cap studs. The cap studs are hydraulically tensioned to insure tightness and minimize distortion of the bearing due to stud tightening variation.

The piston pin has a very large diameter to handle the increased loads and allow it to be straddle mounted. The straddle mounting allows the connecting rod to be located axially, eliminating the need for thrust surfaces on the big end of the connecting rods. The absence of these thrust surfaces increases mechanical efficiency and allows greater oil flow through the big end rod bearings to improve the cooling of the bearings. The piston pin is full floating for long life.

The new GE7HDL engine uses individual heads for each cylinder. The heads are made of cast iron, which has superior thermal conductive properties and low distortion due to thermal expansion. Sufficient strength and stiffness to support the high firing pressure are achieved by a combination of "double deck" and "bore-cooled" design. Because the head, strongback, liner and engine block are all iron, differential expansion and distortion between the parts due to thermal loading is minimized for longer life and consistent, quality manufacture.

Push rods and rocker arms are used on the new engine. However, valve bridges are used for each pair of inlet and exhaust valves. The rockers push down on the bridges rather than the valves themselves. This eliminates any side loading on the valves which causes wear of the valves or their guides. With the wear minimized, valve to guide clearance remains constant and as the valve guides are additionally fitted with seals any oil flow past the valve can be closely controlled. This will minimize engine "souping" and emission problems from the engine lubricating oil.

The silchrome inlet and inconel exhaust valve materials are retained for the new engine. The valve seats are stellite inserts expanded into the cast iron cylinder head. The exhaust valve seat inserts are liquid cooled. For the marine engine, or if a locomotive engine is called upon to burn heavy fuel, other materials can be used for the exhaust valve itself.

As on the current engine, the camshaft of the new engine is a segmented shaft bolted together, with one segment per cylinder. This allows the cams to be very large to handle the increased fuel pump loads, which will supply fuel pressure to 10,341 psi without increasing the size of the cam chamber. It also reduces maintenance costs should any damage occur, as only a small section needs to be replaced. If desired, the entire camshaft is also removable from the side of the engine.

The camshaft is driven by a gear train at the generator end of the engine. This is the accepted practice on large engines to reduce the crankshaft torsional vibration input to the camshaft. Double reduction or two-state gearing is used so that a large single piece drive gear can be used on the crankshaft. The intermediate gear shafts are straddle mounted for high rigidity.

The 16 cylinder model of the new GE7HDL engine is fitted with two turbochargers, one for each bank. This will improve the response of the engine to power level changes. The turbochargers, designed and built by GE, incorporate all of the latest design features of modern turbochargers which include backward curved compressor vanes for high efficiency.

Two intercoolers provide the capability to cool the charge air as much as possible to reduce cylinder temperature and emissions and maximize fuel efficiency.

The new GE7HDL engine will accept either an electronic or a mechanical fuel injection system, although electronic fuel injection is the system used on the AC6000 locomotive. Either system will operate at pressures to 10,341 psi which improves the fuel spray and combustion characteristics which will result in highest fuel efficiency and lowest exhaust emissions. The new engine's individual fuel pumps do not have push rods, thus stiffening the system and decreasing combustion variability from cylinder to cylinder.

The diesel engine is "soft-mounted" to the locomotive platform. This reduces the vibration transmitted throughout the locomotive which will lead to increased life of the components, increase driver comfort, and reduce overall locomotive noise.

The engine cooling system uses a split radiator system. Water which exits the cylinder jackets is cooled by the radiators. It then is split into two paths with some of the water re-entering the engine and the diverted water is cooled further before entering the engine intercoolers. Thus, the engine inlet manifold air is held at a low temperature to minimize NOx emissions.

For further information on GE's new 6000 horsepower HDL diesel engine, please contact a GE representative.

LMOA Best Practices Series

II. LOW OIL PRESSURE TROUBLESHOOTING PROCEDURES FOR EMD TURBOCHARGED LOCOMOTIVES

Prepared by: Ray Plaugher, UP & Frank Cowan, NS

With increasing demands for improved locomotive reliability and availability, the amount of time a locomotive is shopped for a defect can be detrimental. In many cases, the time spent troubleshooting a failure will exceed the amount of time required to make the repair. The following is a recommended procedure for troubleshooting low lube oil pressure for EMD turbocharged locomotives.

I. Check lube oil level on dip stick. If found to be low, add oil to proper level on dip stick.

II. Take lube oil sample immediately and forward to test lab for analysis.

III. Apply pressure gauges to turbo housing and main bearing/piston cooling oil pump discharge manifold.

IV. Start engine and allow to warm up. Load test engine and record the following data as you go: oil pressure at oil pressure gauge on accessory rack, turbo filter housing, and main bearing oil pump discharge elbow while engine is cold idle, under full load hot, and at idle hot.

V. Check lube oil level in non-pressurized side (square cover) of lube oil strainer housing while engine is running at idle, during acceleration, and at run 8. The scavenging oil pump normally pumps about 10% more oil than the main bearing and piston cooling pump. The strainer box will normally stay full with some oil flowing back into the crankcase. If strainer housing oil level is low in run 8, or oil level drops and does not recover, or excessive bubbles are observed in the strainer box, then skip ahead to the scavenging oil system qualification.

VI. If main bearing oil pump discharge pressure is good (120-130 + psi), but oil pressure at gauge on accessory rack is insufficient (less than 8-12 psi at idle warm or less than 25-29 psi run 8 hot), do the following:

A. Check the lube oil pressure gauge at the accessory rack for sticking or other defects. Replace if defective.

B. Make sure the Michiana oil filter tank drain valve in non-pressurized side of lube oil strainer housing is in the down position (fully closed).

C. If engine is equipped with hot oil shutdown device, qualify or replace it.

NOTE: The hot oil shutdown device can best be tested off the locomotive. Apply low pressure to inlet side of the device and heat bulb portion in hot oil bath. Device should open between 250° and 260° F.

CAUTION: A line should be attached to outlet side of device to prevent hot oil splatter when device opens.

D. Remove, inspect, and test lube oil relief valve located inside left bank accessory end of engine behind engine protector relay, insure that no foreign material is under valve seat during inspection.

1. Test lube oil relief valve. Valve should not open

below 125 psi (can be tested with air pressure).

2. If lube oil relief valve opens at less than 125 psi pressure, loosen the top valve guide locknut and adjust valve guide until total length from top of valve guide to safety plate is exactly 1 1/2 inches.
3. If lube oil relief valve still opens at less than 125 psi after adjustment, replace it.

E. Remove and inspect the check valves in the turbo filter housing, paying particular attention to valve springs and seats. Insure that no foreign material is under valve seats. Foreign material under the small check valve seat will cause low oil pressure by allowing main lube oil pressure to back flow through the soak-back system during engine operation and is an indication that the soak-back filter element is missing or plugged allowing debris to bypass filter during soak-back operation. It should be noted that when lube oil bypasses the soak-back filter during soak-back operation, unfiltered oil is pumped directly to the no. 2 idler stubshaft brushing and turbocharger bearing and planetary gear system. Foreign material under large check valve seat will cause the soak back pump to back flush the main lube oil system during engine shut down.

F. Replace the turbocharger oil filter.

G. Back blow the oil pressure sensing line from the pressure gauge to remove any obstructions.

VII. After completing item VI, try load testing and take oil pressure readings again. If oil pressure at gauge on accessory rack is still insufficient, continue as follows:

A. If oil pressure reading is good at the gauge on the turbo filter housing but insufficient at the oil pressure gauge on the accessory rack, find and correct hole or leak in the copper oil pressure sensing line that runs through the right bank top deck to the oil pressure gauge on the accessory rack.

B. If oil pressure reading is insufficient at the turbo filter housing gauge and the oil pressure gauge on the accessory rack, do the following:

1. Take a temperature drop test across the oil cooler while load testing per EMD M.I. 928. If oil cooler fails the temperature drop test, replace it.
2. Inspect main bearing/piston cooling pump gears for damage. Check end nut torque; if nut is loose, replace the pump. A loose nut indicates that significant internal wear has taken place.
3. Apply a pre-lube to the engine, remove crankcase covers, and observe the following:
   a. Observe oil flow out of engine bearings. If there is more oil flow coming out of one or more bearings than the rest, inspect and determine the cause of excessive oil flow.
   b. Observe oil flow down the cam drive gear train. If oil flow is excessive,

worn gear bushing or a broken/cracked idler stubshaft bracket are indicated.

c. Inspect top deck oiling, paying attention to any excessive oil flow from carnshaft bearings. Inspect for broken rocker arm oil lines.

d. Inspect piston cooling pipe manifold for holes, damaged or leaking patches.

VIII. Qualification of scavenging oil system.

A. Using the layshaft, rev-up engine, then release layshaft. If the non-pressurized side of the lube oil strainer box rapidly fills up with oil and overflows, there is either a lube oil suction leak or the main bearing/piston cooling oil pump is defective.

B. Remove, clean, and inspect strainer elements in strainer box. Replace any strainer elements with cracked, broken, or missing pieces of epoxy. Insure that suction strainer mounting flanges are clean and free of cracks or gouges.

C. While strainer elements are removed, clean the inside of the strainer box thoroughly, paying close attention to any small pieces of foreign material.

D. Apply a pressure gauge to the quick disconnect fitting on the Michiana lube oil filter tank. Start engine. While engine is idling, check pressure at gauge on Michiana tank.

1. If pressure is less than 10 psi, inspect scavenging oil pump, oil suction line from scavenging pump to strainer box, and crankcase oil suction line for suction leaks or mechanical damage. Suction leaks in the scavenging oil system will often be indicated by air bubbles in the strainer box housing.

2. If pressure is greater than 10 psi, change out Michiana oil filter elements. After filter change, if pressure is still high, replace the oil cooling core account plugged.

E. Increase engine speed to 8th notch. Record pressure on Michiana lube oil filter tank gauge.

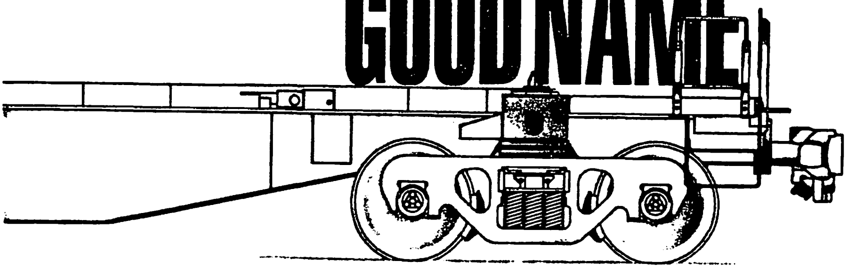
1. If pressure is greater than 25 psi, change out Michiana oil filter elements.

2. If pressure is 10 psi or greater, perform temperature drop test to qualify oil cooler core per EMD M.I. 928.

3. If pressure is less than 3 psi, replace the bypass valve inside the Michiana oil filter tank.

F. If all above steps are performed and scavenging oil system does not work properly, replace the scavenging oil pump.

YOUR GOOD NAME RESTS ON OUR GOOD NAME



AND WE NEVER FORGET IT

When the railroads really got rolling in the 1880's, it was on Griffin wheels. Ever since, Griffin has proven to be one of the industry's most dependable names in providing the finest rolling and stopping dynamics for railcars and locomotives. Staying on the cutting edge of technology got us there. You keep us there. And we never forget it.

GRIFFIN Wheel Company

200 West Monroe Chicago,IL 60606 312.346.3300
IN CANADA: GRIFFIN CANADA, INC., 514.774.5311

III. HOW CAN A REGIONAL OR SHORT LINE JUSTIFY A WHEEL TRUING MACHINE?

Prepared by: Jim Fisk and Joe Calvey, Wisconsin Central

What will have to be considered before any railroad will spend the ever so tight and in-demand capital dollar on an in-ground wheel machine? How can railroads justify purchasing one? This paper will attempt to answer these questions.

Before we can determine if a wheel truing machine is justified we need to identify what options exist for having wheels contoured.

The most common method of wheel contouring is to use an abrasive brake shoe. It has been around a long time and is used to regain an acceptable profile on many roads. Its advantages are that it is, first, relatively inexpensive to buy and, second, simple to use. The problems with the abrasive brake shoe method are that it is very labor intensive, the quality of the finished product is at the mercy of the condition of the brake rigging at each wheel location (which can make duplicating exact profiles virtually impossible), and it is likely to produce an out of round wheel. It will also require the locomotive to be out of revenue service for a lengthy amount of time in order to accomplish the job of contouring (which is a poor job at best). Typical costs associated with this method of contouring are as follows: (all data shown are for the cost of contouring one wheel set on an average locomotive). Depending on the problem with the wheel profiles, costs can vary significantly.

Labor	20 Man Hours.
Material	$140
Locomotive Out of Use Time	3 days
Fuel & Maintenance	$1,116.

The next most common method of contouring is with flange cutting shoes. This method is strictly for cutting down high flanges. It is not capable of restoring a narrow flange, slid flat condition, tread worn hollow, or any other condition other than high flanges. This time the quality of the finished product is at the mercy of the mechanic performing the task, as well as the condition of the brake rigging at each wheel location.

To use this method of contouring the mechanic must replace the brake shoe with a tool holder. The tool holder will hold a carbide cutting tool against the top of the flange while one person moves the locomotive slowly and the mechanic walks along trying to regulate the amount of tool pressure by partially opening the brake cylinder cut out. To say the least, it is impossible to have any two wheels come out the same, but it is all too possible to cut a double flange because of carbide breakage.

The costs of this method to contour one wheel set, are as follows:

Labor	4 man hours
Material	$240
Locomotive Out of Use Time	1 day
Fuel & Maintenance	$289.20

The third option for wheel contouring is the use of a portable wheel lathe. This device is designed to be similar to the compound on an engine lathe.

To use this method you must raise the wheel set to clear the rail, disconnect the traction motor leads, secure the wheel set from lateral movement (while it is turning), mount the machine to track structure after removing the brake rigging on the wheel to be contoured, hook up a variable power source (typically a welder to traction motor leads), and then hand feed the tool head across the profile of the wheel until the desired contour is obtained.

This method can result in a reasonable profile, provided you have a seasoned operator of the equipment and he/she exhibits an extreme amount of patience.

The average cost to contour a wheel with this method are as follows:

Labor	16 man hours
Material	$11.52
Locomotive Out of Use Time	2 days

Not included in costs are capital expenditure and maintenance costs for the portable wheel lathe, welder, and jacks.

The fourth option is to have wheels contoured by another railroad if possible. Some larger railroads will not do this work at any price. Others seem eager to perform this task to help offset their overheads.

This method will produce excellent results provided the larger railroad has the cutters to match the profile you desire on your wheels. If it does not, often the only recourse is to settle for the profile that is standard to that railroad.

Aside from the profile choice, another problem to consider is the expense of shipping your locomotive to and from the larger railroad's shop location. A large amount of locomotive out of use time due to shipping, and shop time waiting for service can also cause added expense.

The average cost to contour a wheel set by this method is as follows:

Labor	2 man hours
Shipping	$0 To ? Depending on distance and relationship with connecting carriers
Repair Bill	$437
Locomotive Out of Use Time	3 days plus

The fifth method of contouring is to remove the traction motor wheel set combination from the locomotive, put the assembly into a wheel lathe, contour, and reapply the assembly to the locomotive.

This method will produce excellent results and gives the railroad the choice of contours, as well as control of when it will be done.

It does require capital investment to purchase a wheel lathe, drop table or jacks, and an overhead crane. Some or all of these devices may already be in place on some properties but, due to capacity issues, may still need to be purchased and installed.

The average cost to contour a wheel set by this method is as follows:

Labor	12 man hours
Material	$58
Locomotive Out of Use Time	1 day

Not included in the costs are capital expenditure and maintenance costs for the wheel lathe, drop pit or jacks, and overhead crane.

The last, but not least option is to use an in-ground wheel truing machine.

This method produces excellent results with a minimum of labor and a minimum of locomotive down time. By having your own wheel machine it also gives the owner the option of selecting the contour to which its wheels are contoured (which will allow the railroad to select the best profile to match its track conditions).

The problem with this method is the capital investment it requires to purchase and install an in-ground wheel machine.

The average cost to contour a wheel set with this method is as follows:

Labor	1 1/2 man hours
Material	$21.00
Locomotive Out of Use Time	1 1/2 hours
Maintenance on Wheel Machine	$30

Depreciation $26

Now that we have defined all the methods to contour wheels we need to look at each one to determine which is most cost effective for the particular needs of your railroad. This sounds simple enough at face value but there are many things that need to be considered. I will attempt to guide you through this exercise with a fleet locomotives I am familiar with, my own.

The first area of expense that we need to look at is the operating expense of each type of contouring available, as well as, the frequency with which it will have to be done over the life expectancy of the wheel set.

The first method, grinding shoes, in my estimation is required to be done an average of four times over the life of a wheel. This would cost an average of $17,544 per wheel set over the life expectancy of each wheel. This estimate is based on a labor cost of $44 per hour fully burdened, locomotive replacement cost at $750 per day, fuel cost to operate the locomotive while grinding the wheel at $621 each, additional maintenance cost incurred on the locomotive while grinding the wheel $495, and material cost of the grinding shoes required to contour a wheel set.

The second method, flange cutters, is estimated to be required seven times over the life of a wheel. It is not possible to correct contour problems other than flange height with this method. Using the previously mentioned rates and material costs, it would cost an average of $10,186.40 per wheel set over the life expectancy of each wheel set.

There is also another item, though hard to quantify, will need to be considered with both of the previous methods. This is the diminished locomotive performance both from a fuel efficiently stand point and an adhesion standpoint. With the inability to be able to produce repeatable results, both items would always suffer to varying degrees.

The third method, portable lathe, is required an estimated three times over the life of the wheel set. Using the previous mentioned rates and material costs, it would cost an average of $6,646.56 per wheel set over the life expectancy of each wheel set. Again, locomotive performance would suffer due to poor repeatability. With this method one has to also make a capital investment in equipment of approximately $14,000, assuming all equipment would require purchasing to complete this task.

The fourth method, outsource, is required an estimated three times over the life expectancy of the wheel set. Using the previous mentioned rates the cost would be $8,325, per wheel set over the life expectancy of each wheel set.

The fifth method, removal, is estimated to be required three times over the life of a wheel set. The cost to use this method would be $4,008, per wheel set over the life expectancy of the wheel set. This method would require a capital expenditure of $650,000 assuming that all equipment would need to be purchased in order to complete the task.

The sixth method, in-ground wheel lathe, is required an average of three times over the life of the wheel. The cost of this method using previously mentioned rates would be $569.62 over the life of the wheel set. This method would require an capital expenditure of $1,000,000 assuming all equipment would require purchasing to complete the task.

A word of caution at this point - the costs and man hour estimates are only an example. Each railroad would have to develop these numbers for its own unique conditions, circumstances, and accounting methods.

With all that behind us we now need to look at our fleet size in terms of how many wheel sets are in the fleet, how many miles do we operate our locomotives in a year, and do we have a flange lubrication program?

Once we have answers to these questions we are ready to begin the task of analyzing the data. For the purpose of this exercise, we will use some assumptions, which will undoubtedly be different for each railroad:

Labor cost $44 per hour
Locomotive out of use or replacement cost of $750 per day
Locomotive maintenance cost of $250 per day
Wheels will require to be trued every 100,000 miles
Fuel consumption rate is at that of an EMD GP 40 or SD40
Railroad is using the Temple or Fat 40 wheel
A fleet size of 200 locomotives, with an average of 5 axles each
When grinding or flange cutting wheels an average throttle position of 3rd notch
A fuel cost of 75 cents per gallon
Locomotive mileage of 100,000 miles per year
Wheel replacement at 400,000 miles
Outsource cost of $437 per wheel set
Freight expense to outsource of $600 per trip.

Next we have to figure out which method is the most cost effective for your railroad and what kind of return on investment we need to motivate a purchase of a wheel truing machine.

It is safe to assume that from a quality perspective the only acceptable methods are outsourcing or owning our own machine.

With the cost of $17,544 per wheel for grinding it would cost $17,544,000 for the entire fleet over the life expectancy of the wheel sets. This would put your annual cost at $4,386,000 for this method.

Using the same methodology we have developed the following for each method:

Wheel grinding	$4,386,000.00
Flange cutting	$2,546,600.00
Portable wheel lathe	$1,661,640.00
Outsource	$2,081,250.00
Removal	$1,002,000.00
In ground wheel truing	$ 142,405.00.

We now have to look at the capital expenditure required to do each method. This will vary depending on which items your railroad already has or how resourceful you are:

Wheel grinding	None
Flange cutting	None
Portable wheel lathe	$2,000 to 14,000
Outsource	None
Removal	$250,000 to 650,000
In ground wheel truing	$350,000 to 1,000,000

Next we have to weigh our capital expenditure against annual operating expense reduction to come up with an valid return on investment. Keep in mind when doing this the added benefits of increased adhesion, fuel efficiency, and longer rail life, which are difficult to measure, if not impossible. However, they do need to be considered in a return on investment calculation.

The large range of capital required for each method is an item to take notice of. I will explain this for an in-ground wheel truing machine, but the same theory will hold true for any of the capital expenditures involved.

Well, you want to buy a wheel machine, Just come on down to Wheely Bob's Wheel Machine Emporium and we'll fix you right up. First you'll have to look at several choices, availability, and installations.

First choice, do we buy new? American or European technology? How quickly can we set up? What are the maintenance costs? How user friendly is the machine to operate? What are our consumable costs? What options do we want, Cadillac or Geo?

Second choice, do we buy used? What are our sources, down sizing railroads, OEM's trade in's, or foreign market? What condition will we accept? What will a used machine do to our maintenance costs? Who will we get to support our material needs? What options are available and which ones do we want?

Third choice, how will we install our machine? What is a suitable location? Will soil conditions allow us to do so economically? Can we put the machine in an existing building, or will we have to build a new building as well? Do we contract out the engineering? Do we do our own installation, or contract out the entire operation:

With all those questions answered we will get to the dreaded R.O.I.. How many years will it take of savings over the present method to pay for our new toy.

Annual costs:

	Wheel machine	Estimated savings annually
Wheel grinding		
$4,386,000	$142,405	$4,243,595
Flange cutting		
$2,546,600	$142,405	$2,404,195
Portable wheel lathe		
$1,661,640	$142,405	$1,519,235
Outsource		
$2,081,250	$142,405	$1,938,845
Removal		
$1,002,000	$142,405	$859,595

Next, armed with all this information we go to our accounting department and find out what the cost of capital funds are. Will the investment be funded internally or placed with an outside financial institution? What method of accounting will be used? How much monetary consideration will be given to better fuel efficiency, better adhesion, and longer rail life?

One last thing to consider when justifying a wheel truing machine is that it can be used to generate an alternative income source depending on potential customers in your area.

We hope this report has answered some questions you might have regarding the capabilities and costs of a wheel truing machine in comparison to other methods. Each company of course must cost-justify this machine or any other equipment according to its own specific situations.

IV. EDM SD60M NATURAL GAS LOCOMOTIVE DEVELOPMENT

Prepared by: Keith Mahalik, EMD & John Baranko, Conrail

Railroad Interest In Alternative Fuels

Railroad reliance on diesel fuel powered locomotives was badly shaken during the 1970's as a result of the two crude oil shortages. From the mid 70's to the early 80's North American railroads experienced fuel supply shortages and unprecedented increases in fuel cost. This led to a directive by US and Canadian railroad managements to find an "alternative" fuel to diesel fuel for their motive power. In response to this challenge, the North American locomotive builders and several railroad R&D departments initiated in depth studies and development programs to determine the feasibility and economic viability of other fuels or energy sources. For a time there was renewed interest in coal burning locomotives, both steam boiler and direct injected internal combustion, and in the electrification of high ton-mile freight corridors. These options did not appear to be practical.

Besides coal, several candidate alternative fuels have been evaluated by the locomotive builders, individual railroads, and research institutes. The use of methanol and other alcohols mixed with #2 diesel fuel as a fuel extender has been successfully demonstrated in modified EMD diesel locomotive engines. However, these fuels proved to be uneconomical and posed potential environmental risk. From these studies, the best alternative fuel was found to be natural gas.

Natural Gas - An Alternative Railroad Fuel

It appears that natural gas can best meet the needs of the North American railroads as an alternative to #2 diesel fuel. Natural gas is found in ample supply throughout North America and an extensive network of gas wells, pipelines, and pumping stations is currently in place. The cost of natural gas, on an energy basis, is less than diesel fuel and is expected to remain so. Natural gas has been used for many years as a fuel in spark ignited internal combustion engines and as the primary fuel in compression ignition engines requiring small amounts of diesel fuel to initiate combustion. Natural gas burning engines have also been found to produce lower exhaust emissions, particularly oxides of nitrogen. Although quite reliable, the gas engines that were available in the past suffered from low specific power output.

EMD 567 Dual Fuel Engine

For several years EMD produced natural gas burning "dual fuel" engines based on the 567 series of engines. These engines incorporated roots blowers for scavenging. The primary usage of these engines was in stationary applications in locations where natural gas was more economical to use than diesel fuel.

The 567 dual fuel engine was designed to operate on low pressure natural gas with ignition provided by a small diesel fuel pilot charge. An additional valve in the cylinder head was used to control the flow of gas into the cylinder. This valve was timed to allow gas to enter the cylinder immediately after the piston closed off the inlet ports while the pressure in the cylinder was still low. As a consequence of this arrangement, the gas inside the cylin-

der would become mixed with the charge air and compressed as the piston traveled to top dead center. The compression heating of this mixture often resulted in pre-ignition or "knock" if the natural gas contained too high a percentage of propane or butane. To prevent engine damage from knock, the 567 dual engine had a lower compression ratio and lower specific power output than the diesel engine counterpart. The lower output and poor tolerance for variations in natural gas composition limited the engine's acceptance.

Burlington Northern RR Natural Gas Locomotive Development

The Burlington Northern Railroad's search for an alternative to diesel fuel also led to natural gas. In the early 1980's the BN converted an older low horsepower EMD road locomotive to run on low pressure natural gas. The engine was reconfigured for dual fuel operation using existing EMD hardware. Although problems with engine detonation were encountered and concern was raised for the limited operating range provided by the gas storage system, the BN and the railroad industry gained valuable experience from this program.

In the late 1980's, BN broadened its natural gas locomotive evaluation program to include the development of high horsepower natural gas fueled locomotives, liquified natural gas (LNG) tenders, and an LNG filling facility. BN selected two EMD SD40-2 locomotives for this phase of its evaluation, with the goal of retaining the full 3000 traction horsepower diesel rating. The engines in these locomotives were modified to operate on low pressure natural gas that is high in methane content. The engine configuration used is similar to the EMD 567 dual fuel design but incorporates computer control and additional charge air cooling to reduce both the tendency for "knock" under full load conditions and also engine exhaust emissions, particularly oxides of nitrogen (NOx). The BN project was discussed in detail in a 1994 LMOA Diesel Mechanical Committee paper.

EMD 710 Natural Gas Engine Development

In the last few years a number of North American railroads and stationary power users have encouraged Electro-Motive to develop a modern high horsepower natural gas engine. About four years ago, an EMD engineering development project, partially funded by the Union Pacific Railroad, was initiated to design, build, and test a natural gas burning dual fuel engine based on the 710 engine series. The following goals were established for the project:

* Engine to be based on the current 16-710G3 engine.
* Engine designed for safe natural gas operation.
* Maximum substitution of diesel fuel with natural gas.
* Produce full diesel power rating while running on natural gas.
* Operate on either natural gas with diesel fuel pilot or on straight diesel fuel.
* Maintain high thermal efficiency.
* Produce lower exhaust emissions, particularly oxides of nitrogen.

To meet these goals EMD engineers felt that the natural gas engine technology incorporated earlier on the 567 series engines would not be adequate. A different design concept would be needed for the 710 natural gas engine. To eliminate the knocking problems associated with the premixing of low

pressure natural gas with charge air, it was decided to develop a natural gas injection system that could "inject" high pressure natural gas directly into the cylinder chamber near top dead center. This would allow the engine to retain diesel-like operating characteristics. This approach has become known as "late cycle high pressure direct injection."

To aid in the design of the 710 natural gas engine, EMD put together a team made up of Diesel Technologies Corp. (DTC), the manufacturer of EMD injectors, and Southwest Research Institute (SwRI), a leading engine development and testing facility. During the last two years this team has been engaged in an intensive development and prototype build program. To support the project with hardware, EMD has provided SwRI with a single cylinder 710 research engine and a 16-710G3A rail engine/generator package. The team is in the final stages of the program. The single cylinder 710 engine has been successfully operated on natural gas at full diesel rating, and is being used to refine the combustion process. The 16-710 engine has been completely reconfigured for gas operation and has also reached full rated power (4200 BHP) on natural gas. This engine will be used for extensive performance testing and full load durability tests.

EMD 710 Natural Gas Engine - New Features

The 710 natural gas engine configuration that has been developed incorporates a number of new features:

* Modified cylinder heads to accommodate gas injectors.
* Electronically controlled diesel unit injectors.
* Electronically controlled high pressure natural gas injectors.
* High pressure actuating fluid system to activate gas injectors.
* High pressure actuating and natural gas manifolds.
* Microprocessor engine control.

The main advantage of the new EMD 710 natural gas engine is that it operates like a diesel. The only major change to the engine is the replacement of the standard cylinder heads with heads designed to accommodate the diesel injector and a specially designed gas injector. The 710 gas engine requires an externally generated source of 3000+ psi natural gas for proper operation. This high level of gas pressure is needed for two reasons:

(1) To overcome the pressure of the compressed charge air when the pistons are near top dead center and allow fuel to enter the cylinders in large enough quantities to provide the same energy as the diesel fuel replaced.

(2) To provide adequate penetration and mixing in the combustion chamber to allow "diffusion burning" combustion to occur.

The EMD 710 natural gas engine is started on straight diesel fuel and can run at full power on diesel fuel if necessary. Switchover to natural gas with diesel fuel pilot is possible at all powered throttle notches. To maintain diesel engine operating characteristics, the high pressure natural gas is injected directly into the cylinders when the pistons are near top dead center through a set of injector nozzle holes, much like a diesel injector. A small amount of diesel fuel is also injected at approximately the same time to initiate ignition. Electronic control modules, located on the top of the injectors, control the flow of the actuating fluid that is then used to lift the gas injector needle valve mechanism. Specially designed manifolds located on the outside of the top deck frames are used to pipe the high pressure natural gas and actuating

fluid to the engine. Heavy duty junction blocks located at each cylinder along the gas manifolds provide robust termination points for the high pressure jumper lines to each gas injector.

The 710 natural gas engine is completely electronically controlled. Two microprocessors are used: one dedicated to the control of the diesel unit injectors and the other dedicated to the control of the gas injectors. The primary objective of the control system is to maintain rated load at preset engine speeds. Precise engine speed is fed into the computers from hardened speed pickups. Other engine sensors also provide signals to the computers for protection and diagnostics.

Union Pacific will be using liquid natural gas tenders for fuel storage. One tender will serve two locomotives. In this arrangement, the tender is positioned between the locomotives. LNG is transferred to the locomotives through vacuum jacketed lines. Special pumps located at the bottom of the tenders are used to pump LNG into the lines. Power for these pumps will be supplied by the locomotives.

Natural Gas Handling Equipment

The overall arrangement of the EMD natural gas locomotive can be divided into two parts, the gas handling equipment and the EMD 710 gas engine. The gas handling system is designed to receive low pressure LNG from the storage tender and to convert this liquid into warm high pressure natural gas suitable for use in the engine.

The main components of the natural gas handling equipment are:

* Cryogenic natural gas handling skid
* Hydrostatic drive system
* LNG to CNG glycol heating loop
* Microprocessor control and safety systems.

The cryogenic natural gas handling skid is provided by Air Products and Chemicals, Inc., and is located in the right rear of the locomotive. Mounted on the skid is a series of control and safety relief valves, the high pressure liquid natural gas pump and a high pressure surge vessel. The valves are computer controlled and route LNG from the tender through various pipe branches to control the delivery of high pressure liquid natural gas and to maintain the high pressure pump at cryogenic temperatures. The high pressure LNG pump raises the pressure of the liquid natural gas to the 3000 psi level required by the engine.

From the skid, high pressure LNG is piped into a large high pressure stainless steel heat exchanger where the LNG is warmed to approximately 100 deg F from hot antifreeze pumped through the shell side of the unit. The antifreeze is heated by the engine cooling system through an auxiliary heat exchanger. Once in gaseous form, the high pressure natural gas is piped to the engine manifolds. A number of pressure and temperature sensors are installed in the gas piping to control the flow and monitor the characteristics of the gas.

The natural gas handling system is controlled by a micro-processor manufactured by the Woodward Governor Co. The processor is located in the outer vestibule at the front of the locomotives. In addition to controlling the flow of high pressure gas to the engine, this microprocessor also monitors the natural gas leak detection system. In the event of a gas leak, the gas handling system computer will light a warning light, discontinue flow of gas, shut off the LNG supply valve at the tender, and return the engine to diesel only operation.

At the present time, natural gas is the best alternative to diesel fuel. The EMD natural gas locomotive can pro-

duce full rated power on gas and will undergo full field performance testing on Union Pacific in 1995. This performance testing will further evaluate the feasibility of operating road locomotives on natural gas.

REPORT OF THE COMMITTEE ON DIESEL ELECTRICAL MAINTENANCE

TUESDAY, SEPTEMBER 12,1995
1:45 P.M.

Pre-Convention Presentation Southern & Southwestern Rwy. Club

July 7, 1995
Ponte Vedra Inn & Club
Ponte Vedra Beach, FL

JOHN NIXON, Chairman
Dir. Equipment
AT&SF
Schaumburg, IL

Vice Chairman
J. POPP
Mgr.-Quality Control
Amtrak
Wilmington, DE

COMMITTEE MEMBERS

N. Anderson	Mgr-Elect. Engrg.	Morrison Knudsen	Boise, ID
S. Anoo	Elect. Engr.	C & NW	Chicago, IL
R. Blanchard	Mgr-Loco. Maint.	Conrail	Conway, PA
B. Brown	Mgr.-Loco.Projects	Montana Rail Link	Missoula, MT
J. Chessario	Prod. Analyst-Loco. Cont.	General Electric	Erie, PA
T. Fitzgerald	Mech. Forman	Illinois Central	Homewood, IL
M. Fitzpatrick	Mgr. Loco. Tech. Svcs.	Conrail	Beaver Fall, PA
B. Hathaway	Gen. Mech. Foreman	Florida East Coast	New Smyma Bch, FL
R. Lebold	Dir. Elect. Engrg.	CSX Transportation	Jacksonville, FL
M. Pasini	Ch. Elect. Engr.	Via Rail	Montreal, PQ
L. White	Sr. Tech. Officer-Elect.	Canadian National	Montreal, PQ
C. Wilkerson, Jr.	Asst. Mgr. Mech-Maint.	Norfolk Southern	Roanoke, VA
J. Youngwirth	Sr. ServiceTech. Engr.	Electro-Motive	La Grange, IL

PERSONAL HISTORY

John Nixon

John was born March 15, 1949 in Marshall, MO. He was raised in Kansas City and graduated from Wyandotte High School in 1967. He served three years in the US Army and received an honorable discharge.

John attended three years of college and pursued a business degree. He completed a two year course at an industrial electronics school and received a 2nd class FCC license. He started working on the Santa Fe in 1972 as a laborer. He completed a four year apprenticeship and was promoted to ASDE in 1979. He has worked as a travel lift foreman, mechanical training instructor, Asst. to the Manager of Locomotive Maintenance and Performance, Engineering Assistant, Asst. Manager of Locomotives, General Equipment Supervisor. He was recently promoted to Director of Equipment.

John is married and has four children.

THE SOUTHERN AND SOUTHWESTERN RAILWAY ASSN.

717 Pinecliffe Drive
Chesapeake, Virginia 23320

PURPOSE

The purpose of the Southern and Southwestern Railway Association is to promote customer and supplier relationships and provide an educational opportunity. The Association is aimed at middle management including shop, service, engineering, purchasing and sales personnel. Meetings are held to discuss current and developing trends in the industry. Presentations are made by railroad and supply representatives. The meetings also provide opportunities to cultivate ideas and personal relationships in social atmosphere.

The Southern and Southwestern Railway Association holds four (4) meetings per year at important railroad cities in the southeast.

Please drop our Secretary a line for an application for further information.

J. S. Mastrangelo
Secretary
717 Pinecliffe Drive
Chesapeake, Virginia 23320

I. CANADIAN NATIONAL BATTERY WATER USAGE

Prepared by: Les White, Canadian National

Water usage in a lead acid battery is a natural characteristic and you may ask what was the driving force that caused CN North America to closely examine this process. There are two main reasons that necessitated the review of this process:

1.) Abnormal water usage on the Dash8 fleet.
2) Implementation of 180 day inspection.

The electrolyte in a lead acid battery is a solution of sulphuric acid in water. As the lead acid cell reaches a full state of charge, some of the water in the electrolyte is broken down into hydrogen and oxygen gasses by the recharging current. These gasses escape from the vent on the top of each cell. This process called "gassing", accounts for the water lost from the cells. If the cells of a lead acid battery are to be totally equalized, then a certain amount of gassing will have to take place. Obviously the implementation of a 180 day inspection has a large impact. Most batteries will go 90 days without service but will not be able to achieve 180 days without substantial water loss. This is a major concern as working a battery with low electrolyte can substantially effect the condition of the battery.

When a cell is allowed to operate with low electrolyte for too long a period of time, that portion of the plates will become inactive and the capacity of the cell or cells is decreased.

The portion of the separator allowed to dry out may become plugged with lead sulphate salts. This will decrease the resistance of the cell or cells which results in reduced counter voltage. The problem becomes further aggravated because now the battery bank will be subjected to a higher float current which in turn causes greater water consumption.

As a cell operates on low electrolyte, the current concentration on the remaining submerged area increases, further aggravating the problem.

Under extreme conditions when a battery is subjected to over-charge the temperature may rise above 125 degrees F. This is a dangerous point as the counter voltage may collapse and thermal runaway could result.

It is very apparent that a large percentage of the batteries removed from service are initially weakened and or damaged from the root cause of low electrolyte. This issue is becoming more common as locomotives are being equipped with automatic stop and start systems, low idle and engine purge features. In addition to these features, shut down policies have also increased. All these features and policies put more demands on the batteries and will cause longer charge cycles or increase duty cycles which increases the amount of gassing. The question is what can we do to try and improve this situation? In our investigation it was found that there was three key areas that would improve or reduce this problem:

1) Review And Examine Internal Battery Design

We found that different suppliers have different designs and some of these designs can effectively improve the electrolyte reserve without changing the external dimensions of the battery while retaining required capacities. The definition of electrolyte reserve is the distance from the top of the plates

to the full point of the battery. The deeper this reserve the longer the battery can go without requiring servicing. This is a major point if you are experiencing problems with low electrolyte levels between periodic inspections. By examining different designs we have been able to improve this reserve from an original 2.45 inches to a new standard of 3.75 inches improving the reserve by 54%. This increase is substantial and will definitely increase the time between required servicing.

2) Review And Examine Add On Options

Two options were looked at. One is irrigation systems that could be adapted to keep water levels full at all times. These are quite interesting but when dealing with cold climates the systems will freeze and not work. However, if your operation is in an area where freezing is not a major concern, this is a method that should be looked at. The second option we looked at was catalyst battery caps. The best way to explain a catalyst battery cap is to quote an article that appeared in Home Power magazine.

"A catalyst battery cap is a catalytic gas recombiner that converts hydrogen and oxygen gasses into pure water. A catalyst is a substance which encourages other substances into chemical change without participating in that change, sort of a chemical ambassador. The process occurring in the cap is similar to that occurring in an automotive catalytic converter.

The catalyst battery cap replaces the regular cell cap. When the cell is gassing the hydrogen and oxygen gasses are vented into the cap. Inside the cap, a catalyst of platinum and other platinum group metals recombine the gasses into pure water. This water is then dripped back into the cell. The cap recycles the water that the cell gives off as hydrogen and oxygen gasses. This eliminates the danger posed by the hydrogen gas and vastly reduces watering the cells."

This of course sounds too good to be true, and there were many skeptics. In order to verify claims we equipped several of our Dash8 locomotives with these caps. Two cells in each battery were run with catalyst caps and two with regular caps. These batteries were filled then released and monitored by measuring the depth of electrolyte remaining above the splash plate. This comparison showed that we could expect an improvement of a minimum of .5 inches to a maximum of 1.5 inches over a 90 day period. We should point out that this test was conducted on our Dash8 locomotives and as mentioned earlier they were experiencing abnormal water usage. We found the main reason for this after the test was conducted, so the figures reflect the worst condition and figures will improve under normal operation. It is expected that under normal condition an improvement of 1 inch of electrolyte would be consistently seen. If we take this figure and add it to the improved electrolyte reserve obtained through different battery design the overall improvement is 94%. Because of this improvement these caps are now a standard on all new and rebuilt batteries purchased by CN.

3) Review And Check Voltage Regulation

Due to problems experienced with higher voltage levels and variable voltage systems used in the past, CN North America locomotives operate on a setting of 74 volts DC plus or minus .5 volts. This setting is across the auxiliary generator with an end result at the battery knife switch of a nominal 73 -

73.5 volts. The setting of the voltage regulator is critical to the amount of gassing produced at the batteries. Experimental data found in technical books on batteries shows the following:

Experimental Data On Gassing
(% By Volume)

Cell Voltage	Gassing	Composition Hydrogen,%	Oxygen,%
2.20	None	..	..
2.30	Slight	52	47
2.40	Normal	60	38
2.50	Hard	67	33

As can be seen by this chart, slight variations in cell voltages will make considerable difference to the amount of gassing. The importance of setting voltage regulators correctly cannot be over emphasised when dealing with battery problems.

The abnormal water usage problem on our Dash8 locomotives came down to a simple error on our part. That error was to take for granted that the 74 volt charging level shown on the DID Panel was the voltage across the auxiliary generator. When we examined the system closely it was found that while the DID Panel displayed 74 volts DC there was 75.2 to 75.3 volts across the battery switch. GE was approached on this problem and it appears the voltage displayed on the DID panel is a couple of diode drops down from the battery switch. In short the displayed voltage was what the system was seeing but not the true voltage being applied to the batteries. A fix to this problem has been requested, but as of the moment no answer has been received. In conclusion if you are experiencing low water conditions on your batteries or you intend on extending inspection periods, reviewing the three key areas of this paper will definitely produce positive results.

II. REMOTE DIAGNOSTICS-RADIO DOWNLOAD

Prepared by: Brian Hathaway
Florida East Coast Rwy. Co.

When the thought of having locomotives installed with another "black box" known as the event recorder was first conceived, some railroads rejected the idea. Many felt that the cost of installation, training, downtime and maintenance would only add to their existing list of headaches. Those thoughts have now changed.

The Diesel Electrical and other committees over the years have published articles on the subject of event recorders. Since the conception of the recorder, many advantages in technology have come into being. This report is an expansion of the recorder.

The basic recorder is required to record and store data on train speed, direction of motion, time, distance, throttle position, brake applications and operations (including train brake, independent brake, and if so equipped, dynamic brake applications and operations) and where the locomotive is so equipped, cab signal aspect(s), over the most recent 48 hours of operation of the electrical system of the locomotive on which it is installed. Recent developments in the electronic industry have resulted in drastically reduced prices for high performance microprocessors and peripheral components. A relatively simple device such as the event recorder can now be considered as an onboard computer, instead of a single function black box, capable of fulfilling the FRA requirements plus other tasks. With the advancement in the electronic event recorders the vision or reality is to let the recorder do the work for you, using it beyond the requirements set by the FRA...and several railroads have done just that.

On those railroads that have expanded the basic system, the following is just the beginning of what is and can be accomplished with the system. One of those "other" tasks mentioned before is to act as onboard locomotive health monitor. This task can be used as a means to improve component life, which tends to increase locomotive reliability and the scheduling of overhauls, or to minimize power requirements.

Historically, locomotive diagnostics and health monitoring systems meant the addition of a multitude of sensors and processing equipment. These additional components have typically meant additional maintenance, something they were supposed to help reduce in the first place. This increased maintenance leads to reduced availability of the locomotive, something that we would have expected to improve on by adding such a system in the first place. We have not even mentioned the costs involved.

The alternative to onboard diagnostics and monitoring has usually been annual or semi annual load box testing. Besides the labor involved to connect and operate, load box testing is not always convenient due to noise and other environmental restriction. A second restriction may be the load box itself. The typical running shop load box does not necessarily have flexibility to evaluate the excitation system over the complete operating spectrum from low voltage/high current to high voltage/low current. We definitely don't think that the load box is obsolete, but by evaluating the locomotive in real conditions, we can now be very selective about when and which locomotives actually need this type of testing.

Consistent with our opening statement about lessening the reliability of a locomotive by adding test devices, a

minimum number of inputs must give a maximum amount of information. In the case of the FRA recorder system, traction motor current is one of the required signals to be measured. If we add main generator alternator voltage, a fairly accurate horsepower measurement can be attained. By going one step further and measuring the difference between the load regulator wiper and the top of the pot, we get feedback from the engine as to the load regulator/governor balance point.

Anyone who has used event recorders will easily recognize that the data come at a price, the time required to retrieve the download. In the case of an event recorder/health monitor the benefits of the health monitor are only attainable by downloading at virtually every opportunity. So what we have done by combining the two devices? We have created more work for someone involved in downloading, right? Not necessarily!

The electronics revolution that we spoke of earlier has made it possible to add an integral data radio to the event recorder. This high speed radio can download an event recorder at speeds in excess of fifty miles per hour, making the download process transparent to the user. Now, the data are transferred automatically to a personal computer for processing without human intervention.

The event recorder is set to automatically download after 128 KBytes of the memory has been overwritten with new data, or the locomotive has traveled more than 50 miles. As a locomotive moves down the track, new data are stored as certain events take place.

The core of the complete system is the data radio. The one employed for the base station is a low power, high speed military design installed in a rugged housing. A railroad having radio base stations installed at locations averaging 90 miles apart from each other throughout the system, can download the recorded data from the locomotive at close intervals, to obtain the most recent information available. A personal computer is required to control software at each base station and provide a temporary storage place for the download data. The same basic computer also handles communications via modem to a central server.

The radio base station is programmed to poll every few seconds for locomotives between a range of 1/3 to 1/2 mile, depending on buildings, etc. When a locomotive comes within range, the base station radio and the locomotive recorder's radio communicate by the low power radio and if the recorder has enough data a download will take place. If the recorder does not have enough new data, the base station will go back to polling, looking for other potential candidates for downloading.

Depending on the speed of the train, it is possible that the lead locomotive will download at one location, the second locomotive at the second location and the third at the third location. In this way, the whole consist will eventually be downloaded. Most of the time the consist will download at one station.

In order to make the recorded data information available, a central file storage computer or the server is required. The server's job is to call the base station computers downloading the data at regular times and coordinate time setting, etc. The server then loads all data received from the base stations onto the railway's mainframe computer. Personnel requiring data from the locomotive can communicate with the mainframe from the terminal on their desks or via modem. In this way downloads are available to anyone on the system for complete analysis into reports, surveys or problem areas.

Custom software is then used to run exception reports on each download. These exception reports contain search functions looking for things such as alarms, low horsepower, fuel consumption, duty cycle, traction motor cutout, ground relay action, wheel slip, etc. They also contain search functions for the Transportation department for such items as power braking, speeding, overloading, etc.

In a typical exception report if an item is identified that needs further investigation, the relevant data file is made available for manual analysis.

The goal of the system is to provide both Mechanical and Transportation personnel with their required information in a fast and effortless manner. The installation of event recorders has been required by the FRA, but the use of the data does not have to be limited to FRA required items. Operating and health monitor information is stored, downloaded and processed automatically in a central location available to those requiring this information.

III. PROGRAMMED PREVENTIVE MAINTENANCE

Prepared by: John Nixon
AT & SF Rwy. Co.

It is the goal of every Mechanical team to provide reliable equipment at the lowest possible cost. The railroad that does the best job in reaching that goal has the competitive edge. Maintenance is a cost. Poor maintenance of equipment or over maintaining equipment cost more than doing only the required amount of maintenance. The ideal maintenance program is one that replaces the component just before it wears out, thereby reducing road failures and detention time.

A heavy preventive maintenance program reduces on-line failures but adds a lot of detention time for maintenance, while a "no preventive maintenance" program drives up on-line failures and shop repair time. So is your policy run-to-failure or heavy in the preventive maintenance area? This is the question each Mechanical team must struggle with. In the real world, the best strategy may be run-to-failure on some components and programmed change-outs on others.

Railroads have used various strategies to develop what they perceive as the best possible maintenance program. Life cycle analysis is one approach and a very useful tool in developing a cost-effective maintenance program. This approach is not new nor it it unique to the railroad industry. The airline industry and the automobile industry have used it for years.

Chart 1 shows two approaches to maintenance - Preventive maintenance and run-to-failure. Where the two lines intersect is the most cost-effective approach to maintenance from a pure maintenance perspective. It may not be the most cost-effective approach for the railroad when one considers the cost of the failure. One broken axle could cause a derailment that could cost the railroad millions. Therefore, the cost of the failure must be considered in the analysis.

One of several approaches to life cycle analysis is the use of the Weibull distribution. Weibull distribution is a statistical distribution commonly used for reliability engineering. Weibull distribution provides a cumulative probability of failure and a failure rate. One way to explain this is by a bath tub curve (Chart 2). The bath tub curve is divided into three regions. The first region is called the infant mortality curve. This has a decreasing slope. The second region is relatively flat and is considered a constant or random failure rate. The third region is the wear out point. This has an increasing slope. Obviously, if you know the wear out point, you can design a maintenance program to replace the component before wear out occurs.

Component specifications have an effect on the curve. The curve will have fewer infant mortality failures and a longer region two if the specifications are designed for durability and reliability. The curve will have more infant mortality failures and a shorter region two if the specs are designed strictly for cost considerations. One has to balance cost versus durability and reliability.

Let's use a hypothetical railroad that we will call LMOA and assume it completely overhauls all components at seven years. The LMOA railroad will start the analysis with two components, water pumps and cooling fans. For seven years they have been accumulating detailed data on these two components. The data were analyzed through the use of Weilbull distribution. The graphs are a pictorial representation of that data. Let's look at the water pump first.

The water pump graph, Chart 3, shows a region one infant mortality region lasting about 100 days. A region two has an area of about 1300 days. At 1400 days, one can see a dramatic change in the slope indicating region three, which is wear out. One can now design a program to change out the water pump every four years. This will eliminate many road failures.

Cooling fans are a different story. This graph, Chart 4, illustrates that region one lasts about 100 days. Region two begins but region three does not. This graph shows that the present maintenance program does not allow the component to reach wear out. The wear out point could be 7 1/2 years or even 15 years. Therefore this component should not be overhauled at seven years but allowed to run until the wear point is reached.

Obviously, there are some components, such as axles, which we do not want to get into the wear out region. The maintenance program for these components will be very strict and conservative. There are also components, such as traction motor wheel assemblies, which have so many variables influencing the failure rate that it is almost impossible to predict the wear out point. The maintenance program for these components will be run-to-failure.

Each component on the locomotive will need to be analyzed in the same manner until a comprehensive maintenance program has been designed. Designing a maintenance program in this manner will provide an extremely reliable locomotive at the lowest possible cost to the railroad.

MAINTENANCE COST
VERSUS TIME

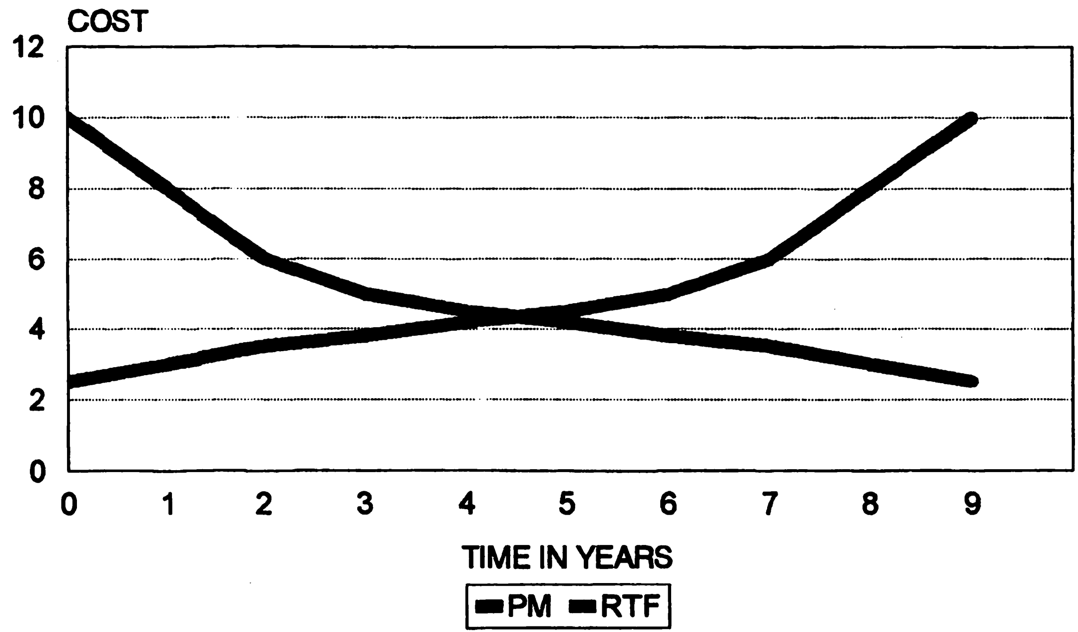


Chart 1

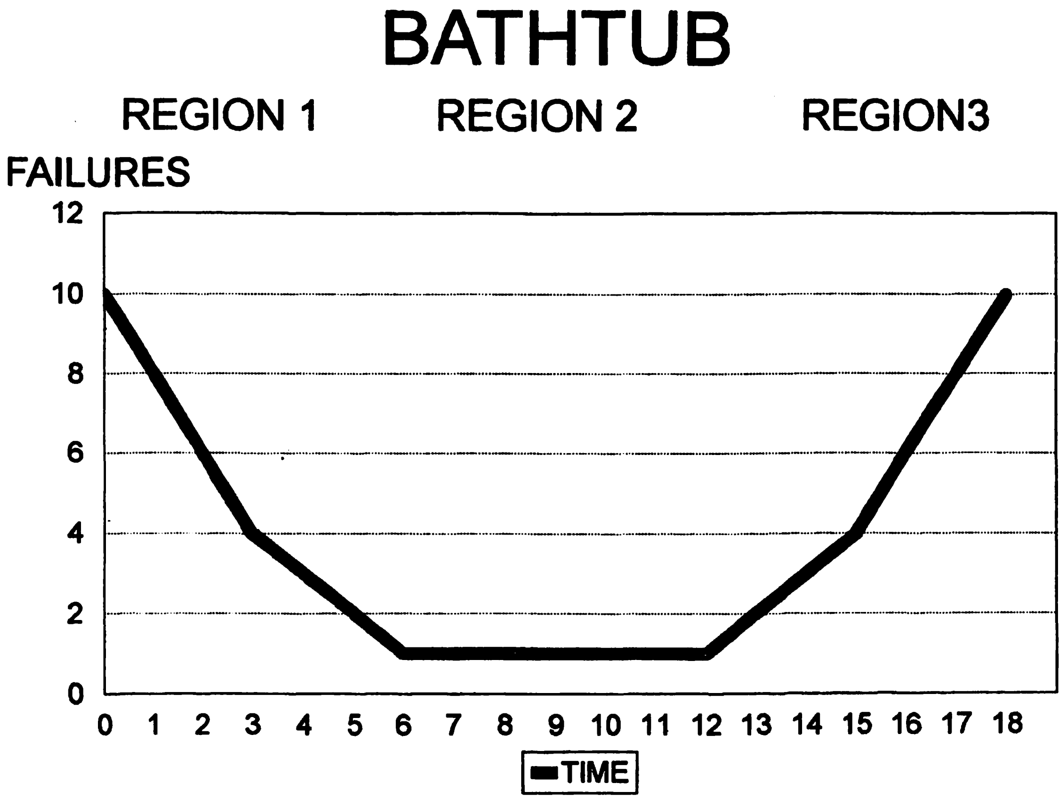

BATHTUB
REGION 1
REGION 2
REGION3
FAILURES
12
10
8
6
4
2
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
TIME

Chart 2

WATER PUMP

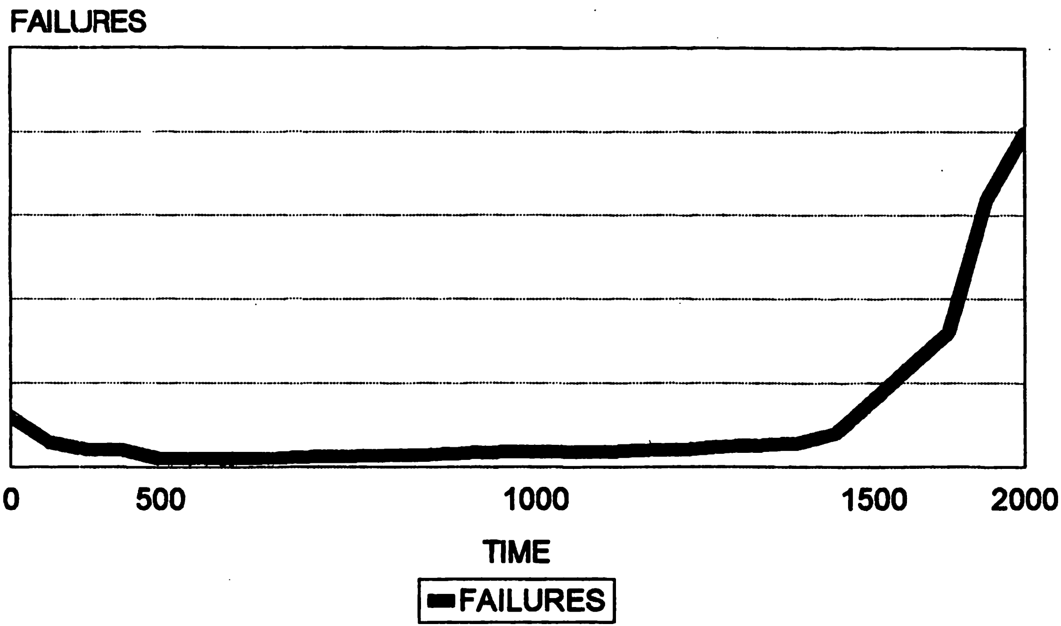


Chart 3

COOLING FAN

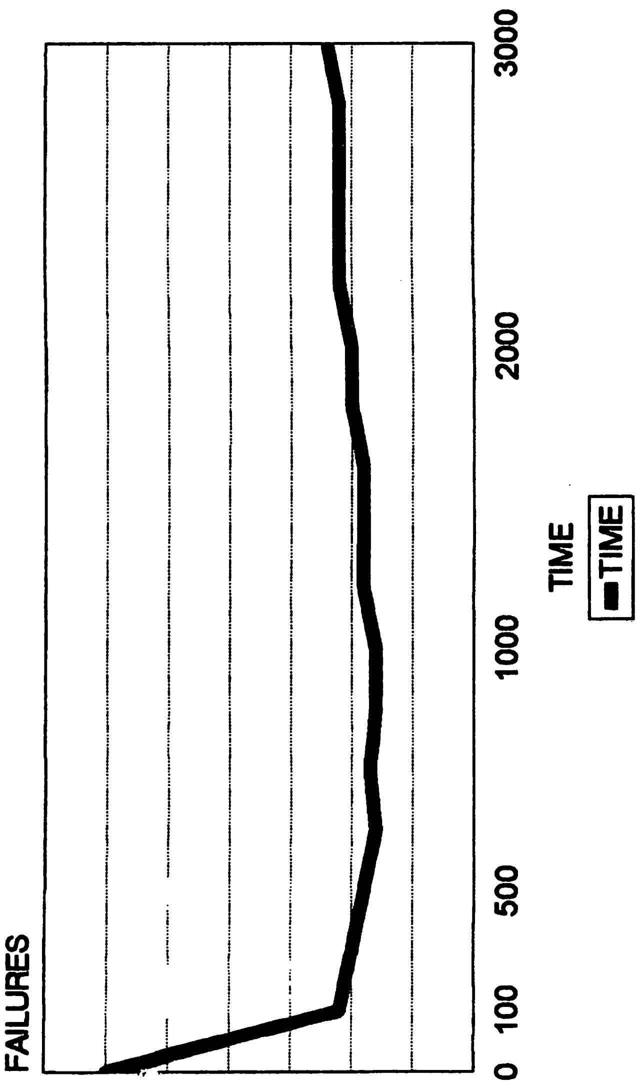


Chart 4

IV. COMMUTATION MONITORING IN LOCOMOTIVE DC TRACTION MOTORS

Prepared by: Michael P. Treanor,
Lockheed Martin Corp.
and
Gerald B. Kliman,
GE Corporate Research
& Development

Abstract: The problem of machine condition monitoring of dc traction motors on diesel-electric locomotives is addressed. Techniques for detecting poor commutation to allow an operator to take action to prevent flashover were studied. The focus of the study was frequency-domain analysis of the motor current at the bar-passing frequency, although other techniques were found to be successful. A fast-fourier-transform of the motor current indicated a peak at the bar-passing frequency which increased in magnitude by a factor of five when the commutation quality was degraded. A relation is provided between the visual sparking level and the magnitude of the bar-passing peak.

Keywords: brushes, commutation, dc, diesel-electric, locomotive, motor-current-signature analysis, sparking, traction.

Introduction: The ability to monitor commutation quality degradation as a precursor to flashover in dc machines would provide a significant payoff in steel mills, paper mills, and, in particular, the locomotive industry. One of the largest sources of maintenance effort on diesel electric locomotives is the traction motor, which has warranted some investigations (1, 2). In part this is due to problems inherent in all electric motors but exacerbated by the very difficult thermal, humidity, contaminant and shock environment of the traction motor, which far exceeds that of industrial motors in general. A further complication and added cost is that, when something is seriously wrong with the motor, it must be removed from the truck which must first be removed from the locomotive by means of a drop table. It is often the case that locomotives may be backed up for many days waiting for a turn at the drop table adding to the already high cost of removal. Advance knowledge of developing problems in the motors would be a major advantage in scheduling scarce repair facilities. It is also very important to note that some motor problems can be corrected without removal of the motor if they are caught early enough.

Diesel-electric locomotives have dominated the railroad industry for almost 70 years. In that time the diesel engines have grown in power from around 1500 HP to 4500 HP on dc drive locomotives. At the same time, the 4, 6, or 8 dc traction motors on a locomotive have had a corresponding growth in rated power from around 300 HP to 750 HP with much of that growth not accompanied by an increase in size. The motors are always axle-hung, hence they are subjected to a high level of road vibration and shocks in excess of 50 g. All of the motors are cooled with ambient air that may range from -40 deg F to + 130 deg F. This air, taken from the right of way with little or no filtering, may contain particulates, chemical contaminants and moisture ranging from zero to 100% relative humidity. To complete the stress picture the motors are normally run at very low speeds at high loads for extended periods as well as at high speeds over rough track.

The conditions described above may quickly degrade the commutators in the

dc motors. A degraded commutator will show excessive sparking, as the brushes bounce over the rough surface and the conduction period for a particular segment ends prematurely, or a winding remains shorted for too long by a spark region which extends between segments. Ultimately a short circuit will develop, through an extended spark region over the commutator bars, between opposite-polarity brushes. This "flashover" is often severe enough to destroy the motor and can cause the axle to lock.

It has been found that flashovers are usually preceded by poor commutation. This condition can be recognized by excessive sparking while the motor is running, or by careful examination of the commutator surface for an improper film development, out of round, scoring, and other signs. These examination methods are not practical for a running locomotive traction motor, nor is it practical to train the operators or to perform the level of inspection necessary to certify each motor periodically. It is clear that there is a need for automated monitoring of the quality of the commutation for locomotive traction motors.

Several methods were investigated for gaging the quality of commutation in dc traction motors. The first method, motor current signature analysis, is similar to methods which have been applied to other motor types (3). The motor current was examined in two frequency bands: below 100 Hz and below 10 kHz. The brush voltage was also examined between 10 kHz. and 10 mHz. Spectra were obtained as the commutation quality was degraded by adjusting the current in the commutating poles. Spectral analysis of the armature current is described in detail. Other techniques were also considered: Antenna pickup of sparking, photodiode measurement of sparking, acoustic analysis, and O_3 and NO_x detectors. These other techniques were either less successful or were ruled out for practical reasons.

Preliminary tests and discussions with locomotive maintenance personnel resulted in a focus on motor current signatures as the best route to a useful instrument for actual locomotive road testing. If successful it could then be incorporated, at low cost, into the locomotive monitoring systems already in place.

General Description of the Tests: A laboratory test with a motor on the test stand in the steady state was carried out. The motor was a standard GE 750 HP locomotive traction motor on which the brush position was fixed at neutral but where the commutation poles were accessible for buck and boost. Figure 1 shows the test setup for the GE752-AH1 traction motor. The series connection of the motor and generator allowed a practical amount of power to be used to conduct the tests.

750-HP Traction Motor Measurements: Measurements were made on a 750 HP GE752-AH1 dc traction motor connected in the arrangement indicated in Figure 1. The traction motor had 184 commutator bars and the windings for the commutating poles were available for bucking or boosting. The brush ring could not be moved. Results showed that the frequency of rotation was easily discernible and the current magnitude at the bar-passing frequency was found to be a strong function of the level of sparking. An interesting feature of these results is that 12 Hz., and its harmonics, appear, which were determined to be related to resonant frequencies in the test stand. The magnitude of the bar-passing harmonic appears to be linearly dependent on the magnitude of the armature current.

Figure 2 indicates the bar-passing current at three levels of sparking at 1220 RPM and 2440 RPM while boosting the commutating poles. The level of sparking is visually observed at the brushes. It was found that the magnitude of the bar-passing current was independent of speed, so that, in Figure 2, straight lines were drawn through the buck and boost data regardless of speed. The data appear to fit to these straight lines. For each spark level, there was a larger bar passing current while boosting than while bucking the commutating pole current. Lines of the same slope as in Figure 2, but displaced downward, fitted well to the buck data. This non-symmetrical behavior is typical and can be seen clearly in Figure 3, which summarizes the variation of bar-passing current with spark level at one speed and armature current level.

It may be noted that the identical motor and generator were connected in series, so that the "A" sparking is the output of two machines, both assumed to be commutating well. It is reasonable, therefore, to subtract 1/2 of the "A"-sparking value at all points to obtain the contribution from one machine.

Since a plot of the current at the bar-passing frequency as a function of the dc armature current produces a straight line, a plot can be made of the slope of this line as a function of the spark level. This is done in Figure 4, where 1/2 the "A"-spark level has been subtracted as described above. The figure illustrates that the bar-passing harmonic can be related to the spark level, as discussed above.

Conclusion: Several methods were considered by which the condition of the commutator of a dc traction motor can be monitored. The results of frequency analysis of the motor current, and the effect of poor commutation on the current magnitude at the bar-passing frequency were explained in detail. It was found that the motor speed can be determined by recognizing the frequency of rotation within a low-frequency spectrum. From this information, the bar-passing frequency can be estimated. The magnitude of the motor current at the bar-passing frequency was found to be a strong function of the commutation quality, and could be related to the well-known visual spark levels. It should be noted that the speed of a dc motor is often known by other means, so that the frequency-analysis routines can be made simpler. Acquisition times should be kept as short as possible. This method was found to provide a significant remote indicator of commutation quality.

For a more complete discussion of the tests, including R.F. and ozone methods, see Treanor and Kliman (4). That paper also includes a description of similar tests done on a 10 HP dc motor with a movable brush ring which was moved to degrade commutation. The commutation monitor described here was tested briefly in an operating locomotive. The results of that test are related in Kliman and Steeples (2).

References:

(1) D.D. Steeples "Electrical Characteristic Changes from Artificially Induced Defects on an EMD D57 Traction Motor," Submitted to IAS (1994)

(2) D.D. Steeples, G.B. Kliman, "On-Line Commutation Monitoring of Locomotive DC Traction Motors In Service," to be presented at the 8th International COMADEM, Kingston, Ont, 6/27/95

(3) M.E. Steele, R.A. Ashen and L.G. Knight, "An Electrical Method for

Condition Monitoring of Motors", IEE Conference on Electrical Machines - Design and Applications, Pub. #213, July 1982, pp. 231-35.

(4) M.P. Treanor, G.M. Kliman, "Incipient Fault Detection in Locomotive Dc Traction Motors," 49th Meeting of the Society for Machinery Failure Prevention Technology, Virginia Beach, VA, April 18-20, 1995.

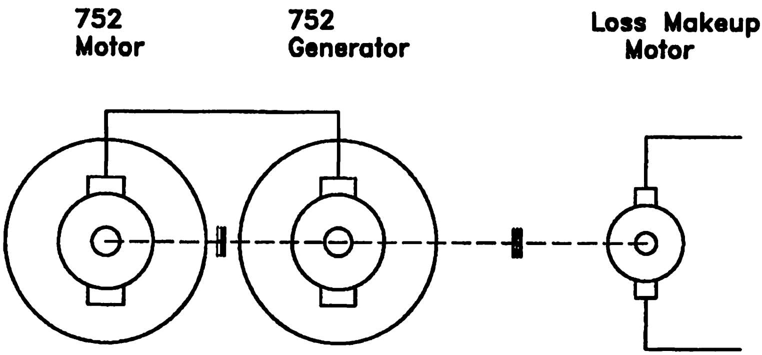


Fig. 1
Locomotive Traction Motor Test Setup at GE Transportation Systems

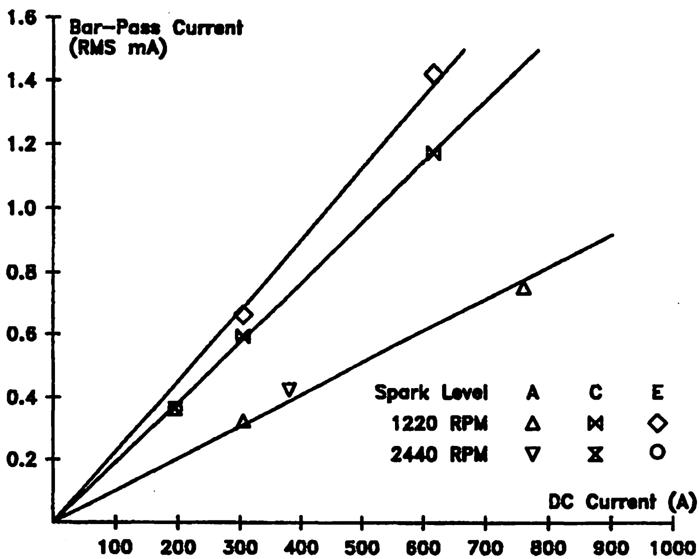


Figure 2
Current at the bar-passing frequency as dc current and spark level are varied.

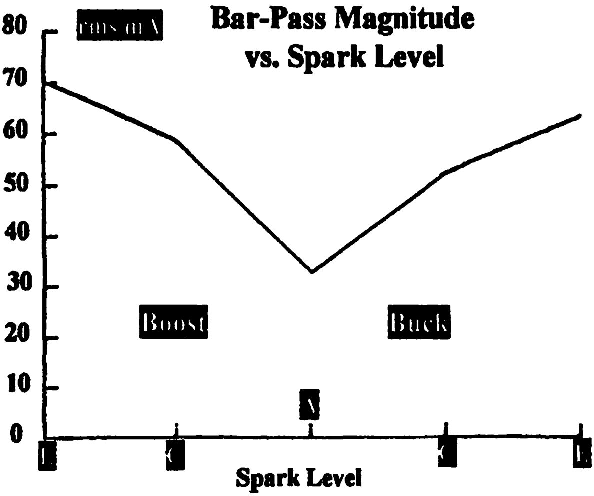


Figure 3
Bar-passing current magnitude at 1220 RPM,
615A dc as commutating pole current is varied.

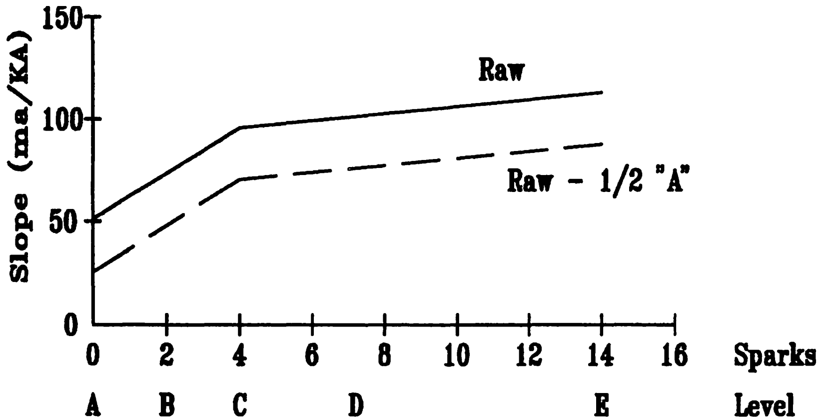


Figure 4
Slope of Bar-passing current vs. Dc current as a function of spark level.

V. THE EMDEC SYSTEM

Prepared by: Mike Fitzpatrick
Conrail

Because of the recent changes in locomotive technology, the Locomotive Maintenance Officers Association has recognized the need for different troubleshooting and maintenance techniques and has requested this report.

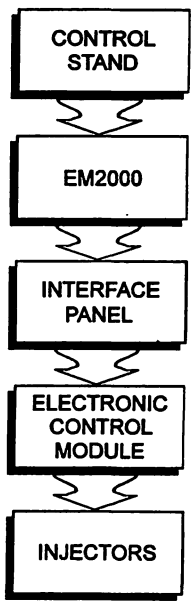
Electromotive diesel engine control, or EMDEC, is a new technology designed to optimize combustion on EMD locomotives.

The radical differences in electronic fuel injection require updated maintenance techniques.

A brief review of the mechanical fuel injection process will help in understanding the contrast with electronic fuel injection. Combustion requires three basic elements, fuel, oxygen and heat. Oxygen is forced into the cylinder when the piston is at the bottom of its stroke. Fuel is injected by the mechanical unit Injector, and is ignited by the heat generated through the piston's upward movement that compresses the air in the cylinder. The timing of the fuel injection is controlled by the camshaft, which is driven by the crankshaft. The amount of fuel is controlled by the engine governor through linkages and racks on each injector.

With electronic control, several of these components are unnecessary. The governor, associated linkage, and the injector rack have all been eliminated. The mechanical energy needed to atomize and inject the fuel is still generated by the camshaft driven off of the crankshaft.

The Figure 1 block diagram shows the major components in the EMDEC system.



Throttle request from the engineer's control stand goes to the EM2000 computer.

The EM2000 computer controls the locomotive's electrical system.

The EM2000 passes the throttle request to the interface board. Here the 74 volt signals are changed into 24 volt signals for use by the ECM, electronic control module.

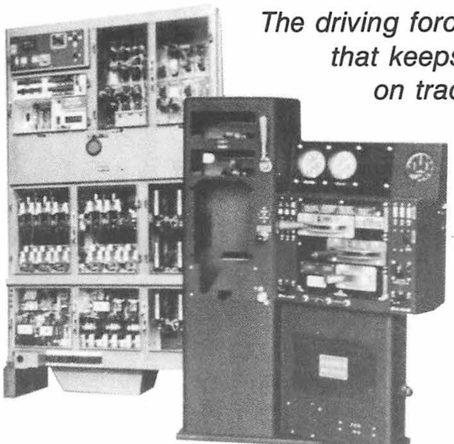
The ECM sends signals to the electronic unit Injectors, energizing the solenoids at the optimum time for the cleanest, most efficient fuel burn possible.

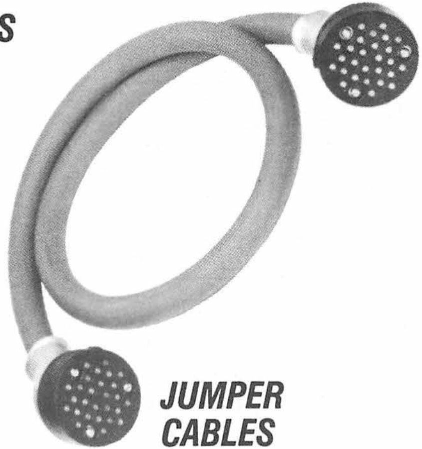
The ECM monitors many critical engine parameters. It adjusts fuel timing and the amount of fuel accordingly.

FOR ALL YOUR LOCOMOTIVE ELECTRICAL NEEDS

CUSTOM STANDS & CUSTOM CABINETS

The driving force that keeps you on track





JUMPER CABLES

Let G&G be your connection

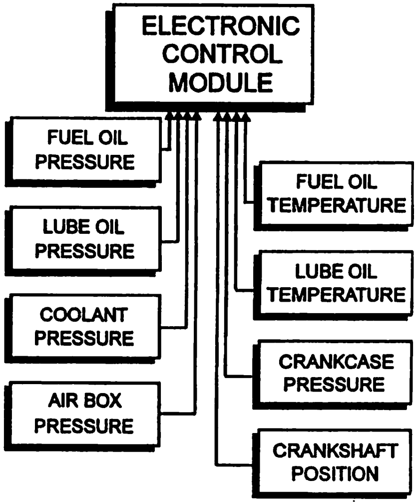
G&G MAXITRAX

Maxitrax is a dash 2 enhancement system designed to provide a 25% increase in dispatchable adhesion

G&G *Locotronics, Inc.*

900 West Hollywood Avenue • Itasca, Illinois 60143
Phone: 708-875-2600 • Fax: 708-875-2601

The following information is sensed by the ECM, as shown in Figure 2.



Fuel oil pressure and temperature...
Lube oil pressure and temperature...
Coolant pressure...
Crankcase pressure...
Air Box pressure...
and Crankshaft position.

EMDEC employs the best of the mechanical unit injector system and adds precise timing control.

To troubleshoot the EMDEC system, consider **both** the mechanical side as well as the electronic side.

Mechanical Troubleshooting

One aspect of the mechanical system that has changed is the amount of fuel pressure. On the mechanical unit, fuel pressure was regulated by a 5 psi regulating valve in the fuel sight glass. The relief valve opened at 60 psi.

On the EMDEC system, the regulator pressure has been increased to 30 psi and the relief pressure to 120 psi. These check valves should **not** be intermixed. Piping has been changed, in some places, from 5/8 inch to 3/4 inch.

The EMDEC primary fuel filter is the same as the one used on the conventional system. However, the engine mounted filters are new 5 micron filters. The older 12 micron filters **cannot** be used.

Electronic Troubleshooting

Figure 3 shows a block diagram of the electronic side of the EMDEC system.

Battery voltage is supplied.

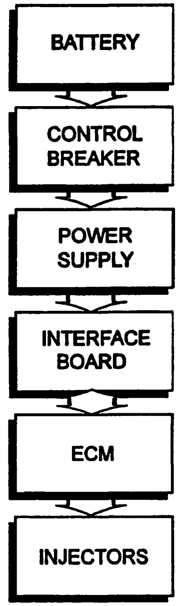
via the control breaker, to the power supply.

The power supply delivers 24 vdc to the interface board, which also receives signal inputs from the EM2000 computer.

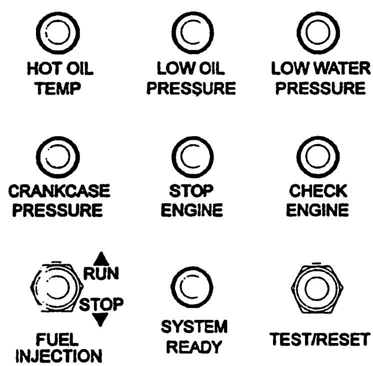
The interface board sends signals to and receives signals from the ECM.

The ECM processes inputs from the engine mounted sensors, and, based on the throttle request,...

energizes the injector solenoid at the proper time and for the proper duration.



Annunciator Panel



The annunciator panel shown in figure 4, gives a visual indication of the status of the electronic system.

The fuel injection switch has two positions and should normally be in the RUN position.

Under normal conditions the SYSTEM READY light should be on. After a shutdown, the system must be reset by moving the START PRIME switch to the start position.

The HOT OIL TEMP, LOW OIL PRESSURE, LOW WATER PRESSURE, and CRANKCASE PRESSURE illuminate to indicate problems with their associated systems.

As a test, STOP ENGINE comes on for 5 seconds when power is first applied. When illuminated at any other time, a fault is indicated. One of the above warning lights will also be illuminated.

The CHECK ENGINE light lets you know that a fault occurred, but is no longer present.

The TEST/RESET switch allows annunciator lights to be tested and activates the self diagnostic system.

The self diagnostic system will cause the STOP ENGINE light, and/or the CHECK ENGINE light to flash in a specific sequence, called the flash code.

For example, to show flash code 25, the STOP ENGINE LIGHT, in the center of the annunciator panel, blinks twice. Following a two second pause, the CHECK ENGINE light blinks five times.

The code identity, as well as help in troubleshooting, can be found in the engine maintenance manual.

A red light on the power supply indicates that a protective shutdown has occurred in the power supply. There are three possible causes:

an overvoltage on the input...

an overcurrent on the output...

or a failed power supply.

To isolate, cycle the engine control breaker. If the green light illuminates and stays on, the fault was caused by an overvoltage condition that no longer exists. If the red light is still on, drop the EC breaker and disconnect the "PO" plug from the power supply. If the fault can be reset, the fault is in the output.

Diagnostic Data Reader

For more troubleshooting help, EMD has developed a device called the diagnostic data reader. This software is also available on a laptop personal computer.

The DDR allows access to any operating data while connected to the system. The DDR can help find:

a faulty input...

a faulty output...

and a faulty reaction to a command.

This software also allows the mechanic to cut out individual injectors, monitor their performance, and monitor all of the inputs to the ECM. Monitoring these inputs can isolate the problem to the engine, the sensors, or the EFI system.

This software will be continually updated to provide the latest in troubleshooting assistance. We should be able to look forward to better efficiency both in fuel utilization and in locomotive performance.

CONSTITUTION AND BY-LAWS LOCOMOTIVE MAINTENANCE OFFICERS ASSOCIATION

Article I - Title:

The name of this Association shall be the Locomotive Maintenance Officers Association (LMOA).

Article II - Purpose of the Association

The purpose of the Association, a non-profit organization, shall be to improve the interests of its members through education, to supply locomotive maintenance information to their employers, to exchange knowledge and information with members of the Association, to make constructive recommendations on locomotive maintenance procedures through the technical committee reports for the benefit of the railroad industry.

Article III - Membership

Section I - Active Railroad Membership shall be composed of persons employed by a railroad company and interested in locomotive maintenance. Membership is subject to approval by the Board of Directors.

Section 2 - Associate Membership shall be comprised of persons employed by a manufacturer of equipment or devices used in connection with the maintenance and repair of motive power, subject to approval of the Board of Directors.

Associate members shall have equal rights with active members in discussing all questions properly brought before the association at the Annual Meeting, but shall not have privilege of voting or holding elective office.

Section 3 - Honorary Membership: Honorary Membership may be issued at the discretion of the President, subject to the approval of the Board of Directors. Honorary Members may not vote or hold elective office; all Honorary Membership shall expire at the end of the current membership year.

Section 4 - Life membership shall be conferred on all Past Presidents. Honorary life memberships shall be conferred on others for meritorious service to the Association, subject to approval by the General Executive Committee.

Section 5 - Dues and Fees: Membership dues for individual active and associate membership shall be set by the Board of Directors and shall be payable on or before September 30th of each year. The membership year will begin on October 1 and end September 30. Life and honorary life members will not be required to pay dues. Members whose dues are not paid on or before the opening date of the annual convention shall not be permitted to attend the annual meeting, shall not be eligible to vote and/or shall not be entitled to receive a copy of the published Pre-Convention Report or the Annual Proceedings of the annual meeting. Failure to comply will result in loss of membership at the end of the current year. A registration fee will be set by the Board of Directors for those attending the annual meeting. Life, life honorary, and honorary members will be entitled to receive a copy of the Pre-Convention Report and Annual Proceedings.

Article IV - Officers

Section 1 - Elective Officers of the Association shall be President, First Vice President, Second Vice President and Third Vice President. There

will be one Regional Executive for each technical committee. Each officer will hold office for one year or until successors are elected. In the event an officer leaves active railroad service, he may continue to serve until the end of his term.

Section 2 - Board of Directors: There shall be a Board of Directors composed of the President, Vice Presidents, and all Past Presidents in active official railroad service. In the event a member of the Board of Directors becomes inactive, he may continue to serve until the end of his term of office.

Section 3 - General Executive Committee: There shall be a General Executive Committee, composed of the Board of Directors, the Regional Executives, and the Technical Committee Chairpersons.

Section 4 - Secretary-Treasurer: There shall be a Secretary-Treasurer, appointed by, and holding office at the pleasure of the Board of Directors, who will contract for his or her services with appropriate compensation.

Section 5 - Advisory Board - There shall be an Advisory Board composed of at least nine members, who are Senior Mechanical Officers, Assistant Vice Presidents or Vice Presidents. They will be invited by the Board of Directors and serve as ex-officio members of the General Executive Committee without vote.

Article V - Officer, Nomination and Election of

Section 1 - Elective officers shall be chosen from the active membership. The nominating committee, composed of the Board of Directors, shall submit the slate of candidates for each elective office at the annual convention.

Section 2 - Election of officers shall be determined by a voice vote, or if challenged, it shall require show of hands.

Section 3 - Vacant offices. Vacancies in any elective office may be filled by presidential appointment, subject to approval of the Board of Directors.

Article VI - Officers - Duties of

Section 1 - The President shall exercise general direction and approve expenditures of all affairs of the Association.

Section 2 - The First Vice President, shall in the absence of the President, assume the duties of the President. he shall countersign all expenditures of the Association and be responsible for preparing and submitting the program for the Annual Meeting.

The Second Vice President shall be responsible for selecting advertising. He will coordinate with the Secretary-Treasurer and contact advertisers required to underwrite the cost of the **Annual Proceedings.**

The Third Vice President will be responsible for maintaining a strong membership in the Association. He will ensure that membership applications are properly prepared and distributed, monitoring membership levels and reporting same at appropriate time to the General Executive Committee.

Section 3 - The Secretary-Treasurer shall:

A. Keep all the records of the Association.

B. Be responsible for the finances and accounting thereof under the direction of the Board of Directors.

C. Perform the duties of the Secretary of the Board of Directors, Nominating Committee, and General Executive Committee, without vote.

D. Furnish surety bond in amount of $5000 on behalf of his/her assistants directly handling Association funds. Association will bear the expense of such bond.

Section 4 - The Board of Directors shall be responsible for the following duties:

A. Assist and advise the President in long-range Association planning.
B. Contract for the services and compensation of a Secretary-Treasurer.
C. Serve as the Nominating Committee.
D. Serve as the Auditing and Finance Committee.
E. Determine the number and name of the Technical Committees.
F. Exercise general supervision over all Association activites.
G. Handle all matters of Association business not specifically herein assigned.
H. The Vice President shall perform such other duties as are assigned them by the President.
I. Those present at any meeting called on not less than thirty days advance written notice, shall constitute a quorum.

Section 5 - There will be one Regional Executive officer assigned to each technical committee. Their duties wil consist of:

A. Participate in the General Executive Committee meetings.
B. Monitor material to be presented by the technical committees to ensure reports are accurate and pertinent to the goals of the Association.
C. Represent LMOA in their respective regions.
D. Promote Association activities, especially those held within their assigned region and monitor membership activities on those railroads so assigned.
E. Promote and solicit support for LMOA by helping to obtain advertisers.

Section 6 - Duties of General Executive Committee:

A. Monitoring technical papers for material considered unworthy or inaccurate for publication.
B. Approve topics for the **Annual Proceedings** and Annual Meeting program.
C. Approve the schedule for the Annual program.
D. Administer all Association activities not specifically assigned to the Board of Directors.

Section 7 - The Advisory Board shall act in a consulting capacity. Past Presidents still in official active railroad service shall automatically become members of the Advisory Board.

Section 8 - The Board of Directors are entrusted with all public relation decisions within LMOA and coordinated associations with confidentiality.

Article VII - Technical Committees

The technical committees will consist of:

Section 1 - A chairperson, appointed by the President and approved by the Board of Directors.

Section 2 - A vice chairperson, selected by the chairperson and approved by the President.

Section 3 - Committee members will be made up of:

A. Representatives of operating railroads and regional transit authorities submitted by their Senior Mechanical and Materials Officers and approved by the President of LMOA.
B. Representatives of locomotive builders designing and manufacturing locomotives in North America.
C. The Fuel and Lube Committee will include members from major oil companies or their subsidiaries as

approved by the General Executive Committee.

D. At the discretion of the General Executive Committee, non-railroad personnel may be allowed to participate in committee activities, subject to annual review.

E. All individuals who are on technical committees must be LMOA members in good standing. (See dues and fees, Article 3, Section 5).

Subjects for technical papers will be selected and approved by the General Executive Committee.

Article VIII - Proceedings

The Locomotive Maintenance Officers Association encourages the free interchange of ideas and discussion by all attendees for mutual benefits to the railroad industry. It is understood that the expression of opinion, or statements by attendees in the meeting, and the recording of papers containing the same, shall not be construed as representations or statements ratified by the Association.

Article IX - Rules of Order

The proceedings and business transactions of this Association shall be governed by Roberts Rules of Order, except as otherwise herein provided.

Article X - Amendments

The Constitution may be amended by a two-thirds vote of the active members present at the Annual Meeting.

Article XI - The Constitution and By-Laws have been amended at the Annual Convention on September 19, 1988.

FUEL, LUBRICANTS AND ENVIRONMENTAL COMMITTEE FOURTEEN YEAR INDEX

FUEL, LUBRICANTS AND ENVIRONMENTAL COMMITTEE FOURTEEN YEAR INDEX

1984

1. Locomotive Filters
2. Traction Motor Gear Lube Field Test.

1983

1. Field Test Update of Mulitgrade Oils.
2. Update of Alternate Fuel Testing.
3. A Review of Locomotive Fuels.

1982

1. Energy Conserving Lube Oils.
2. Alternative Fuels Update.
3. Availability of Medium and High Viscosity Index Railroad Oils.
4. Journal Box Oil and Aniline Point.
5. Traction Motor Gear Lubricant Update.
6. Traction Motor Gear Case Seals.

1981

1. Effects of Using Alternate Fuels on Existing Diesel Engines.
2. Update on Cold Weather Procedures for Fuels.
3. New Techniques in Lube Oil Analysis.
4. Traction Motor Gear Lubrication.
5. Multi-Viscosity Oils as an Energy Conservation Technique.

DIESEL MATERIAL CONTROL COMMITTEE
FOURTEEN YEAR INDEX

1983

1. Improved Locomotive Productivity Through Computerized Data.
2. Inbound Material Inspection.
3. Minimize Maintenance Cost Through Material Management Systems.
4. New Ideas In Material Storage Containers.

1982

1. Use of kits in locomotive maintenance.
2. Cost effective methods of shipping material from vendors.
3. Union Pacific's Component Inventory Maintenance System (CIMS).
4. Advantages of using shipping containers.

1981

1. Disposal of Unserviceable Component Parts: What is the Most Profitable Method?
2. Innovations in Stores Material Handling, Via Computer Technology.
3. Locomotive Held for Material: an Update for the 80's.
4. The Best Approach to Procuring Material; New, UTEX, Repair and Return or Shop Repair.

SHOP EQUIPMENT COMMITTEE
FOURTEEN YEAR INDEX

1994

1. Electronic Fuel/Unit Injection Tooling.
2. Locomotive Roller Support Bearing Tooling.
3. Fall Protection and Man Lifts.
4. Locomotive Washing Systems.

1993

1. Dynamic Balancing for GE Dash 8 Model Locomotives
2. Air Compressor Automated Station
3. Ergonomics in the Work Place
4. Hydraulic Traction Motor Shimming Table

1992

1. Automated Test and Production Equipment
2. Safety Corrective Action Team
3. Automated Locomotive Wheel Shop
4. Cleaning and Surface Preparation with Sodium Bicarbonate Based Abrasive Blasting
5. Trainline Continuity Tester
6. BN - Railroad Power Assembly Shop of the 1990's.

1991

1. Economic Separation of Emulsified Oil from Waste Water Using Ultra Filtration Membranes.
2. EMD Cylinder Head Valve Seat Machining.
3. Automated Barring Over Machine for EMD Diesel Engines.
4. New Equipment for Testing EMD Engine Protectors.
5. Compressed Air for Railroad Facilities Issues and Solutions to Achieve Clean, Dry, Oil Free Air.

1990

1. EMD Valve Bridge Machine
2. GE Traction Motor Roller Suspension Bearing Replacement Equipment and Procedure.
3. Locomotive Component Replacement Forklift Attachment.
4. Locomotive Sanding, Fueling and Drop Tables.
5. Hazardous Waste Disposal.

1989

1. Automated Locomotive Wheel Shop.
2. Laser Guided Material Handling Vehicles.
3. Bulk Rail Lubrication Storage & Fill System.
4. Pilot Plate Straightening Equipment.

1988

1. Fuel Management Control Systems.
2. Locomotive Mounted Rail Lubrication Fill Systems.
3. Comparison of Shop Air Compressors.
4. Locomotive Toilet Servicing Equipment.
5. Innovations in Blue Flag and Derail Protection.

1987

1. Modern Servicing Facility for Improved Reliability and Availability.
2. New Developments in GE Tools.
3. Implementation of a Quality Process.
4. A Quality Traction Motor Shop.
5. Wheel Truing Machine Technology.

1986

1. Robotics Update 1986 - Now What?
2. CNC Machine Tools.
3. A New GE Power Assembly Area.
4. Locomotive Wash System - 1986.

1985

1. Computer-Assisted Preventative Maintenance.
2. New Tools for Material Handling and Overview of Balancing Technology.
3. Effect of Governmental Regulations on Locomotive Finishing.

1984

1. Shop Tools.
   A. New Tools.
   B. Shop-Made Tools.

   Traction Motor Shop Equipment Up-Date.

   Hazardous Waste Handling and Disposal.

1983

1. Locomotive Maintenance Using a Production Line Process.
2. Shop Tools to Increase Productivity and Improve Quality.
3. Dynamic On-Line Performance of Locomotives Without On-Board Tele-Metering.
4. Management in Action.
5. New GE Training Center.
6. Welding Qualifications.

1982

1. Tools.
2. Rebuild line for EMD turbochargers.
3. Air brake equipment line.
4. Industrial robots.
5. Automated machines.
6. Safety related items and equipment.

1981

1. Training Aids.
2. Testing Devices Inspired by New FRA Laws.
3. Tools and Training for Productivity.
4. Changes to Shop Facilities Required by Newly Adopted EPA & OSHA Regulations.
5. Tour Through Conrail Altoona Shop.
6. Supply/Service Facilities.
7. GE Assembly Shop.

NEW DEVELOPMENTS COMMITTEE TWELVE YEAR INDEX

1994

1. Electronic Fuel Injection Systems.
2. Status of Distributed Power in Freight Trains.
3. Advances in Distributed Power-Iron Highway..

1993

1. New Technology to Solve Old Problems
2. Developments in Off-Shore Technology
3. Updates on AC Traction Developments

1992

1. Talking to the "Smart' Locomotive
2. Cab Noise Abatement
3. Electronic Management of Locomotive Drawings
4. Update on High Productivity Integral trains
5. AC Traction - A New Development

1991

1. Locomotive Cab Integration and Accessory Management
2. Improvements in Locomotive Adhesion Performance.
3. The Role of Duty cycles in Locomotive Fuel Consumption.
4. What's New in Gadgets and Black Boxes: What do our Locomotives Really Need?
5. Failure Analysis

1990

1. Motor Driven Air Compressors for Diesel-Electric Locomotives
2. Locomotive Cab (HVAC) Heating, Ventilation and Air Conditioning Systems.
3. Effect of Technology on Standardization of Cab Control Equipment.
4. Locomotive Durability, Reliability and Availability - Understanding Your Abilities.

1989

1. A Rational Approach to Testing Locomotive Components.
2. New Developments in Locomotive Cab Design.

1988

1. Amtrak F69 PH AC Passenger Locomotives
2. New Component Developments Retrofittable to Older Model Locomotives
3. Locomotive Applications of Catepillar Engines.
4. Wheelslip Control for Individual Axles.

1987

1. Electronic Fuel Injection Systems.
2. Update on Electronic Governors.
3. Recent Advances in Steerable Locomotive Trucks - the E.M.D. 4 Axle, 4 Motor HT-BB Articulated Truck.
4. Converting an F40 Locomotive to A.C. Traction.

1986

1. Future Train Control Systems.
2. Bringing Future Train Control Systems Back to Earth.
3. Low Maintenance Locomotive Batteries.
4. Electronic Engine Control Systems.

1985

1. The Sprague Clutch for E.M.D. Turbocharged Engines.
2. A.C. Traction Locomotives Update.
3. Natural Gas Locomotive Update.
4. Ceramic Coated Engine Components.
5. Locomotive Cab Developments.

1984

1. G.E. Dash 8 Locomotives.
2. E.M.D. 50A Series Locomotives.
3. Natural Gas Locomotives.
4. Appraisal of the A.C. Traction Locomotive.

1983

1. Microprocessors for Locomotive Control and Self Diagnosis.
2. Locomotive Fuel Tank Gauges.
3. Locomotive Aerodynamics
4. Bombardier HR 616 Locomotive.
5. Missouri Pacific - Phase III Locomotive Heavy Repair Facility, N. Little Rock, Arkansas.

DIESEL MECHANICAL MAINTENANCE COMMITTEE FOURTEEN YEAR INDEX

1986

1. Rebuild of Valve Bridge Assemblies.
2. Update of New Locomotive Service Problems, EMD and GE Effecting Quality Performance.
3. Chromium Plating and Its Uses.
4. Development of a New Diesel Engine for Heavy-Duty Locomotive Service.

1985

1. Procedures for Storing Serviceable Locomotives for Quality Performance.
2. New Locomotive Service Problems, EMD and GE.
3. 92 Day Service Requirments: EMD, GE and Bombardier.

1984

1. Mechanical Aspects of New Locomotive Designs.
2. Maintenance of Locomotive Components.

1983

1. Leaks: Cooling Water, Lube Oil, Fuel Oil and Air.
2. Torquing Recommendations.
3. Update on Fuel Efficient Locomotives.
4. Radiator Screens
5. Alternate Starter Systems

1982

1. Fuel Conservation - Effects on Maintenance.
2. Fuel Conservation - What It Costs.
3. Diesel Fuel Receipt and Disbursement.
4 Turbochargers.

1981

1. Running Gear.
2. Filtration.
3. FRA Rules.
4. Follow-up on Previous Topics.

DIESEL ELECTRICAL MAINTENANCE COMMITTEE FOURTEEN YEAR INDEX

1986

1. Cleaning, Handling & Storage of Electrical Equipment
   A. Solid State Components.
   B. Rotating Equipment
2. Qualification of Locomotive Power plants through self load.

1985

1. Locomotive Microprocessor Technology in Retrospect.
2. Dynamic Brake Protective Devices and Troubleshooting EMD-2 and GE-7 Locomotives.
3. Indicators and Recorders for Locomotive Retrofit Application - Fuel, Speed, Power and Selected Events.

1984

1. On-Board Diagnostics.
2. GE's **CATS** (Computer Aided Troubleshooting System).
3. Fuel Conservation Through Electrical Modifications.
4. Performance of Locomotives After Storage.

1983

1. Ground Relay Trouble Shooting.
2. Specification for remanufactured D87 Traction Motor Frames (Using D-77 Armature Coils)
3. Locomotive Storage (Electrical).
4. Water Cooling and Refrigerating Methods for Locomotive Cab Application

1982

1. Tests on Traction Motors.
2. Transition Trouble-Shooting.
3. Onboard Diagnostic Systems.
4. Starting Systems.

1981

1. Evaluation of Improved Test Methods.
2. Teflon Bands.
3. New Generation Locomotives.
4. Electrical Troubleshooting.
5. Batteries and Charging Systems.
6. Troubleshooting EMD AC Auxiliary Generator System.
7. Selection of Locomotives for Major Locomotive Overhauls.

COPIES OF TRANSCRIPTS
FROM PREVIOUS
TECHNICAL PAPERS
ARE AVAILABLE
UPON REQUEST.

CONTACT
OUR SECRETARY-TREASURER,
RON PONDEL,
AT
312-772-4600.